Conceptualizing a theory of ethical behavior in engineering

Mr. Luan Minh Nguyen, Iowa State University

Luan M. Nguyen is an MA/Ph.D. student in Anthropology/Civil Engineering, who completed his Master of Science in Biochemistry at Iowa State University and his Bachelor of Science in Chemistry at Hartwick College. His first master's thesis focused on the structural analysis of the schizophrenic gene DISC1 using transmission electron microscopy and hydrogen-deuterium exchange mass spectrometry. For his second master's thesis, he focuses on identifying the individual and institutional factors that contribute to a "culture of disengagement" from the ethical dimension of engineering work among students in the engineering profession. His Ph.D. project is funded by the NSF and is concerned with promoting and improving engineering students' ethical behavior and sensitivity through on-campus student organizations. His academic interests include mental health, international development, human rights, and engineering ethics. Currently, his ambition is to work within an international organization such as UNESCO and to be an advocate for promoting science and technology as critical tools of sustainable development as well as to participate in the dialogue between scientists, policy-makers, and society. Luan enjoys traveling, reading, and watching documentaries.

Dr. Cristina Poleacovschi

Dr. Poleacovschi is an Assistant Professor at Iowa State University. She researches issues of diversity, ethics and critical thinking in engineering.

Dr. Kasey M. Faust, University of Texas at Austin

Dr. Kasey Faust is an Assistant Professor in Civil, Architectural and Environmental Engineering at the University of Texas at Austin. Her research on sociotechnical systems—primarily water sector infrastructure—aims to improve service to communities. Dr. Faust's work spans the project phase during construction through the operations phase, exploring human-infrastructure interactions, infrastructure interdependencies, and the institutional environment. Current studies within her research group include: human-water sector infrastructure interdependencies in cities experiencing urban decline; disaster migration and the resilience of the built environment; incorporating equity into water infrastructure decision-making; sociotechnical modeling of infrastructure systems including gentrification and food deserts; the impact of policies and regulations on the built environment; understanding the impact of institutional elements on projects; and modeling of public perceptions.

Kate Padgett Walsh, Iowa State University

Dr. Kate Padgett Walsh is an Associate Professor of Philosophy at Iowa State University. She received a B.A. from Middlebury College, an M.A. from the University of Wisconsin-Milwaukee, and a Ph.D. from Northwestern University. Her research focuses on ethics and the history of ethics, including the ethics of debt and finance, as well as the scholarship of teaching and learning.

Dr. Scott Grant Feinstein

Dr. Scott Feinstein is an expert in research design and comparative and identity politics.

Dr. Cassandra Rutherford, Iowa State University

Dr. Cassandra Rutherford is an assistant professor in the Department of Civil, Constructions and Environmental Engineering. Her research focuses on geotechnical engineering and engineering education.

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ABSTRACT

Traditional engineering courses typically approach teaching and problem solving by focusing on the physical dimensions of those problems without consideration of dynamic social and ethical dimensions. As such, projects can fail to consider human rights, community questions and concerns, broader impacts upon society, or otherwise result in inequitable outcomes. And, despite the fact that students in engineering receive training on the Professional Code of Ethics for Engineers, to which they are expected to adhere in practice, many students are unable to recognize and analyze real-life ethical challenges as they arise. Indeed, research has found that students are typically less engaged with ethics—defined as the sensitivity and judgment of microethics and macroethics, sensitivity to diversity, and interest in promoting organizational ethical culture—at the end of their engineering studies than they were at the beginning. As such, many studies have focused on developing and improving the curriculum surrounding ethics through, for instance, exposing students to ethics case studies. However, such ethics courses often present a narrow and simplified view of ethics that students may struggle to integrate with their broader experience as engineers. Thus, there is a critical need to unpack the complexity of ethical behavior amongst engineering students in order to determine how to better foster ethical judgment and behavior. Promoting ethical behavior among engineering students and developing a culture of ethical behavior within institutions have become goals of many engineering programs. Towards this goal, we would like to present an overview of the current scholarship of engineering ethics and propose a theoretical framework of ethical behavior using a review of articles related to engineering ethics from 1997-2020. The review engages in theories across disciplines including philosophy, education, and psychology. In this work-in-progress paper, we present a subset of initial results based on a review of the first 50 articles out of the systematically selected 409 articles from Springer, Engineering Village, and EBSCO-Education Full Text. Preliminary results identify two major kinds of drivers of ethical behavior, namely individual level ethical behavior drivers (sensitivity to microethics, sensitivity to macroethics, implicit understanding, and explicit understanding) and institutional drivers (sensitivity to diversity and institutional ethical culture). Our preliminary results indicate that a sensitivity to both microethics and macroethics as well as the implicit and explicit understanding of ethics are essential in promoting ethical behavior amongst students. Furthermore, while drivers of ethical behavior at the individual level is important, one should not ignore the roles of the drivers of ethical behavior at the institutional level in promoting a collective ethical culture within organizations. The review also points to a need to focus on increasing students' macroethical sensitivity to topics such as sustainability and protection of human rights. This research thus addresses the need, driven by existing scholarship,

to identify a conceptual framework for explaining how ethical judgment and behavior in engineering can be further promoted.

INTRODUCTION

The field of engineering tends to place relatively less emphasis on the teaching of ethics to students; instead, technical background is often favored. Engineering ethics can be broadly defined as a subfield of professional ethics, encompassing both microethics and macroethics. Microethics concerns individual engineers, how they relate to one another in the profession, and ethical dilemmas with a limited scope [1], [2], [3]. In contrast, macroethics concerns sustainability, public policy, and broader impacts such as human rights [1], [4], [5]. At many institutions, ethics is not a required course for engineering students; instead, students are often instructed to memorize abstract ethical codes, likely causing them to take ethics less seriously [6], [7]. That is, memorizing abstract ethical codes does not provide a solid foundation for providing solutions to ethical dilemmas. As such, many students tend to draw from personal experience rather than from their professional ethical education when facing ethical dilemmas, which can lead to undesirable outcomes [6], [7], [8]).

Troublingly, Cech (2014) shows that there is a reduced interest in public engagement of engineering students at the end of their engineering studies as compared to that at the beginning [8]. This disconnect between engineering and public engagement can follow students from the classroom to the workplace, resulting in ethical lapses and inequitable outcomes that fail to consider community concerns and broader impacts upon society [6], [7], [9]. To address this challenge of students' disengagement from ethical dimensions of their work, earlier studies have focused on developing and improving the curriculum surrounding ethics through, for instance, exposing students to case studies [10], [11], [12], [13]. However, these methods can present a narrow and simplified view of ethics that students may struggle to assimilate with their broader experience as engineers because such methods often focus only on the individual engineers and their interactions with one another as professionals, i.e. they focus only on microethics [1].

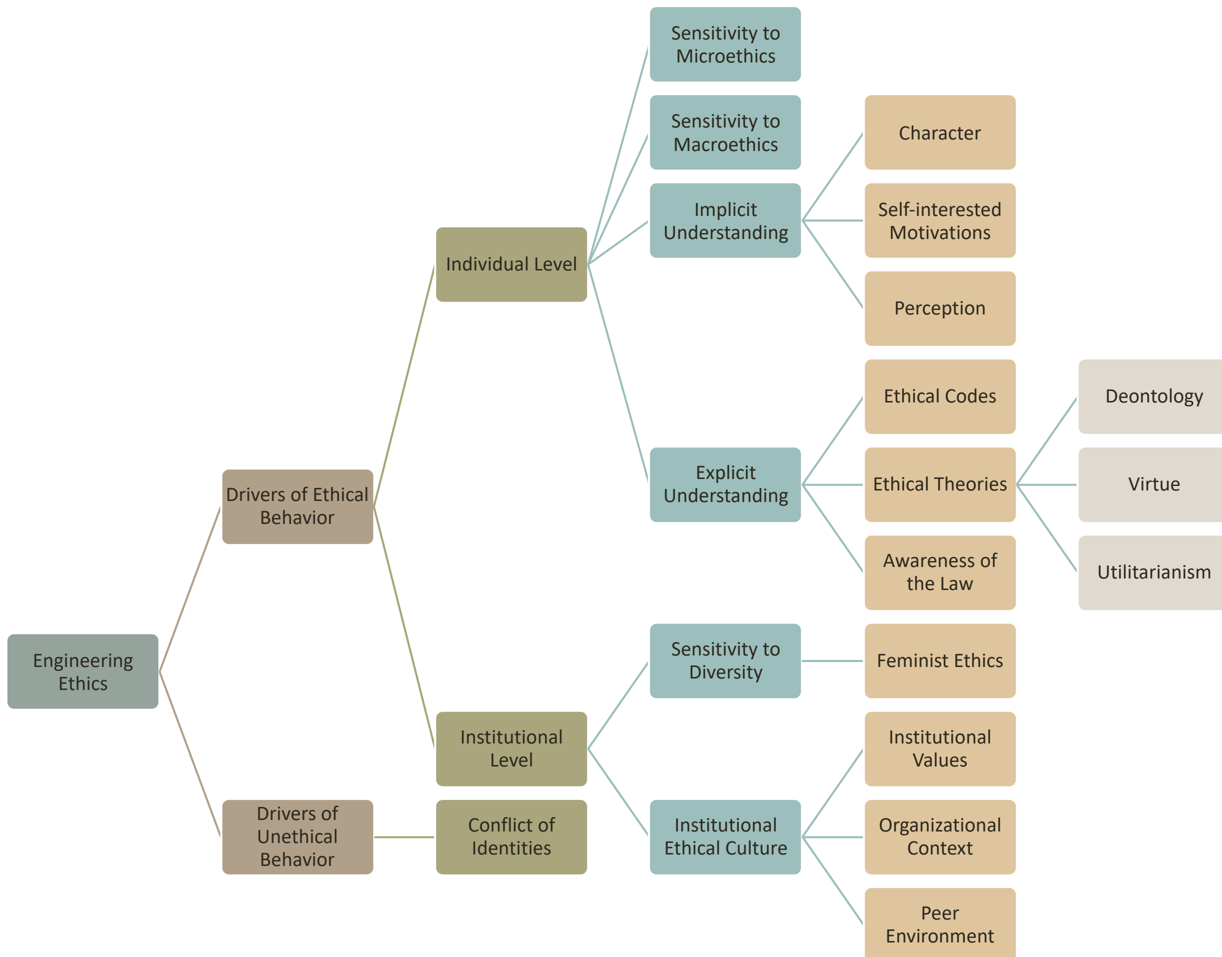
Another reason current ethics teaching methods can fail to improve ethical behavior amongst engineers is that they are not based on a standardized framework for what drives ethical behavior in engineering contexts. This is in part due to the lack of a consensus on the definition of engineering ethics [14], [15], [16], [17]. Baum (1980) defines engineering ethics as: "concerned with the actions and decisions made by persons, individually or collectively, who belong to the profession of engineering" [14]. Harris et al. (1996), on the other hand, consider engineering ethics as professional ethics, offering this definition: "those special morally permissible standards of conduct that, ideally, every member of a profession wants every other member to follow…" [15]. In addition, Fleddermann (2008) argues that engineering ethics is simply ethics that is applied to the professional engineers [16]. Lastly, Shuriye and Ismail (2011) concur that engineering ethics is "a purpose of virtues and the ideals to the goal of creation of useful and safe technological products and services" [17]. These different ways of defining engineering ethics illustrate not only the lack of a commonly accepted definition, but also an outdated understanding of the complex factors that drive ethical behavior. That is, they only focus on the awareness of microethics. Yet, understanding the factors that drive ethical behavior requires considering both microethics and macroethics. This understanding is of crucial importance to develop a curriculum that produces future graduates who are proficient in both technical and ethical knowledge to take on the many challenges of development in a sustainable and environment-friendly way. Previous literature has focused on singular interventions that drive ethical behavior and have showed successes and failures [1], [2], [3], [6], [7], [9]. However, the literature indicates that multiple drivers may matter in combination [1], [4], [5]. This demonstrates the need to create a framework which connects the various drivers of ethical behavior in a comprehensive manner. Towards this goal, we commence with an extensive literature review.

We conducted a literature review of journal articles on the topic of engineering ethics from 1997 to 2020 to identify the factors that motivate ethical behavior in engineering. We chose this period because the concept and importance of sustainability (and macroethics) became more prominent in the late 20th century. Preliminary results identify two main sets of drivers of ethical behavior (Figure 1), namely individual level ethical behavior drivers (awareness of microethics, awareness of macroethics, implicit understanding, and explicit understanding) and institutional drivers (awareness of diversity and institutional ethical culture). Our results indicated that an awareness of both microethics and macroethics is essential to promoting ethical behavior amongst students. However, the coded articles (Table 1) also point to the lack of a focus on increasing students' awareness of macroethics. Engineering students may, on the one hand, fail to notice or be aware of the ethical dimensions of their work. On the other hand, they may fail to reason correctly about ethics when confronted with the sorts of complex ethical challenges that occur in real life. This research thus addresses the need, driven by existing scholarship, to identify a conceptual framework for explaining how ethical judgment and behavior in engineering can be promoted.

ETHICS EDUCATION

Finelli et al. (2012) emphasize the need to better promote ethical development in engineering students [18]. As the field of engineering advances, ethical dilemmas that come with this advancement are becoming more complex [19]. For example, an engineering project on improving infrastructure within a refugee camp by the United Nations (UN) requires the engineers to understand the needs and perspectives of the refugees in this camp towards the project. The project might, for instance, face resistance from some refugees if they feel that the UN has thereby given up on helping them return to their home country. Refugee camps are supposed to be temporary; but improvements in camp infrastructure mean that the refugees are likely to stay for much longer, and they might thus feel abandoned. This example illustrates a complicated and interdependent relationship between technical and ethical aspects of engineering work. Engineers could easily make the mistake of ignoring the attitudes of refugees towards their project, and thus fail to provide the best solutions to help these refugees.

Figure 1: Overview of preliminary results.



A major challenge in teaching engineering ethics is to help students acquire the ability to identify a range of solutions to complicated ethical dilemmas, such as the one mentioned above [19], [20]. The aim of teaching engineering ethics to students, then, is not to simply to teach principles of right and wrong, but rather to provide insight and methods to assist engineers in actual decision-making processes [21]. Behaving ethically (i.e. making ethical decisions) requires understanding different ethical issues from different theoretical approaches (e.g. virtue theory, utilitarian, and deontological approaches), considering a range of solutions with multiple consequences, and communicating with other colleagues involved as well as the community [22].

Some educators have focused on teaching ethical theories to engineering students in order to help students develop ethical awareness using different perspectives [20], [23]. However, ethical theories are not emphasized in many engineering courses with ethics components; instead, the emphasis is often placed on teaching ethical codes [20], [23]. Instruction focuses especially on the professional Code of Ethics that engineers are expected follow once they enter the work field [1], [6], [10], [23], [24], [25]; [26]. In contrast to other professions, such as law, where lawyers are licensed and are therefore bound to uphold the professional ethical codes, many engineers are not licensed and consequently have not explicitly sworn to uphold any of the professional engineering codes of ethics; however, the codes do provide a basis for engineers to prepare for some ethical problems they will likely face [10]. Yet, following professional codes may not be sufficient to prevent harm if the engineers are not trained in identifying and analyzing complex ethical dilemmas [24]. The codes themselves cannot resolve dilemmas except to recommend that engineering professionals act according to the codes [10]. The codes also primarily address only interactions amongst professional engineers, ignoring a whole set of other different actors impacted by engineering work [25]. Therefore, students may have trouble understanding and resolving complicated ethical dilemmas if they are taught only to follow the codes. Students need to be able to move beyond just learning the formulaic ethical codes to a more holistic approach that integrates public needs and experience with ethics; yet, many students reported that they have only been instructed on ethical codes during their ethics education [27], [28], [29].

In addition, many educators and researchers in the field of engineering ethics have focused only on teaching microethics (which concerns individual engineers, how they relate to one another in the profession, and ethical dilemmas with a limited scope) [1]. Macroethics has only recently received attention, and pedagogical techniques for integrating microethics and macroethics into the curriculum have not been well developed [1]. We need, therefore, to develop a more comprehensive account of what drives ethical engineering to better incorporate engineering ethics into the curriculum so that it includes both micro and macroethics in engineering education.

Ethics instruction methods in the classroom usually depend on individual professors, and how ethics is incorporated into the curriculum can change from institution to institution. Required courses and elective courses inside and outside of the discipline, across-the-curriculum, and bridges between ethics and society are some of the predominant ways institutions have incorporated engineering ethics into their curricula [11], [30]. Requiring a course within the discipline is commonly conducted as a multiple-credit, full semester class that all engineering students must take to graduate, allowing the class to focus on discipline-related issues [30]. The elective, outside-of-the-discipline method often relies on courses offered from philosophy departments and is good for exposing students to a more general background of ethics; however, this sacrifices the disciplinary context covered by the within-the-discipline method [30]. The across-the-curriculum method presents students with ethical dilemmas repetitively in multiple courses during their engineering education; while effective, this method calls for a commitment among faculty members to conduct ethics discussions in their courses [30]. Lastly, an effective approach of bridging engineering with societal concerns involves the use of a curriculum model with a range of required courses that have ethics components which highly emphasize engineering ethics and the role of engineers in society [11], [30].

However, despite such efforts, it continues to be the case that student understanding of ethics is poor, suggesting that there is a misalignment between ethics instruction and students' ethical behavior [18]. Employers expect to hire engineering graduates with a wide range of professional skills including the ability to identify and make appropriate decisions regarding ethical dilemmas [7], [19], [31]. Engineering as a field has not sufficiently focused on preparing graduates that can demonstrate ethical behavior as compared to other professions, which is especially concerning given the embedded social and political nature of engineering projects [5].

Table 1: Article Selection Process

Database	Keyword	Filter	Initial Results	Retained
Springer	Engineering Ethics	Limit to 1997-2020, English only journal articles, Subdisciplines Engineering-general and Ethics	1,784	271
Engineering Village	Engineering Ethics	Limit to 1997-2020, English only journal articles, Engineering Education,	308	107
EBSCO-Education Full Text	Engineering Ethics	Limit to 1997-2020, English only journal articles, Publication type (academic journal/review), document type (article/review)	316	33
Total			**2,408**	**411**
Total Retained After Removing Duplicates				**409**

METHOD

Springer, Engineering Village, and EBSCO-Education Full Text were used for selection of articles. Springer and Engineering Village were chosen because of their extensive collections of research articles related to engineering ethics. EBSCO-Education Full Text was chosen because it contains a large variety of articles at the intersection between ethics and education. Table 1 contains a summary of the article selection process. In each database, the following selection criteria were used to retain articles after initial results: (1) the article must be specifically about engineering ethics and engineering ethics education, (2) the article must be a research article or systematic review and must not be a workshop report, conference summary, or commentary, (3) the article should be general to most fields of engineering, and (4) the article must not be specific only to gene-editing technology because this mostly pertains to the field of bioethics. In this work-in-progress, we chose 50 out of the total 409 selected articles that we considered central our work to highlight the current understanding of what drives ethical behavior in the field of engineering. The coding process were done in Nvivo. The emerging themes from these 50 articles were used as the backbone to building our diagram of drivers of ethical behavior illustrated in Figure 1. The definitions of the codes are listed in Table 2.

DRIVERS OF ETHICAL BEHAVIOR AT THE INDIVIDUAL LEVEL

Ethical behavior is partly driven by the individual's understanding and awareness of the ethical questions (e.g. whether to ignore refugees' attitude towards infrastructure improvement projects) raised by situations they encounter [1], [2], [3], [4], [5], [18]. Drivers of ethical behavior at the individual level are defined as theoretical explanations of how individuals make ethical decisions, encompassing microethics [1], [2], [3], macroethics [1], [4], [5], implicit ethical understandings [32], and explicit ethical understandings [29], [32]. While microethics concerns individual engineers, how they relate to one another in the profession, and ethical dilemmas with a limited scope [1], [2], [3], macroethics concerns sustainability, public policy, and broader impacts [1], [4], [5]. Even though important work must still be done in the field of engineering microethics, more work is needed in the area of engineering macroethics. Even more discouraging is the fact that there is insufficient amount of work on integrated approaches to address both micro and macro issues in engineering, that is, linking personal and professional ethics as well as linking professional and social ethics [1]. The micro-macro distinction, however, is not always clear and one might find it difficult to encourage ethical reflection at a micro level without taking macro aspects into account [4]. To understand how microethics and macroethics are related, we will now discuss each in detail.

Sensitivity to Microethics

Microethics focuses on issues for the most part internal to engineering practice, such as the relationship between individual engineers, or between the engineers and their clients [1], [2], [3]. Research in the field of engineering ethics has mostly focused on students' understanding of microethics issues even though the impacts of engineering work extend far beyond microethics [4], [5], [6], [7], [27], [28], [33]. The majority of engineering ethics interventions and recommendations have evolved around issues of microethics taking place among individual engineers such as exchanging technical knowledge in a responsible manner or how to manage a good engineer-client relationship [5]. That is, formal education has mostly focused on an engineer's responsibility to themselves, their company, and the project at [33].

Microethical sensitivity concerns the individual's attitudes towards those they come in contact with (e.g. colleagues and clients) and their awareness of their obligations to, for example, provide assistance and be honest [6], [27], [28]. Individuals tend to orient themselves to the people in their environment; that is, they tend to be able to imagine themselves in the positions of people with whom they come into contact [6]. The alignment of engineering students is significantly associated with the majors and careers they choose to pursue [6]. Therefore, when facing ambiguous ethical dilemmas, orientation to others in their environment is likely to predict microethical understanding [6].

Bairaktarova and Woodcock (2015) also found that differences in individual attitudes towards ethical behavior, especially when considering the social environment may matter in determining how individuals detect ethical breaches in ambiguous situations [6]. This is because when responding to ethical dilemmas, an individual's feelings of moral obligations influence ethical behavior [7]. However, Conlon and Zandvoort (2011) argue that ethical dilemmas are difficult to resolve at the level of the individual engineer [4]. Higher level (macroethics) action is needed to help engineers effectively provide solutions to ethical issues in their work [4].

Sensitivity to Macroethics

Macroethics applies to the collective social responsibility of engineers to society, as well as how society makes decisions about the use of technology [1]. Sensitivity to macroethics, thus, focuses on social significances of technological policy decisions (e.g. refugees' attitude towards the camp infrastructure improvement project) and on issues for the engineering profession as a whole such as protection of public safety, health, human rights, and welfare [2], [3]. Previous literature discussing macroethics has emphasized the lack of focus on students' macroethical sensitivity issues [5]. Take the issue of sustainability as an example; sustainability is one of many macroethical topics that does not get extensive attention across different fields within the field of engineering. The topic is often taught to some extent in environmental, materials, civil, chemical, and general engineering but rarely touched on in biomedical, computing, and electrical engineering [33].

Moreover, engineering professionals have not devoted sufficient attention to many complex macroethical issues, such as the impact of development on the environment or the risk of nuclear technology and, thus, have been criticized by the public for unintended effects of technology [3]. That is, the public believes that many engineers are not sufficiently engaged in societal and community concerns [27], [28]. This indicates that the fields of engineering and engineering education should engage more with macroethics at the societal level, focusing on how engineers reflect on and evaluate their social responsibilities with regard to technological advancement [5]. More work is needed in the area of engineering macroethics to develop integrated approaches that address both micro and macro issues in engineering, i.e. to link personal professional ethics with social professional ethics [1], [4].

Implicit Understanding

Implicit understanding is demonstrated through a person's actions, attitudes, wording choices, and communication style, all of which constitute her or his non-declarative knowledge [32]. Various sources such as microethical cultures, informal education, and personal experiences are involved in implicit understanding and students' implicit understanding could be a foundation resource for the process of making ethical decision [32]. In fact, students had proceeded more easily with ethical cases in which they had an understanding of some specific issues that were involved or when their own sense of ethics seemed to aligned well with a range of possible solutions in a study by [23]. Three factors contribute to implicit ethical understandings: self-interested motivations, character, and perception [32]. *Self-interested motivations* describes how personal ends feed into responses to ethical questions. *Character* describes the background beliefs and traits such as honesty that influence how individuals respond to situations and dilemmas. Lastly, *perception* describes the sensitivity to and awareness of the ethical dimensions of professional engineering [32]. These three factors together provides a foundation for formulating ethical reasoning and judgment—explicit understanding.

Explicit Understanding

Explicit understanding is established through students' declarative knowledge and explicit reasoning [32]. Explicit ethical knowledge refers to a student's understanding of professional engineering ethical codes and ethical theories that constitute other rules governing ethical behavior [29].

+ ***Ethical codes***: represent the professional Code of Ethics that engineers are expected follow once they enter the work field [1], [6], [10], [23], [24], [25], [26]. In contrast to other professions, such as law where lawyers are licensed and are therefore bound to uphold the professional ethical codes, many engineers are not licensed and consequently have not explicitly sworn to uphold any of the professional engineering codes of ethics; however, the codes do provide a basis for engineers to prepare for the ethical problems they will likely face [10]. Yet, following professional codes may not be sufficient to prevent harm if the engineers are not trained in identifying possible problems [24]. The codes themselves could not resolve the ethical problems except to recommend that engineering professionals act according to the codes [10]. One reason is because these codes address only the professional engineers, ignoring a whole set of other different actors involved in the engineering world [25]. Lynch and Kline (2000) suggested that engineering students should be encouraged to attend to features of everyday practice rather than only focusing on abstract moral theories or professional codes because these generally do not have an obvious connection to engineering practice, even when considering rights and duties within organizational context [24]. Bairaktarova and Woodcock (2015) found that there is no difference in performing ethical dilemma tasks between students who had taken an ethics class and those who had not taken one [6]. In contrast, Clancy et al. (2005) found that most students believed that exposure to the code of ethics help broaden their thinking about ethical issues and that these codes were useful when solving ethical dilemmas [23]. Furthermore, as ethical codes evolve over time, they might be tempered by societal rules [26]. For instance, the engineering codes of ethics seem to demonstrate a logical compatibility and consistency with many common morality principles; however, what distinguishes the engineering ethics principles from common morality principles is their expansion on the basic tenets of common and personal morality to specific circumstances of engineering practice [21]. That is to say that engineering codes of ethics are motivated by the ideologies of common morality. In addition, young engineering graduates are often not aware that their responsibilities go beyond corporate loyalty even though many current engineering societies have well-established codes of ethics [19]. For example, a code of ethics by the American Society of Civil Engineers (ASCE) states that engineers should avoid unfair competition and to offer only services that are compatible with their expertise because those who participate in unfair competition will diminish the value of all engineering work which makes it difficult for unemployed engineers to find work, indirectly reducing the wages of engineers who are employed [34]. Additionally, there is a call for voluntary organizations such as ASCE to set higher standards for their members in their codes of ethics than is imposed by the law [35]. While many engineering codes of ethics vary from one professional society to another, they all share common features in describing the obligations of engineers to the public, employers and clients, and their colleagues [1]. These societies hope that engineering professionals and students will easily recognize a breach of ethics in order to identify a range of solutions to ethical problems once they are introduced to the codes [6]. As ethical codes evolve over time, aspects of both micro and macroethics have been included. Among the codes of ethics by different professional engineering societies, all begin with stating the responsibility to protect human health, safety, and welfare; more than half of these codes include environmental protection; and less than half directly include sustainability [33]. In fact, even though ASCE has taken a large step forward by incorporating environmental values into its Code of Ethics, its incorporation of principles of sustainable development has been criticized as insufficient [36], [37].

+ ***Ethical theories***: explicitly learning ethical codes might not be sufficient enough to prepare engineers to face complex ethical problems; thus, one needs to combine ethical codes with philosophical principles of ethical judgment—*ethical theories*—such as happiness, morality, and virtue [38].

- ***Happiness*** specifies how an action can affect the happiness of others and is something complete and self-sufficient because it is the end goals of the things pursued in action [38]. However, having an understanding of happiness does not mean that one must be engaged the active affairs of life, but this does hold for being virtuous [38]. In fact, by using the term happiness for the end goal aimed for by a virtuous life might lead to a disconnection of the activity of virtue from the end goal [38].
- ***Virtue*** begs the question, “does an action express virtuous character and thought processes?” [38]. Humans express our virtues in a range of situations and the practice of ethical virtues are not in themselves ends but rather “instrumental pursued as means to some further end their practice seeks to realize” [38]. Professional virtues are indeed a subset of ethical virtues, for they characterize the end of professional activities. Thus, one could say that professional engineering virtues are both technical and non-technical virtues of engineers specifically.
- ***Morality*** is the principles of an individual regarding right and wrong [6], [22], [39], [40], [41]. Moral responsibilities represent the obligation to follow a certain strategy to perform or avoid doing specific activities [6], [41]. Many engineers are

not part of professional societies and those who are have not read the ethics codes for their professional organization; thus, they rely directly on their untrained moral competence when confronted with ethical dilemmas [39]. Veach (2006) distinguishes between moral intelligence, knowing what to do, and moral competence, the skill of applying moral intelligence to do the right things [39]. He advocates for the application of the Golden Rule as a starting point to fill the gaps missing in the ethical codes in order to link between engineering ethics and other aspects of life. In addition, Jonassen and Cho (2011) suggests that rather than studying professional ethical codes, students should analyze and solve ethical problems based on moral theories [22]. However, Lynch and Kline (2000) maintains that engineers should not rely on moral philosophy entirely but also draw on the in vivo study of technical practice by social scientists and historians in anticipating potential threats to public safety [24]. Furthermore, Bairaktarova and Woodcock (2015) suggest that moral awareness has not been demonstrated to translate directly into ethical behavior [6].

+ ***Liability law****:* explicit understanding of the law might prove useful to the decision making process in solving ethical dilemmas [42]. Nichols (2005) introduces the concept of negligence, a broad principal of liability [42]. Generally speaking, legal concepts of negligence are related to moral fault, failure to live up to an ideal of conduct [42]. Professional negligence, a special case of negligence, represents the standards to which society holds members of the engineering profession [42].

DRIVER OF ETHICAL BEHAVIOR AT THE INSTITUTIONAL LEVEL

Taken together, factors of microethics, macroethics, implicit understanding, and explicit understanding constitute a theoretical framework that drives ethical behavior. However, as many engineering professionals and students belong to organizations and institutions, one needs to consider the institutional factors that drive ethical behavior in addition to theoretical drivers. We begin the discussion of the role of institutions in driving ethical behaviors by describing institutional drivers as institutional factors that explain how individuals make ethical decisions [1], [4]. These factors include diversity [6], [7], [8], [43], [44] and institutional culture [29], [31], [33], [38], [45]. A great deal of attention has been focused on the notion that members of professional societies have a collective responsibility for nurturing ethical behavior [1]. In fact, many have argued for an emphasis on an institutional ethics rather than an individual one [4]. Moreover, Conlon and Zandvoort (2011) suggest that simply improving the teaching of ethics to engineering students does not certainly address the problem of whether professional engineering bodies have the will and capability to promote real change [4]. In fact, they advocate for the need to examine the organizational, institutional, and cultural resources accessible to engineers that allow them to be able to intervene in the process of making public policies, meaning that both individual and institutional values and beliefs should be considered [4].

Sensitivity to Diversity

Diversity represents the effects of gender and racial representation and awareness [6], [7], [8], [43], [44]. As the world is advancing towards globalization, understanding of the ethics of diversity is becoming more important than ever for students in engineering face a future in which they will need to work with a diverse range of people from different social and educational backgrounds [44]. Bairaktarova and Woodcock (2017) suggest that elements such as students' gender, age, work experience, personality, nationality, and cultural background might play a role in ethical decision making [7]. For example, women tend to be more perceptive towards ethical scenarios than men and work experience is more important than education when it comes to ethics as people with more work experience are exposed to more ethical challenges [7]. Additionally, students from different educational and cultural backgrounds will have different perspectives regarding moral codes of behavior; these factors, thus, add complexity to the teaching of professional ethics [6], [7]. For instance, Cech (2014) found that Asian and Asian American students are less likely to emphasize on understanding how people use machines than white students [8]. In fact, while Cech's work indicates that Asian and Asian American students' focus on the understanding of the consequences of technology and how people use machines has decreased marginally more than that of white students [8], Miller and Brumbelow (2017) suggest that black students placed a higher priority on the quality of life and economic growth and a much lower priority on the quality of the environment [46]. In addition, STEM workers remain significantly white, male, and able-bodied, leaving talented women, minorities, and those with disabilities at a significant disadvantage [43]. Thus, in order to remain competitive in an environment of increasing international competition, institutions need to train a diverse population of engineers for the new work force [43].

+ ***Feminist Engineering Ethics*** represents an emerging field of engineering ethics that is included within the ethics of diversity is feminist engineering ethics that is involved in the uncovering of sexist norms [5], [8], [47]. As mentioned above, women, in general, tend to have stronger social consciousness beliefs and to find the understanding of the consequences of technology more important than men do [8]. Thus, it is appropriate to incorporate more feminist ethics into engineering education [5]. Feminist engineering ethics begins often from a place of critique by examining practices that have not been feminist in order to uncover sexist norms, identify the ways in which women and others have been excluded from the profession, and provide directions forwards [47]. In fact, feminist ethicists study rhetoric and discussion around a situation by asking who the moral agent is and how social structures limit or enable agency [47]. Riley (2013) suggests that scholars doing feminist work should be able to use the word freely without negative consequences in order to improve feminist engineering ethics [47]. However, for reasons, many still take issues with the word "feminist." Thus, to foster a diverse ethical culture, one should target the institutional culture that is male-dominated.

Institutional Ethical Culture

Institutional ethical culture, as we define, represents the role of professional institutions in regulating the practice of engineers in a well-ordered society [29], [31], [33], [38], [45]. Stovall (2011) suggests that a well-ordered society is one where professional work would be recognized as having contributed to the practical role of the profession and to the aspect of the constitution of the society that the profession's purpose is directed toward [38]. Therefore, a well-ordered society is one that nurtures the accomplishment of the functions of its professions [38]. In fact, it rewards its virtuous professionals by providing them professional success, therefore, preparing the professionals for further work in the profession [38]. Stovall (2011) goes on to argue for an essential condition for a well-ordered society that is existence of institutions that nurture the virtuous values among its professions [38]. When applied to engineering ethics, institutional culture describes the culture of the engineering school in the context of the institution as a whole that influences student understanding of ethics [29], [31]. Institutional culture matters in engineering as it sets the framework to identify, for example, what is important, what should be ignored, who is important as well as to guide and restrict modes of communications [45]. Furthermore, it is recognized that different engineering disciplines have different cultures; for example, civil engineering is considered conservative and bound by standards in contrast to the creative and innovative mechanical engineering [33]. However, Cech (2004) found that there is a common culture of disengagement from public welfare commitments in the engineering profession [8]. In order to understand the institutional ethical culture and how it aids in the process of ethical decision making, one needs to consider institutional values, organizational context, and peer environment.

+ ***Institutional Values***: represent the collective values of the students' institutions [8]. Cech (2014) suggests that engineering institutions tend to value technical knowledge such as math and science over engagement-relevant factors such as ethical and social issues [8]. He also found that variation in cultural emphases by these institutions does not readily translate into public welfare commitments amongst engineering students which suggests that commitment to public welfare concerns is not highly valued in students' engineering professional identities and that this commitment decreases over the course of their studies [8]. Based on the fact that collective institutional values do seem to affect students' ethical awareness and that these values do place an emphasis on technical background over ethical or social one, we need to improve these institutional ethical and social emphasis in order to promote an ethical awareness culture among engineering students.

+ ***Organizational Context****:* represents formal organizational structures, academic and institutional priorities, mission, and ethos as well as faculty culture [4], [8], [18], [24], [29]. In practice, most engineers work in an environment where their decision making capacity is restricted by the corporate or organizational culture [4], [24]. As mentioned above, a disengagement culture is embedded within the broader culture of US engineering and materializes at the organizational level in many engineering educational programs [8]. In fact, many argued that accidents could be better understood as a result of organizational failure rather than individual error or technical failure; thus, analysis of accidents should be examined through historical background and organizational context [4], [24]. However, while it is true that organizational context is significant in confining individual ethical behavior, the peer environment in which the individuals operate also plays an important role.

+ ***Peer Environment***: represents student characteristics, values, attitudes, beliefs, and behaviors [18], [29]. Holsapple et al. (2012) suggest that the student individual experiences within an institutional culture can vary widely despite the fact that there is a shared peer environment within that culture [29].

DRIVER OF UNETHICAL BEHAVIOR

Drivers of unethical behavior represent factors that tend to decrease ethical behavior such as self-interest, lack of awareness, failures of judgment, and the fear of facing repercussion [1], [2], [20], [31], [35], [39]. No professionals want anything harmful to happen in their work; indeed, the majority of the times, the problem does not come from the engineers' intentions but it comes from their inability to predict or prevent an unfortunate outcome [20]. Hoffmann and Borenstein (2014) suggests that one needs to recognize that there is an ethical challenge that is always linked to one's decisions [20]. Furthermore, Veach (2006) indicates that people make unethical choices when faced with ethical dilemmas for three reasons: they do what they feel is most convenient (lack of awareness), they do what benefit themselves (self-interest), and they justify their decisions with relativism (failures of judgment) [39]. The highly aspired to "always ethical" category is not reached in favor of convenience; it is inconvenient to always be ethical [39]. Moreover, people tend to engage in unethical activities that put them at an advantage over others for they believe that doing what is ethical would limit their options and opportunities to success [39]. And according to Veach (2006), it is easy to justify their engagement in unethical activities using relativism [39]. In short, unethical behaviors occur when personal or business goals conflict with core values [39]. For example, engineers who accept untaxed payments for work are considered unethical because they had violated tax law [34]. In fact, engineering professionals are overwhelmed with opportunities to behave unethically [31]. For instance, engineers may compromise their efforts to provide quality work to the client, leading to low quality work that might actually be harmful to the safety and welfare of the public, in order to do what is convenient for themselves [35]. Another factor that might deter engineers from behaving ethically is the repercussion they might face such as demotions and getting fired from their employers [1], [2]. In fact, corporate influence provides explanations for the lack of supports for ethics by the professional societies [1]. Furthermore, the engineering/business culture highly values economic efficiency while downplays engineering societal context, leading to a reduction in ethical awareness amongst engineering professionals [1]. In addition, this duality of being both engineering and business professionals creates what we call a conflict of identities amongst engineers.

+ ***Conflict of Identities*** represents conflicts between the multiple different roles of an individual and engineer [24], [48]. For students, having established an identity as engineers means navigating a dualism that frames themselves as extremely technical personnel and that supposes everything other than technical to be less valuable [48]. Furthermore, many engineering professionals function as both engineers and managers. Thus, functioning as managers sometimes means that they sometimes feel the need to put business interests first over their engineering interest, leading to unethical outcomes [24].

Table 2: Definitions of Codes

Codes	Definitions
Awareness of Microethics	concerning individual engineers, how they relate to one another in the profession, and ethical dilemmas with a limited scope
Awareness of Macroethics	concerning sustainability, public policy, and broader impacts
Implicit Understanding	demonstrated through a person's actions, attitudes, wording choices, and communication style, all of which constitute her or his non-declarative knowledge
Character	describes the background beliefs and traits such as honesty that influence how individuals respond to situations and dilemmas
Self-interested Motivation	describes the role of personal ends into responses to ethical questions
Perception	describes the sensitivity to and awareness of the ethical dimensions of professional engineering
Explicit Understanding	established through students' declarative knowledge and explicit reasoning
Ethical Codes	represent the professional Code of Ethics that engineers are expected follow once they enter the work field
Moral Theories	philosophical principles of ethical judgment
Deontology	represent the principles of an individual regarding right and wrong
Virtue	represents the character and thought processes of a person that leads to a specific action
Utilitarianism	theory represents how an action would affect the happiness of others
Awareness of the law	represents the liability faced by engineers when performing their professional activities
Awareness of Diversity	represents the effects of gender and racial representation
Feminist Ethics	represents the examination of a body of knowledge and existing practices that has not been feminist to uncover sexist norms.
Institutional Ethical Culture	represents the role of professional institutions in regulating the practice of engineers in a well-ordered society
Institutional Values	represents the collective values of the students' institutions.
Organizational Context	represents formal organizational structures, academic and institutional priorities, mission, and ethos as well as faculty culture
Peer Environment	represents student characteristics, values, attitudes, beliefs, and behaviors
Conflict of Identities	represents conflicts between the multiple different roles of an individual and engineer

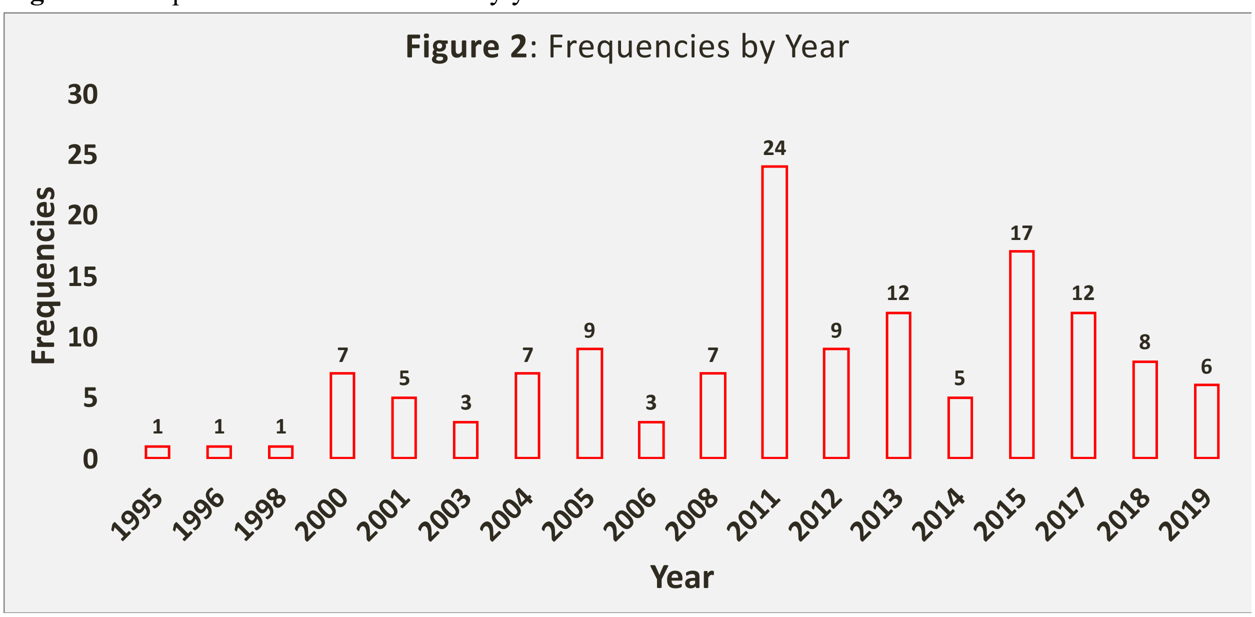
DISCUSSION

The engineering education system in the US typically prioritizes teaching scientific and engineering concepts over social or ethical dimensions [6], [7]. Unfortunately, this disengagement from social and ethical dimensions follows students from the classroom to the workplace, leading to inequitable outcomes and failures to consider community concerns as well as broader impacts upon society [9]. Although most engineering students explicitly receive training on the

Professional Code of Ethics for Engineers [25], to which they are expected to adhere in practice, many students are still unable to recognize and analyze real-life ethical challenges as they arise [24], [49], [50]. Cech (2014) found that students are usually less engaged with ethics at the end of their engineering studies than they were at the beginning [8]. In order to address this challenge of students' disengagement with ethical dimensions of their work, many earlier studies had focused on developing and improving the curriculum surrounding ethics through, for instance, exposing students to case studies [10], [11], [12], [13]. Yet, these cases often present a narrow and simplified view of ethics that students may struggle to assimilate with their broader experience as engineers due to the fact that these courses often focus only on the individual engineers and their interactions with one another as professionals—microethics [1]. Thus, there is a need to increase the focus on research and teaching in the field of engineering macroethics.

Our results indicate that an awareness of both microethics and macroethics is essential in promoting ethical behavior amongst students. The coded articles all point to the lack of a focus on increasing students' awareness of macroethics. Once again, consider the refugee camp example above. In this example, if the engineers and the UN only focus on how to work together (microethics) to improve infrastructure, they may face resistance from refugees when carrying out the project because they have ignored the refugee community's attitude towards the project (macroethics). This example also shows how studying ethical codes alone will not be sufficient for solving complicated ethical dilemmas.

Figure 2: Frequencies of coded articles by year.



Instruction in ethical codes provides a basis for engineers to build their ethical problem-solving skills. However, as a profession, engineering favors a culture of teamwork and collaborative projects, which can generate ethical complexity. Moreover, the problems often faced by engineers are very complex and usually requires group effort to resolve. And when engineers respond to crises, there is an especially crucial need for a collective and cooperative response [51]. In support of this, Ban and Bucur (2018) showed that the personal experience from home, school, and social environment is not enough to help understanding the complexity of ethics in engineering. Instead, they found that elements of professional ethics in engineering are applicable in collective projects and in the teamwork [41]. As an example, potential global threats to life such as climate change, enhanced weapons of mass destruction, and poverty and hardship in the Global South incite a need for a collective ethical consideration in order to address these issues. The implementation of changes in policy will indeed require collective and active decision-making effort by engineers; thus, the image of an isolated engineer facing an ethical dilemma alone just does not fit into the practice in the field of engineering [4].

As we try to solve our complex engineering ethical problems, we must first look into the complicated relationship between science, engineering, and ethics, for this relationship offers insights into understanding how ethics is conceptualized in the field of engineering. Ethics sets values and guidelines that are eventually turned into distinctive goals and behaviors. Scientists and engineers develop systems for implementing these goals and behaviors, while ethicists emphasize the priority of values and guidelines [51]. So while science describes things and explains why they exist with the ultimate goal of offering evidence for predictions of the future, ethics advises on how things should be. And engineers explain how to get from the way things are to the way things should be. Together, these three fields aim to reach desirable end goals [51]. Thus, we must understand how science and engineering fit into our goals in order to pursue these domains in tandem. However, goals change as knowledge expands and, because of the complexity of human behavior, ethical problems can become more complicated [51]. Therefore, the solutions to these problems require interdisciplinary examination. Thus, we advocate for a more holistic approach to solving ethical problems by combining understanding of microethics and macroethics.

The two factors of organizational context and peer environment are significant in contributing to the promotion of ethical behavior amongst engineering students. In order to nurture a culture of ethical behaviors in the engineering profession, we need to aim at improving the ethical awareness at the institutional level. However, one should not underestimate the contribution of theoretical understandings—implicit and explicit—at both the micro and macroethical levels of an individual in the decision-making processes. Yet, despite a long-standing effort to promote ethical awareness and behavior within many institutions and professional societies, many engineering professionals still struggle when faced with complex ethical dilemmas.

The primary goal of engineering ethics for many people is the production or the encouragement of certain attitudes and behaviors as opposed to mere knowledge [21]. In addition to setting guidelines as mentioned above, ethics specifies basic values and the means to achieve those values [40]. Engineering ethics requires reflection on the specific social role of engineers and is concerned with what the standards in engineering should be and how these standards apply to specific situations

[24]. According to Veach (2006), two points are important when it comes to ethics: having a standard to follow and the will to follow it [39]. However, as mentioned above, ethical problems are usually much more complicated, and simply trying to adhere to standards or codes might not provide an adequate solution to these problems. The way to go about resolving these problems, according to Veach (2006), is to examine a range of solutions that are right and disregard solutions that are wrong, while acknowledging that there will be no unique correct solution to most problems [39]. How does one go about examining a range of solutions to complex ethical problems?

In order to produce the most appropriate solutions to ethical problems, one needs to consider the multiple layers of ethics. According to Basart and Serra (2013), the first layer of ethics is that of the personal [25]. Personal ethics derives from an individual's background, such as their faith or religion, and often focuses on honoring religious values. The second layer of ethics, social ethics, is reflected in theories arose in the 17th and 18th centuries, emphasizing law and human rights. This kind of ethics incorporates the interests of human beings more generally, and identifies goals for future social change. Lastly, the third layer of ethics is global ethics and is our current urgent challenge, which demands global attention to protect all life on the planet, not just human [25]. Attending to all three layers of ethics allows us to examine a range of solutions to complex ethical problems. First, one must reflect on her personal beliefs stemming from her personal or religious values. Then, as one tries to narrow down the range of appropriate solutions to a complex ethical problem, one must consider social and global ethics nested within personal ethics in order to select the most suitable solution from the best options. However, this kind of ethical problem-solving skill requires one to have attained a solid level of ethical development. So, how does one go about achieving ethical development, particularly amongst engineering students?

A framework for answering this question is found in the work of Finelli and coworkers (2012) which deals with three constructs of ethical development: knowledge of ethics, ethical reasoning, and ethical behavior [18]. Knowledge of ethics concerns with the students' understanding of professional engineering codes of ethics. Ethical reasoning concerns students' ability to identify a range of options to resolve complex ethical problems. Lastly, ethical behavior concerns students' ability to act consistently upon their reasoned ethical decisions [18]. Knowledge of ethics is an important aspect of ethical development and has been included in most ABET accredited engineering programs [52]; however, the delivery methods and effectiveness of these programs in developing students' ethical reasoning ability vary [18]. Unfortunately, engineering students do not universally exhibit ethical behavior as concluded by Finelli et al. (2012) [18]. This is partly due to the fact that the current understanding of the drivers of ethical behavior is still limited, leading to disagreement on the definition of engineering ethics.

To address this problem, our review identified that awareness of microethics and macroethics are important in driving ethical behaviors amongst engineering students in order to derive a new definition of engineering ethics—*engineering ethics is a subset of professional ethics concerned with interpersonal interactions amongst engineers and between engineers and their communities* *that draws upon implicit and explicit understandings of ethics within the context of institutional cultures and frameworks*. Our definition encompasses the concept of the Anthropocene—the human age—that deals with the influence of human impacts in shaping nature. According to the Millennium Ecosystem Assessment (MEA) report, more than 60% of the world's major ecosystem goods and services were degraded and not being used sustainably [53]. Furthermore, it is well-known that humans have been contributing significantly to climate change in our development process. Thus, our activities are affecting not only our future generations but also the interspecies equity—the rights of nature and non-human species on an equal basis to human well-being [53]. For these reasons, our definition of engineering ethics stated above aligns with the United Nations' (UN) Sustainable Development Goals (SDGs) by adopting a more holistic approach to the study of engineering ethics, taking into account both micro- and macro-perspectives.

By offering a new definition of engineering ethics through the literature review, we now have a basis for addressing the critical need to unpack the complexity of engineering ethics in order to determine how to better foster ethical judgment and behavior amongst engineering students. Promoting an understanding of ethics among engineering students and developing a culture of ethical practice have become goals of many engineering programs. Towards this goal, this review contributes to our understanding of engineering ethics and provides a new theoretical framework of ethical judgment and behavior.

CONCLUSION

By offering a new definition of engineering ethics stemming from the two factors that drive ethical behavior, awareness of microethics and macroethics, we provide a basis for addressing the critical need to unpack the complexity of ethical reasoning amongst engineering students in order to determine how to better foster ethical judgment and behavior. Promoting an understanding of ethics among engineering students and developing a culture of ethical practice have become goals of many engineering programs. By reviewing the current understandings and perceptions in engineering ethics, we hope to provide engineering faculty with a theoretical framework to better understand the drivers of ethical behavior in order to improve their teaching methodologies. Furthermore, to understand how students perceive ethics, we also need to look at their unstated and formulated reasoning and judgment, also known as implicit and explicit ethical understanding respectively. Our future studies will include a more extensive review of the role of implicit and explicit understanding as well as institutional ethical behavior drivers, awareness of diversity and institutional ethical culture (including organizational context and peer environment), in driving ethical behaviors and how these drivers, in combination with the awareness of micro and macroethics, can foster an ethical culture amongst engineering students.

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