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Towards understanding the moral reasoning process of senior chemical engineering students in process safety contexts

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ABSTRACT

Despite process safety and ethical decision making being recognized priorities in many chemical companies, process safety incidents continue to occur with unfortunate regularity. In order to understand why such incidents keep occurring, and to prevent future accidents from happening, it is important to study the decision-making habits of people employed at chemical companies, and to inform students of the difference between the influences of ethics and behavioral ethics in process safety decision making. This study seeks to determine how senior chemical engineering students approach reasoning through process safety scenarios through the use of a mixed methods study. This study found that four out of the five students who participated in the study demonstrated post-conventional reasoning, and the remaining student showed conventional reasoning based on the quantitative analysis of their responses. Students showed mostly post-conventional reasoning in their responses based on a qualitative analysis; however, through comparison of these results it was found that the moral schema students were classified as was not always truly representative of their moral reasoning.

1. Introduction

1.1. Objective

The importance of process safety in the classroom has become increasingly apparent since the addition of process hazard consideration to the program criteria for Chemical Engineering in the Criteria for Accrediting Engineering Programs (ABET) in 2012 (Dee et al., 2015; Shallcross, 2014). However, little research has been conducted on how students make and morally reason through process safety decisions. This study used a mixed methods approach to comprehend students' decision making when confronted with process safety dilemmas. Students were asked to read through the Engineering Process Safety Research Instrument (EPSRI), which is an instrument under development that is meant to assist in measuring how chemical engineering students make process safety decisions. When proceeding through the EPSRI, students read a process safety dilemma which is accompanied by three decision options, and 12–15 considerations (Butler et al., 2018). Students verbally expressed their thought process while working through the EPSRI.

EPSRI scores were calculated from student responses to determine which form of moral reasoning was taking precedence in students' process safety decisions. Student transcripts were also read and analyzed to better understand students' moral reasoning when faced with process safety decisions. Comparisons were later made between the quantitative and qualitative responses to determine if any differences existed in the ways students thought through and finally made their process safety decisions.

1.2. Process safety decision making

Chemical companies are continually striving to improve process safety within the workplace and have applied a variety of techniques to meet this goal. The Dow Chemical company applied discipline systems that included process safety training which resulted in a significant decrease of Tier 1 process safety events (Champion et al., 2017). The American Fuel and Petrochemical Manufacturers (AFPM) and American Petroleum Institute (API) created six programs that included safety training to improve process safety in the petrochemical industry (Swett et al., 2013). Plant simulators have also been used to allow industrial operators to experience

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scenarios within the plant (Nazir and Manca, 2014). Despite these efforts, process safety incidents continue to occur.

The US Chemical Safety Board website shows that over 800 process safety incidents have occurred since the CSB was founded in 1998. The Arkema Inc. chemical plant fire that resulted from floodwaters from hurricane Harvey caused 25 people to be hospitalized from the fumes (csb.org, 2018). In 2016, an operator at ExxonMobil incorrectly removed a valve that caused an explosion of isobutane that severely burned four employees (csb.org, 2017). This occurred due to the unreliable gearboxes that were in use, and the accepted practice to manually remove the gearbox to open or close the valve. A written procedure and training which would describe how to properly remove the gearbox were not made available to the operators.

Despite the number of process safety incidents, chemical engineers still take for granted that, on the whole, they behave ethically in their day-to-day decision making. An "ethics survey" was offered by AIChE in December of 2016 to its members, and received over 1300 responses. Results from this study found that engineers who were educated in the United States rated the importance of ethical behavior as extremely important, had encountered an ethical dilemma within their career, and had rated the importance of acting in an ethical manner as extremely important (Grubbe, 2018). It appears that despite well intentioned efforts decisions are still made that could later result in potential issues leading up to a process safety event. The answer to this lies with the difference between ethics and behavioral ethics.

1.3. Ethics vs. behavioral ethics

Bazerman and Tenbrunsel (2011) describe the difference between ethics and behavioral ethics in their book "Blind Spots". They explain that ethical training alone is not impactful due to the fact that most people will not recognize an ethical dilemma when it occurs. Behavioral ethics describes how one will behave when faced with an ethical dilemma. Bazerman and Tenbrunsel (2011) go on to describe "bounded awareness", which is a tendency to exclude important information and place arbitrary bounds around a problem that influences the final decision. The example the authors used related to the Challenger disaster and the decision whether to launch the space shuttle. Operators working on the shuttle knew the O-rings could fail under the expected operational temperatures that day, but management still made the decision to launch due to their bounded awareness of the situation; this allowed them to look at the situation as a business decision rather than an ethical decision (Bazerman and Tenbrunsel, 2011). As a result of this decision, the shuttle exploded and lives were lost.

Decision making can be separated into two types of thinking; System one and System two (Stanovich and West, 2000). System one thinking occurs when decisions are made intuitively and emotionally. These kinds of decisions are typically made quickly, and without much consideration of underlying details. System one thinking takes over when one's mind becomes overloaded, such as at the end of a work day (Kahneman, 2003). System two thinking occurs when decisions are made logically, and with conscious thought. At this level, costs and benefits are weighed in order to make a decision. As a result of this, System two thinking typically requires more deliberation, and should be used when making important or ethical decisions (Kahneman, 2003).

Ethical decisions can be looked at through a psychological process that is broken into three phases; before, during, and after the decision (Bazerman and Tenbrunsel, 2011). During the "before phase", or predictive phase, people make predictions about their ethical behavior and decision making. These predictions tend to be incorrect, and are referred to as behavioral forecasting errors (Bazerman and Tenbrunsel, 2011; Osberg and Shrauger, 1986; Diekmann et al., 2003). The "during phase", or decision phase, occurs when one is placed in the moment of a decision. In this phase, humans face the "want" self, and "should" self (Bazerman et al., 1998). The "want" self describes how we want to behave based on the outcomes of the decision. The "should" self describes how we know we should behave based on the costs and benefits (Bazerman et al., 1998). In most decisions, the "want" self usually takes over, as a result of system one thinking. Alternatively, ethical decisions may be looked at as business or legal decisions because of ethical fading, which occurs when the ethical dimensions of a decision are ignored or removed (Bazerman and Tenbrunsel, 2011; Tenbrunsel and Messick, 2004). Lastly, the "after phase" occurs after the decision is made. In this phase, humans try to rationalize why they made their decision, and why it was the correct and ethical decision to make. Individuals will also remember their behaviors that support their self-image, and rationalize the unethical behavior they displayed at the time of their decision (Bazerman and Tenbrunsel, 2011).

While the push for process safety is important, there is little research being conducted on the behavioral ethics of plant managers, operators, and employees. Studying or understanding the behavioral ethics of these workers could be key to understanding why process safety incidents continue to occur, and what needs to be done to stop them. As a first step towards this goal, it is important that educators understand how to teach chemical engineering students about behavioral ethics when providing them with process safety instruction to lead to potential changes within industry practice.

1.4. Research positionality

Kohlberg's moral development theory describes the development of a person's form of thought through three schema. The first schema of moral reasoning is pre-conventional thinking (Kohlberg and Hersh, 1977). This form of thinking is represented by decisions that are selfish and revolve around personal concerns, such as health, image, and opportunity. Decisions made at this level are made based on personal consequences and satisfying one's needs (Kohlberg and Hersh, 1977). The second schema of moral reasoning is conventional thinking. This form of thinking is represented by decisions that are made concerning the people directly surrounding one's self, such as family, friends, or co-workers. Decisions made at this level prioritize helping or pleasing others, and are made based on conformity and loyalty to personal expectation and social norms (Kohlberg and Hersh, 1977). The final schema of moral reasoning is post-conventional thinking. This form of thinking is represented by decisions that are made concerning the environment, surrounding communities, and the greater good. Decisions made at this level reflect a clear definition of moral values, and are based on self-chosen ethical principles (Kohlberg and Hersh, 1977).

The instrument that was used in this study was the Engineering Process Safety Research Instrument, or EPSRI. The EPSRI is meant to assist instructors in determining students' moral schema when making process safety decisions. Students are given a dilemma about a process safety scenario, which is followed by three options. Two of the options are deliberate decisions about the incident, and one allows for the student to opt out of making a decision. Following the dilemma, there are 12–15 considerations that fall into pre-conventional, conventional, or post-conventional schemas. Some considerations take the form of an M-item, which is a meaningless item that assists in determining unreliable data. Students rate the considerations on a scale from one (none) to five (great) in terms of how important the consideration was toward their overall decision. Once students were finished rating the considerations, they ranked the four considerations that they believed were most important to their overall decision (Butler et al., 2018).

1.5. Research questions

Through this study, we seek to answer three research questions based on Kohlberg's moral development theory and its application to the reasoning of senior chemical engineering students as they work through the EPSRI. The research questions are as follows.

1 What schemas of moral reasoning do senior chemical engineering students demonstrate when performing process safety decisions?
2 How do senior chemical engineering students reason through process safety decisions?
3 Do the schemas of moral reasoning that students represent truly reflect their moral reasoning process when approaching process safety decisions?

2. Theory/calculation

2.1. Participants

Five senior chemical engineering students participated in this study during the spring semester of 2018. All senior chemical engineering students within the chemical engineering program were solicited via email regarding the opportunity giving no preference to students' academic standing, co-curricular or extra-curricular involvement. Students were informed that the first ten individuals to respond to the e-mail would have the opportunity to participate in the study. Unfortunately, only five students responded to this research opportunity. Although the sample size was smaller than originally intended there is precedent within the literature for small sample sizes when conducting a study that involves qualitative research. The reasons for smaller sample sizes include (1) data generated from qualitative studies tending to be rich in detail; (2) the goal of qualitative research not being focused on providing broad statements about a population as a whole; (3) having additional samples does not always yield new information about the research question under investigation as a point of saturation will eventually be reached; and (4) that qualitative research tends to be more intensive in nature (Ritchie et al., 2014). While students did volunteer to be a part of the study, they were given a $50 gift card after completion of the protocol as compensation for their time. Proper human subjects' approval was obtained prior to the study.

2.2. Data collection

Think aloud sessions were conducted to capture student perceptions of the EPSRI and determine areas necessary for clarification as well as how they processed moving through the instrument. During the session, students were given a hard copy of the EPSRI to read out loud and answer. The EPSRI contained seven dilemmas, which were followed by three potential decision choices, and a corresponding set of 12 to 15 considerations (Butler et al., 2018). After each dilemma, students were asked three follow up questions about their decision making process that focused on the following aspects of human informal reasoning: rationalistic, intuitive, and emotive (Sadler and Zeidler, 2005). Students would read the dilemma out loud, state which option they chose, and explain why they made that decision. Students would then read and rate each consideration on a scale from one to five (one being no importance, and five being great importance), while sharing their thought process. After rating the considerations, students then ranked the four considerations which they felt were most important towards their overall decision. Researchers would encourage students to describe their thought process if it appeared that they were processing the materials but not verbalizing their thoughts. Data was gathered through field notes taken by the researcher during the protocol, as well as audio recordings of students' thought processes that were captured during the think aloud protocol.

A research administrator was present in the room throughout the protocol in case the student required any assistance or clarification in how to proceed. The research administrator also posed the follow up questions. The first think aloud session was administered by a senior member of the research team. The second session was administered by both a junior and senior member of the research team. Following these two sessions, the senior member noticed students looking for validation from the senior research member on their responses and for this reason a modification to the protocol was made for the remaining three sessions. In these final three sessions, the senior member would stay during the first dilemma, and leave for the remaining six. This was done in order to remove any potential power dynamic between the senior member and the students completing the instrument which may have influenced the results obtained. This also ensured trustworthiness of the data.

2.2.1. Quality considerations when making the data

When performing a qualitative-based engineering education study, it is critical that the process for making the data ensures quality in the results obtained. In order to ensure high quality data, the authors referenced the Q3 framework (Walther et al., 2013, 2015). Table 1 describes the steps taken when making the data to ensure the strength of the quality of the data.

2.3. Quantitative analysis

Students fell into one of six types as defined by Rest et al. (1999a). These types are defined by two distinct characteristics. The first characteristic is based on which schema was ranked the highest across the instrument. In order to determine the highest ranked schema, a calculation is applied to each schema that follows the same calculation of the p-score (Rest et al., 1997a). The p-score is used to determine how the students ranked post-conventional items across the instrument. If a post conventional consideration is ranked first, four points are added to the p-score. If it is ranked second, three points are added (third ranking = 2 points, fourth ranking = 1 point) (Rest et al., 1997a). These points are added across all of the dilemmas, and divided by a base score which is the number of dilemmas multiplied by ten points (e.g., seven dilemmas = 70 overall points). The p-score was not used in this study, however, applying the p-score calculation to the post-conventional, conventional, and pre-conventional items individually allows for the highest ranked schema to be determined.

The second characteristic is based on the extent of the schema mix; transitional, or consolidated. A student that is consolidated will have a larger variance between the average ratings of the different schema compared to a student who is transitional (Rest et al., 1999a). A measure for consolidation can be calculated using the CDIT score. The CDIT score finds the ratio of variance of student's ratings within schemas to the variance between schemas. If a student obtains a CDIT score above 15.705, they are considered consolidated (Rest et al., 1999a). If a student obtains a CDIT score below a 15.705, they are transitioning between two schemas (Rest et al., 1999a). The CDIT score was calculated based on Rest et al. (1997b), and was modified to fit the number of items in the EPSRI. The schema types are described in Table 2.

A student would be classified as type one if they ranked pre-conventional items the highest across the instrument, and had a CDIT score above 15.705, meaning they were consolidated. Once the student begins to transition between preconventional and conventional, while still being predominantly in the pre-conventional

Table 1
Q3 framework for making the data (Walther et al., 2013, 2015).

Description	Making the Data
Theoretical Validation *Do the concepts and relationships of the theory appropriately correspond to their social reality under investigation?*	*The research process needs to be able to capture the full extent of the social reality studied.* • Reviewed basics of Kohlberg's Moral Development Theory and Sadler's decision making literature prior to initiation of the study. • Reviewed basics of Sadler's informal reasoning with subject matter expert
Procedural Validation *Which features of the research design improve the fit between reality and the theory generated?*	*Strategies need to be implemented in the research design to mitigate threats to contextual validation.* • Students had reflection questions focused on informal reasoning incorporated into their think aloud protocol • Modified think aloud protocol after observation about possible power dynamic influencing results. Junior member of research team stayed in room throughout protocol but senior member started the protocol and then left and came back at the end.
Communicative Validation *Is the knowledge socially constructed within the relevant communication community?*	*The data gathering needs to capture the respondents' inter-subjective reality.* • Students talked through the EPSRI instrument, only receiving feedback if they were confused on phrasing or a process. • Students were allowed to alter answers and change responses as they moved through the instrument • Researcher took notes on student behavior and mechanisms
Pragmatic Validation *Do the concepts and knowledge claims withstand exposure to the reality investigated?*	*The concepts underlying the research design need to be compatible with reality in the field.* • Senior chemical engineering students participated in the study which represents the demographic of the audience for whom the instrument was created. • Focusing on process safety scenarios and the approaches students take towards decision making could be beneficial for the Chemical Engineering Education community.
Process Reliability *How can the research process be made as independent as possible from random influences?*	*The data needs to be collected and recorded in a dependable way.* • Data was collected from audio recordings of student responses that were later transcribed by a third party. • Audit trail documents all the steps taken as part of the research process and any modifications made.

Table 2
Defining the type of student based on predominant schema and schema mix (Rest et al., 1999a).

	Pre-Conventional Predominant (S23)	Conventional Predominant (S4)	Post-Conventional Predominant (S56)
Consolidated	Type 1	Type 4	Type 6
Transitional	Type 2	Type 3	Type 5

space, they are considered type two. A student who is classified as type three is predominantly conventional, but is transitioning between pre-conventional and conventional, or conventional and post-conventional. Once the student becomes consolidated in the conventional space, they are considered type four. If a student is transitioning between conventional and post-conventional, but is predominantly post-conventional, they are type five. Lastly, once they become consolidated in the post-conventional space, they are classified as type six (Rest et al., 1999a).

The CDIT score is calculated through a five step process, which was adapted from Rest et al. (1997b). The following section will describe the process with a sample calculation. Eq. (1) summarizes the calculation for the sum of squares total.

$$(SS_{Pre} * c_{pre}) + (SS_{Conv} * c_{conv}) + (SS_{Post} * c_{post}) = SS_{Total} \quad (1)$$

The sum of squares for the pre-conventional, conventional, and post-conventional ratings are represented by SS_{pre}, SS_{conv} *and* SS_{post} respectively. The sum of squares (SS) for each schema was found by squaring the ratings for the considerations, and totaling all the values for each schema. To account for the different number of items per schema, a multiplier was applied to each value (denoted by "c"), before being totaled to find the SS_{Total}.

The multiplier is found by first determining the total number of items (excluding meaningless items or M-items). M-items are meaningless items scattered throughout the instrument that ensure responses are not based on high level syntax, and rather an understanding of the prompt (Rest et al., 1999b). The total number of items is rounded down to the nearest third to be evenly divided by the number of schemas, or in this case three (Rest et al., 1997b). The EPSRI contains 82 items, not including M-items. This value is rounded down to 81, then divided by three to obtain 27 as the adjusted number of items. The multiplier for each schema is represented by the adjusted number of items, or 27, divided by the actual number of items within the schema. The EPSRI contains 27 pre-conventional items, 27 conventional items, and 28 post-conventional items. The multiplier for the pre-conventional, conventional and post-conventional items are represented by c_{pre}, c_{conv}, and c_{post} respectively. Table 3 shows the variables necessary to solve the Equations. These variables were obtained from a data set of a student who participated in the study.

Table 3
Variables for sum of squares Equation.

Variable	SS_{pre}	c_{pre}	SS_{conv}	c_{conv}	SS_{post}	c_{post}
Value	182	27/27	332	27/27	598	27/28

Substituting the values from Table 3 into Eq. (1) gives the sum of squares total.

$$(182 * 27/27) + (332 * 27/27) + (598 * 27/28) = 1090.64$$

The second step in calculating the CDIT score is deriving the correction factor of the pre-conventional, conventional, and post-conventional ratings (Rest et al., 1997b). Eq. (2) summarizes the calculation for the second step.

$$((\Sigma_{Pre} * c_{pre}) + (\Sigma_{Conv} * c_{conv}) + (\Sigma_{Post} * c_{post}))^2 / C = CF_{Total} \quad (2)$$

The sum of the pre-conventional, conventional, and post-conventional ratings are represented by Σ_{Pre}, Σ_{Conv}, and Σ_{Post}

Table 4
Variables to calculate correction factor.

Variable	Σ_{Pre}	Σ_{Conv}	Σ_{Post}	C
Value	60	86	124	81

Table 5
Variables to calculate the sum of squares stage.

Variable	Σ_{Pre}	Σ_{Conv}	Σ_{Post}	c_{pre}	c_{conv}	c_{post}	A	SS_{Dev}
Value	60	86	124	27/27	27/27	27/28	27	219.93

respectively. The multiplier that was found previously is again applied to each sum, and is still represented by c_{pre}, c_{conv}, and c_{post}. The sum of the ratings for each schema are calculated, and the multiplier is applied. These values are summed and squared, then divided by the adjusted total number of items, which is represented by C. Table 4 summarizes the variables needed to solve for the correction factor.

Using the variables from Table 4 and substituting into Equation 2 gives the calculation for the second step to obtain the correction factor.

$$((60 * (27/27)) + (86 * (27/27)) + (124 * (27/28)))^2/81 = 870.72$$

The third step in calculating the CDIT score is finding the sum of squares deviation (Rest et al., 1997b). Equation three summarizes the calculation for this step.

$$SS_{Total} - CF_{Total} = SS_{Dev} \tag{3}$$

The sum of squares deviation is found by subtracting the correction factor found in the second step from the sum of squares total found in the first step. The sample calculation below shows the calculation for the sum of squares deviation using values that were previously calculated.

$$1090.64 - 870.72 = 219.93$$

The fourth step in calculating the CDIT score is deriving the sum of squares stage (Rest et al., 1997b). Equation four summarizes the calculation for the fourth step.

$$\{[(\Sigma_{Pre} * c_{pre})^2 + (\Sigma_{Conv} * c_{conv})^2 + (\Sigma_{Post} * c_{post})^2]/ \mathrm{A}\} - CF_{Total} = SS_{Stage} \tag{4}$$

The calculation for this step begins similarly to the second step, where the sum of the ratings for each schema is found and the multiplier is applied. These values are individually squared, before they are summed and divided by the adjusted number of items per schema, which is represented by A. The correction factor, represented by CF_{Total} is subtracted from the Equation to give the sum of squares stage. Table 5 summarizes the variables necessary to solve for the sum of squares stage.

Using the variables from Table 5 and applying them in Equation four gives the calculation for the fourth step to obtain the sum of squares stage

$$\{[(60 * 27/27)^2 + (86 * 27/27)^2 + (124 * 27/28)^2]/ 27\} - 870.72 = 66.07$$

The final step to calculate the CDIT score is summarized in Equation five.

$$(SS_{Stage}/\mathrm{SS_{Dev}}) * 100 = CDIT \tag{5}$$

The sum of squares stage found in Step 4, is divided by the sum of squares deviation, found in step three. This value is multiplied by 100 to give the CDIT score. The sample calculation below shows the final value obtained for CDIT for this student

$$(66.07/219.93) * 100 = 30.04$$

Based upon the CDIT score calculated, this student would be considered to be consolidated (Rest et al., 1997b). This student had also ranked post-conventional items the highest out of the three schemas, which means they are post-conventional predominant. Referring to the matrix in Table 2, a consolidated student who is operating at a post-conventional level would be classified as a type six.

2.4. Qualitative analysis

Leydens et al. (2004) described that the use of qualitative research in engineering education is becoming more commonplace. The use of qualitative methods in research provides deeper insight into the data being obtained. Qualitative data is unlike quantitative data, which can be replicated and analyzed for internal or external consistency (Anfara et al., 2002). Quantitative data is primarily used to provide numerical descriptors of data, and to summarize data to support hypotheses. Qualitative data allows a deeper insight of individual's perspectives, and detailed descriptions of particular situations (Leydens et al., 2004). Quantitative and qualitative data are not meant to answer the same questions, rather they provide different aspects and provide different information (Leydens et al., 2004). Qualitative data can be collected through many different methods, such as observations, interviews, and documents (Leydens et al., 2004). This study was conducted as a think aloud protocol, which consisted of a similar structure to interviews. This method allows capture of participants' perspectives, or in the case of this study, their thought process as they reasoned through different process safety situations (Leydens et al., 2004).

In order to analyze the qualitative data that was collected from the transcripts, coding methods were employed. According to Miles et al. (2014), codes are able to provide a deep reflection and analysis to the data's meaning. They also can describe a large amount of meaningful information allowing a researcher to group common themes or segments of the data in a way that can answer research questions. The type of coding used in this study was provisional coding. Provisional codes are initially generated from possible responses that may appear in the transcripts. As the coding proceeds, the list can be modified to include, adjust, or remove any of the initial codes (Miles et al., 2014). This method was applied as it builds upon Kohlberg's moral development theory (Kohlberg and Hersh, 1977).

For this study, the initial list of codes was generated from the dilemmas and considerations on the EPSRI. A list of codes were generated for each dilemma, and were separated into either pre-conventional, conventional, or post-conventional forms of thinking. Once codes were generated for each dilemma, the lists were reviewed for codes that were similar, or could be combined. A master list of codes was generated that contained codes that had been combined, or codes that were common across the dilemmas. The remaining codes that were relevant to just one dilemma were left on their respective list. Descriptions were generated for each code, and examples were included once the coding process was completed. Student responses were then analyzed using the prescribed code book as shown in Table 6.

Table 6
Codebook Containing Pre-conventional, Conventional and Postconventional Codes.

Category	Sub-category	Description	Example
Pre- conventional	Career concerns	Students mention keeping their job, yearly bonuses, or advancing in their career	"Then also caring about my job, that would be concerning."
	Personal image/satisfaction	Students mention others view or opinion of them	"I think that the plant workers. . . would definitely have a better opinion of you if you chose the option safer for them."
	Personal health/exposure	Personal health, safety, or exposure to chemicals from plant	". . .if you were exposed to this at a high volume, it's going to negatively impact yourself. . ."
	Personal time investment/effort (Found in dilemmas 2, 4, 5, 6 & 7)	Personal amount of time or effort spent on a task	"Even if it takes a month to figure it all out, I would still do it."
	Personal belongings (Found in dilemma 2)	Students mention their personal belongings	"Personal belongings, I would say, that's not really important to me because they can be . . . well, most of the time they can be replaced. . ."
Conventional	Co-worker's concerns	Health, safety, time investment, abilities, and job security of co-workers	"I would feel for the people who not only get exposed to it working every day. . ."
	Company concerns	Company money, time, image, productivity, and equipment	"That is concerning because you wouldn't want to set your company back. . ."
	Company safety culture (Found in dilemmas 1, 2, 4, 5 & 7)	Company safety measures, procedures, and general safety culture	"I wouldn't want to break protocol from how to handle opening a valve, so I would say that that affected me greatly too. I wouldn't want to go against what the company does typically."
	Supervisor perception (Found in dilemmas 1, 3, 4, 6 & 7)	Students mention the opinions or thought process their supervisor or boss may have	"I guess it depends on how the manager sees things, because if they want to make the most money possible or if they want to run the safest business possible."
	Family impacts (Found in dilemmas 2, 3, 5 & 7)	Students mention the impacts of their decision on their family	". . .you have to consider your own safety and the safety of your family."
	Government regulations/legal issues (Found in dilemmas 2, 3, 6 & 7)	Student mentions government regulations (ex. EPA)	"And that's when you start to get into the OSHA problems and fines. . ."
	Contractor's safety (Found in dilemma 3)	Students mention the impact on the workers from a contracted company.	"Chances are it's going to immediately impact the people that were working to load and unload the tanks. . ."
Post- conventional	Product improvement (Found in dilemma 6)	Student mentions ways in which the product could be improved	". . .I would want to know it's improving the product and making it safe."
	Doing the "right" thing	Students mention making the correct decision	"I knew it was the right thing to do to try to find a replacement. . ."
	Potential for negative consequences	Students mention possible consequences that accompany a decision	"I think it's important to see that there are negative consequences. . ."
	Community impacts (Found in dilemmas 1, 2, 3, 5, 6 & 7)	Impacts on health or safety of a community	"I think when it comes to things like that, your duty is less to your company and more to the people in the environment in the surrounding area."
	Environmental impacts (Found in dilemmas 2, 3, 5, 6 & 7)	Impacts made to the environment or ecosystem	". . .be substantially less dangerous to the environment. . ."
	Safety Communication and Practice (Found in dilemmas 3, 4, 5 & 7)	Students mention how safety practices could be improved through communication with their teams	". . .because maybe if I chose to send a correct report about what happened, that would force my company to improve their handling and transporting procedures."
	Greater good for society (Found in dilemmas 2, 6 & 7)	Making a decision that would benefit everyone	"I guess if this product was like curing cancer, maybe that would affect my decision. . ."
	Risk assessment (Found in dilemmas 1 & 7)	Students weigh the potential risk that a decision may have	"The more times you're gonna have someone change a hose, there's just more room for error. And whether there's maintenance procedures in place or not doesn't mean they're actually gonna be followed."

For quality purposes, a training process was completed for the researchers coding the students' responses. The training process ensured that the researcher's coding process was similar, and that the codes were understood by the researchers. The training process began with the researchers separately coding the sixth dilemma using the generated code book. Once the coding was complete, all codes were combined into one document, which was reviewed by all researchers. The researchers met to discuss any discrepancies in the coding, and changes that needed to be made to the code book.

The remaining six dilemmas were each coded by two of the three researchers to ensure quality in the interpretation of the data. Each researcher coded four dilemmas, which allowed for each pair of researchers to code two dilemmas together. Coding was done separately, and codes were combined into one document once the coding process was complete. Researchers met to discuss any discrepancies in the codes. Once the coding was complete across the seven dilemmas, the frequency of each code that was mentioned for each student was recorded to determine the percentage of pre-conventional, conventional, and post-conventional codes that were mentioned for each dilemma. Excerpts of student responses that were coded are provided in the results section of this paper. Grammatical errors are denoted by [sic].

2.4.1. *Quality when handling the data*

When performing a qualitative based engineering education study, it is critical that the process for analyzing the data ensures quality in the results obtained. In this work, the authors referenced the Q3 framework for this purpose (Walther et al., 2013, 2015). Table 7 describes the steps taking when handling the data to ensure research quality.

Table 7
Q3 framework for handling the data (Walther et al., 2013, 2015).

Description	Handling the Data
Theoretical Validation *Do the concepts and relationships of the theory appropriately correspond to their social reality under investigation?*	*Findings should make a meaningful contribution to the relevant body of theory and interpretations need to reflect the coherence and complexity of the social reality under investigation.* • Code book created to align with Kohlberg's Moral Development Theory (Kohlberg and Hersh, 1977). • Looked to literature to understand the difference between behavioral ethics and moral reasoning to understand the results we obtained.
Procedural Validation *Which features of the research design improve the fit between reality and the theory generated?*	*Processes need to be implemented to mitigate risks of mis-constructing the participants' reality in the researcher's interpretations.* • Each transcript was coded by at least two researchers, who met and discussed discrepancies in codes. • Audit trail developed to capture all changes to the analysis plan over the course of the study
Communicative Validation *Is the knowledge socially constructed within the relevant communication community?*	*Interpretations need to be grounded in the accounts of the participants. The knowledge produced needs to be represented in accordance with the meaning conventions of the research community.* • Researchers met to discuss all coded files in order to deliberate discrepancies • Changes to any codes or the code book were discussed and agreed upon by all researchers
Pragmatic Validation *Do the concepts and knowledge claims withstand exposure to the reality investigated?*	*The knowledge produced needs to be meaningful in the social context under investigation* • Examined the data for underlying themes related to process safety decision making which would be relevant to the broader Chemical Engineering Education community
Process Reliability *How can the research process be made as independent as possible from random influences?*	*Procedures for generating and representing knowledge need to be established and documented.* • Each researcher kept their version of the coded transcripts, as well as the combined codes before and after meeting to discuss discrepancies. • Discussions were held between researcher pairings to talk through discrepancies before settling on final codes for the transcript under analysis • Audit trail developed to capture changes to the methodology over the course of the study

Table 8
Student's CDIT score, predominant reasoning and type.

	CDIT score	Predominant reasoning	Type
Student 1	30.04	Post-conventional	6
Student 2	21.70	Post-conventional	6
Student 3	25.16	Post-conventional	6
Student 4	29.81	Post-conventional	6
Student 5	13.79	Conventional	3

3. Results

As outlined in the Introduction of this paper, this study seeks to answer three distinct research questions that will be addressed individually in this section of the paper.

3.1. RQ1: What schemas of moral reasoning do senior chemical engineering students demonstrate when performing process safety decisions?

Each student's predominant reasoning was calculated based on the overall instrument to determine the classification of students into different types (Rest et al., 1999a). Table 8 shows the student's CDIT score, predominant reasoning, and type.

Four students who participated in the study were consolidated in the post-conventional schema, and one student was transitional in the conventional schema. These results conflict with scores that were found in literature. Rest found that moral reasoning increases with education (Rest et al., 1999b). While validating the DIT, Rest *et al.* found that 30% to 50% of the variance in scores had to do with the level of education of the participants. While validating the DIT2, Rest discovered an increase in p-score and N2 score in higher educational levels (Rest et al., 1999b). However, the average p-score and N2 score obtained from college seniors in the validation of the DIT2 was lower than the average obtained from the senior chemical engineering students from this study by about 29 points and 25 points respectively. Overall, while higher scores may be expected from senior chemical engineering students due to the rigor of this technical degree program, the scores that were obtained are unexpectedly high.

An explanation for this behavior could be that the students were working in the predictive phase, and not the decision phase as Bazerman and Tenbrunsel (2011) described. When working in the predictive phase, individuals tend to make more ethical decisions then they may make when put in the decision phase (Bazerman and Tenbrunsel, 2011). Students working in the predictive phase would select more "ethical" responses, which would lead to increases in their p-scores and N2 scores, and result in post-conventional predominant reasoning amongst most of the students. Since students were responding to scenarios about process safety, and knew that their responses had no real-world impact, they were working in a predictive phase.

Additionally, students were asked to verbally reason through each decision, which may have resulted in more ethical behavior than a student who would read the prompt and answer immediately. Students were actively employing System 2 thinking since they were conscious of the implications of their decisions, and they were weighing the costs and benefits of each consideration.

3.2. RQ2: How do senior chemical engineering students reason through process safety decisions?

To address this research question, the transcripts from the think aloud protocol were coded and analyzed for themes. All forms of reasoning were observed in student responses ranging from pre-conventional to post-conventional thinking as will be discussed below.

Pre-conventional thinking captures reasoning based on the avoidance of punishment, or physical consequence. It can also refer to decisions that are made based on satisfying the needs or wants of the individual (Kohlberg and Hersh, 1977). While responding to the provided scenarios, students often expressed concern about having a poor image, losing their job or jeopardizing their health and safety. The following quotes show how a student's response could reflect concern about their image, job, or health:

- "They might not like you suggesting this. They might say 'You're out of place, not working here.' But I think pointing this out, once again, shows that you are proactive. {Pre-conv - Personal image/satisfaction}"
- "That is most certainly a loss of employment and probably a huge black mark on your resume {Pre-conv - Career concerns}"
- And I feel like I would be much more concerned with the immediate risk to my health than I would be to what repercussions might come later. {Pre-conv - Personal health/exposure}"

Occasionally, students expressed how they didn't want to spend much time or effort on a task, or how they wanted to obtain a bonus or job advancement.

- "Again, I think that, I read that as if it's referring to would it be so annoying. Would I have to write up all that paperwork and stuff? {Pre-conv - Personal time investment/effort}"
- "I feel like if anything this might help you get a job after graduation 'cause it's showing that you're taking initiative and actively caring about what the plant is doing and what their safety measures are. {Pre-conv - Career concerns}"

Pre-conventional reasoning was seen the least throughout the protocol, which supports the work done by Rest et al. (1999b). As discussed previously, individuals at a higher age and education level should be operating at higher levels of moral reasoning. Senior chemical engineering students would be expected to be working mainly within the conventional space based upon the work done by Rest et al. (1999b).

Conventional reasoning was also observed in student responses. Conventional reasoning occurs when an individual prioritizes the benefits of others or the law (Kohlberg and Hersh, 1977). Throughout the transcripts, students mentioned the health, safety, time investment, abilities, and job-security of their co-workers or family. Students would also frequently mention the money, time, image, productivity, or equipment of the company. Example responses included:

- "You're not going to be the one changing the lines or working the other chemicals. It's going to be the other employees, so you have to put their needs and safety ahead of any of your own gain that you could get financial from this. {Conv - Co-worker concerns}"
- "An explosion is literally the worst case scenario. Most likely loss of life, millions of dollars in damage and a very big negative impact on the company. {Conv - Company concerns}"

Students often alluded to government regulations such as OSHA or the EPA, or legal issues that could occur as a result of the decision that was made. They also expressed concern over following the company's safety regulations and protocols as shown in the quotes below:

- "Because if you are breaking the law by not inspecting it as much as the law requires, then that's a big issue right off the bat. That shows negligence. It shows not caring and a bad culture. {Conv - Government regulations/legal issues; Conv - Company safety culture}"
- "I would say, once again, it's not technically illegal or wrong for you to do this, but the ethical implications are there and as soon as the EPA says that there is an issue, then you need to change. {Conv - Government regulations/legal issues}"

Table 9
Frequency Table of pre-conventional, conventional, and post-conventional codes across instrument.

	Pre-conventional	Conventional	Post-conventional
Student 1	24%	30%	47%
Student 2	14%	29%	56%
Student 3	17%	34%	49%
Student 4	9%	37%	44%
Student 5	24%	37%	39%

Post conventional reasoning occurs when there is an emphasis on general individual rights, and changing the law based on the situation. It can also include an emphasis on justice, the equality of human rights, and respect for humans as individuals (Kohlberg and Hersh, 1977). Students would often show conflict in their responses over which decision would lead to a greater output. These conflicts could be saving a large group of people over a smaller group of people, or continuing to use a harmful additive because it produced a product that helped a large group of people. The quotes below show some of the conflict students had while moving through the scenarios.

- "Now I'm weighing it on, if you do send volunteers and it all works out, you saved surrounding neighborhoods and the environment from all these bad things that could happen at the expense of, worst case scenario, a couple people who volunteered to be there, even. {Post-conv - The greater good}"
- "If you're making products that have to be [sic] like actively used to help people and help the environment it might be a little bit of weighing the benefits versus the risks to the environment. {Post-conv - Environmental impact}"

During the protocol, students would often mention the health and safety of people living in surrounding communities and the environment. At this level, students were thinking beyond themselves and the immediate people surrounding them, and focusing on the harmful impacts their decision could have on anyone removed from the situation. The following quotes show their reasoning:

- "...'cause if you do have a loss of containment and it does greatly negative [sic] impact the environment and surroundings then even if no one did get hurt during the storm or explosion that your plant might have caused, it could negatively impact the quality of life in the area for a long time to come. {Post-conv - Potential for negative consequences}"
- "They're not sure what it would do the environment. And also with a flood coming through, the organic chemicals could actually probably travel much farther than they would if they just got accidentally released normally. {Post-conv - Environmental impact}"

Post-conventional codes were the most frequent across the instrument for all of the students. While this is a promising theme, it may not be accurate of how the students would act when placed in the decision space. The students are working in the predictive phase, so behavioral forecasting errors are to be expected (Osberg and Shrauger, 1986; Diekmann et al., 2003).

The frequency of pre-conventional, conventional, and post-conventional responses that were observed in the students' think aloud protocols were recorded, and are shown in Table 9. Across all students, pre-conventional was the least frequent ranging from 9 to 24%, and post-conventional was the most frequent ranging from 39 to 56%.

It was expected for students to have a low frequency of pre-conventional codes due to Rest et al. (1999b) showing that college seniors should be reasoning in a conventional space. However, conventional codes were not the most frequent. The most frequent codes were post-conventional, which reinforces the previous hypothesis that students are operating in the predictive phase (Osberg and Shrauger, 1986; Diekmann et al., 2003).

For instance, it was observed that students would often disregard or dismiss the possible negative impacts that could occur to them when faced with a pre-conventional consideration. Students would not care about the possible repercussions or rewards they would be able to attain. These responses were most commonly seen with job security or career advancements, personal image, or money. The responses below show sample student responses that dismissed pre-conventional reasoning.

- “I think ultimately your manager would be a little bit happier which eventually could lead to further promotion or benefits, but that didn’t weigh too much on my decision. {Pre-conv - Career concerns}”
- “I wasn’t concerned about the bonus or accolades or opportunities for career advancement in this decision {Pre-conv - Career concerns}.

While it is promising that students were thinking beyond pre-conventional reasoning, it could be due to the predictive space they were working in (Bazerman and Tenbrunsel, 2011). For example, a student may insinuate that they do not care about the possible bonus money they may receive for making an unethical decision, but when put in the actual decision space, that bonus money may be needed at the time which would cause them to make an unethical decision. Similarly with job security, a student may state that they do not care about their job and they can always find another one, but when placed in the decision space, they may find how important it is to keep their job.

3.2.1. Progression in moral reasoning

Kohlberg’s stages are meant to act as “hierarchical integrations,” which means that an individual operating at a higher moral level will still recognize and understand lower level reasoning (Kohlberg and Hersh, 1977). This observation was a common theme that was prevalent across the student responses. Students would often move from pre-conventional reasoning to conventional reasoning when responding to pre-conventional considerations. This transition occurred when responding to considerations that dealt with personal health or exposure. While students would express concern about their own health and safety, they would often allude to the health and safety of their co-workers as well. The response below gives an example of a student applying both pre-conventional and conventional reasoning in their response to a pre-conventional consideration about their personal health.

- “Just because it’s obviously [sic] if you were exposed to this at a high volume, it’s going to negatively impact yourself and chances are if it’s technically impacting you it’s going to negatively impact[sic] all of your coworkers as well so it’s just adding to a very unsafe plant environment. {Pre-conv - Personal health/exposure; Conv - Co-worker concerns}”

This progression in reasoning would also occur between conventional and post-conventional reasoning. Often students would begin by expressing their concern for the people working in the plant, and would move on to realize the negative impacts on the surrounding communities and environment as well. The following response gives an example of a student moving through conventional to post-conventional reasoning.

- “That is concerning because you wouldn’t want to set your company back; however, it’s definitely the right thing to do, especially if the company can be a cause of people’s health and safety. {Conv - Company concerns; Post-conv - Doing the “right” thing}”

Occasionally, a student would clearly reason through all three levels of moral reasoning. In these responses, there is a clear beginning of pre-conventional reasoning where concern is expressed for the students’ health, safety or job security. That develops to concern for their co-workers, family or company. Finally, the students consider the fallout their decision could have on surrounding communities or the environment. The following quote is an example of a student who moved through all three forms of reasoning.

- . . .some of the first things I thought were Ďo I really want to be around this stuff continually?Ï thought of Ẅell, if we take this month does that slow down productivity and if so, then that will not look good at all if we decide to go with it.Änd I thought about how it was showing up in animals and other environmental areas and they can’t determine if it’s bad yet, but it is showing up {Pre-conv - Personal health/exposure; Conv - Company concerns; Post-conv - Environmental impact; Post-conv - Potential for negative consequences}.

Another theme that was observed was the consolidation of students within their decisions. The options that accompany the dilemma do not represent a “right” or “wrong” course of action, and the considerations are meant to equally represent both decision options. However, students almost always kept their decision the same throughout the protocol. Instead of the considerations causing a student to reflect back on their decision and whether it was the most appropriate course of action, the students instead used the considerations as a way of backing up their initial decision.

3.3. RQ3: Do the schemas of moral reasoning that students represent truly reflect their moral reasoning process when approaching process safety decisions?

To address this research question, results from the qualitative methods and quantitative methods are compared to analyze how well they coincide with one another. In the previous sections, these results were analyzed for the overall instrument. In this section, predominant reasoning and frequency of codes are analyzed on a dilemma level as it was felt that this would be a more accurate method of capturing students reasoning and decision making process when faced with a process safety scenario.

3.3.1. Overall instrument comparison

According to the quantitative results, four students showed predominant reasoning that was post-conventional consolidated, and one student showed predominant reasoning that was conventional transitional. However, the frequency of the codes across the instrument shows that post-conventional reasoning was most common for all of the students. This indicates that the predominant reasoning that is obtained from the quantitative results is not fully representative of the students reasoning on the overall instrument. Predominant reasoning is meant to reflect the schema that students ranked the highest on the instrument, while the codes show the full spectrum of reasoning the students were using. This could be due to the hierarchical stages that moral development follows. According to Kohlberg, students operating at a post-conventional level will also understand and reason at lower levels (Kohlberg and Hersh, 1977). Overall, student five was conventional predominant according to the quantitative analysis however, student five mostly applied post-conventional reasoning as shown in the qualitative results.

Table 10
Predominant reasoning per dilemma.

	Dilemma 2		Dilemma 6	
	Quantitative	Qualitative	Quantitative	Qualitative
Student 1	Post-conv	Conv	Post-conv	Post-conv
Student 2	Conv & Post-conv	Post-conv	Post-conv	Post-conv
Student 3	Post-conv	Conv	Post-conv	Post-conv
Student 4	Post-conv	Conv & Post-conv	Conv	Conv
Student 5	Conv	Conv	Conv	Conv

However, the quantitative results may reveal Student 5 operating in the post-conventional space if it is analyzed on a dilemma basis. Similarly, students who are operating at post-conventional levels overall could be operating at lower levels of moral reasoning on the individual dilemmas. In order to further investigate the hierarchical stages of all the students, predominant reasoning will be calculated on a dilemma basis.

3.3.2. Dilemma level comparison

In order to determine if student five's post-conventional reasoning was reflected in their quantitative data, the predominant reasoning was determined for each student on a dilemma basis. Four of the students showed deviation from their overall predominant reasoning on a dilemma basis. Students one, two, and four, who were overall post-conventional, showed predominant conventional reasoning in at least two dilemmas each. Student five, who was overall conventional, was predominantly post-conventional for two out of the seven dilemmas. These observations corroborate Kohlberg's point that an individual operating at a higher level of moral reasoning will still understand and reason through lower levels (Kohlberg and Hersh, 1977). However, student five demonstrates there can be discrepancies between the quantitative and qualitative data. To truly understand if predominant reasoning is reflective of the students reasoning, the qualitative results must be investigated on a dilemma basis as well.

All students showed post-conventional codes most frequently across the entire instrument. However, when analyzed on a dilemma basis, students showed mostly conventional codes on one to two of the seven dilemmas. Occasionally, pre-conventional codes were most frequent, or were second most frequent. This could be due to the negative pre-conventional and conventional codes where students would dismiss the pre-conventional or conventional reasoning. While these results are similar to the quantitative results, it is important to analyze the frequencies on a dilemma basis to determine if they are the same as the predominant reasoning on a dilemma basis. This analysis will determine if predominant reasoning is truly reflective of the student's moral reasoning.

Table 10 shows the comparison of the quantitative and qualitative results for two of the seven dilemmas as an example for the comparison that was performed. Predominant reasoning for the dilemma is shown in the quantitative columns, and the highest frequency of codes is shown in the qualitative columns. Dilemma 2 represents a dilemma where the predominant reasoning was not reflective of the student's moral reasoning, and dilemma six represents the opposite.

Due to the low number of considerations per dilemma compared to the overall instrument, it was common for students to tie between two levels of reasoning. On dilemma two, student five's moral reasoning was well represented by their predominant reasoning. However, for students one through four, this was not the case. Student one and three were predominantly post-conventional on dilemma two, but showed mostly conventional reasoning in their transcripts. For example, when prompted with a post-conventional consideration about the company's responsibility to locate its facilities in areas where negative impacts to the surrounding communities are minimized, student one responded in a conventional manner, which can be seen below.

> "...It is important for the company to make sure that companies surrounding the plant aren't affected by our mistakes... {Conv - Company concerns}"

Student 2 was mostly post-conventional in their reasoning for dilemma two, but was predominantly reasoning just as much conventionally as they were post-conventionally according to their responses to the considerations on the instrument. Similarly, student four was predominantly post-conventional on dilemma two, but showed the same amount of conventional and post-conventional reasoning in their transcript. When prompted with the same post-conventional consideration mentioned previously, student four responded in both a conventional and post-conventional manner, which is shown below.

> "...This is the type of situation where there could potentially be a drastic effect on the surrounding community leading to really bad consequences for the company and the community. {Conv - Company concerns; Post-conv - Community impacts}"

Dilemma 6 tells a different story, in which all of the student's moral reasoning was well represented by their predominant reasoning. This occurred for dilemmas four and seven as well. For most of the dilemmas, moral reasoning was well represented by the students predominant reasoning. Across the seven dilemmas and five students, the quantitative and qualitative results matched on 28 out of the possible 35 comparisons made. Discrepancies in the data could be a result of a few things. Students would often dismiss pre-conventional or conventional questions, however, their responses would still be coded. Dismissing pre-conventional or conventional concepts could be representative of post-conventional reasoning, but are still coded as pre-conventional or conventional. Additionally, students were consolidated in their decisions for each scenario. The options that accompany each dilemma do not represent a "right" or "wrong" course of action, and the considerations are meant to equally represent both decisions. However, students almost always kept their decision the same throughout the protocol. Instead of the considerations causing a student to reflect more on their decision, the students instead used the considerations as a way of backing up their initial decision. Therefore, a student may be reasoning post-conventionally, but may have used conventional considerations to support their decision.

Overall, it can be concluded that predominant reasoning is not truly representative of students moral reasoning when faced with process safety decisions due to what it is intended to measure. Predominant reasoning determines which schema students had ranked the highest. Predominant reasoning can provide insight as to which form of reasoning is being used the most, but it cannot represent the full spectrum of reasoning the student moves through while making a decision. With this in mind, qualitative methods should be used to investigate student responses in order to accurately depict how they reason through process safety decisions.

3.4. Limitations

Within this study were a few limitations, the first being the sample size of students who participated in the study. Five students participated in the think aloud protocol. While a large sample size was not expected for this study, the results that were obtained may only be representative of the five students who participated in the study. Additionally, all five students attended the same university. The results that were obtained from this study may only be representative of this specific institution and as such may not be transferable.

Additionally, students did not always recognize the considerations while they were reasoning through the dilemmas. Often, students would take a short amount of time to reason through their decision, however, they only addressed details given in the dilemma. When students read through each consideration, they often hadn't thought of them when making their decision. The considerations were meant to represent thoughts a student may have when attempting to make a decision. However, the results from this study show that the students only considered the information given to them, and did not appear to think much further.

Another limitation of this work is that it was conducted with senior chemical engineering students who have been taught to approach process safety decisions based on classroom instruction. Although some of the students may have had internship or co-op work experience within the chemical industry, their personal experiences within the chemical industry are not based on a lengthy exposure to the chemical industry environment. As such, the transferability of these results beyond an educational context are limited.

4. Conclusions

The importance of process safety is becoming increasingly apparent as companies strive for a better work environment through various training programs and methods (Champion et al., 2017; Swett et al., 2013; Nazir and Manca, 2014). However, we argue that it is likely that process safety incidents will still occur and continue to occur until more focus is placed on the behavioral ethics and moral reasoning of those making decisions. To better understand the moral reasoning of senior chemical engineering students, a mixed methods approach was used to classify students' moral reasoning when confronted with process safety dilemmas. Students were asked to read through the Engineering Process Safety Research Instrument (EPSRI) and share their thought process as they made their decisions.

Quantitative data that was collected during the protocol was used to calculate the students CDIT score and highest ranked schema. One student was determined to be conventional transitional (Type 3) whereas all other students were post conventional consolidated (Type 6). Student responses were analyzed and coded using provisional coding. Themes of pre-conventional, conventional, and post-conventional reasoning were prevalent throughout the responses. Post-conventional codes were the most frequent, however, senior chemical engineering students should be reasoning at a conventional level based on prior work focused on the moral reasoning of undergraduate students (Rest et al., 1999b). This discrepancy could be due to the students working in the predictive phase, where behavioral forecasting errors are common (Osberg and Shrauger, 1986; Diekmann et al., 2003). When placed in the decision phase, some of the responses might change due to ethical fading and differences between System 1 and 2 decision-making processes. Quantitative and qualitative results were compared on a dilemma level for the overall instrument to determine if the predominant reasoning was representative of the students' moral reasoning. When comparing the results for the overall instrument, it was found that the predominant reasoning was not representative of the students moral reasoning. On a dilemma level, the predominant reasoning was representative of their reasoning more often, but was not consistent. Predominant reasoning does not accurately represent the full moral reasoning the students expressed in their responses, however, it is a good measure of the type of reasoning that occurred most on a dilemma level. This study provided a first step towards understanding how senior chemical engineering students reason through process safety decisions. Moving forward additional work should be done to verify this study on a larger scale. We would also encourage that students be taught about their behavioral ethics which may result in students truly becoming post-conventional in their reasoning.

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