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Impact of Ethical Awareness on Engineering Identity Formation Using Ordinary Least Squares Analysis

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Abstract: The 21st century marks a world where scientific, humanistic, technological, and societal issues are integrated. The complexity caused by the reciprocal effects among technology, engineering, cultural, and social values raises new ethical problems. This study addresses recent increased attention to the relationship between ethical awareness and engineering identity factors. Participants in this study were 246 undergraduate engineering students enrolled in a research university located in the northeast U.S. Bivariate correlation, and ordinary least squares regression were conducted. Bivariate correlations showed that ethical awareness was positively correlated to engineering interest, engineering recognition, and engineering performance/competence, which are the three factors of engineering identity. The OLS regression showed the r2 value for the computed regression equation indicated that there was a non-zero relationship between the set of all independent variables (engineering identity factors, gender, ethnicity, years in school, and first-generation status) and the dependent (ethical awareness) and that the final set of independent variables accounted for approximately 22% of the variation in the dependent variable, Ethical Awareness. Undergraduate engineering education is a key to ensuring engineers will uphold the ethical values of the profession. This study contributes to the practical value of engineering ethics awareness by affirming that engineering identity is sound and should be applied in practice.

Keywords: *Engineering education, engineering ethics, engineering identity, ethical awareness.*

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Introduction

The 21st century marks a world in which scientific and technological developments are complexly integrated with societal issues (Williams, 2003). This complexity caused by the reciprocal integration of technology, engineering, cultural, and social values has raised new ethical issues in modern society (Kiepas, 1997). Abrupt integration and dissemination of the latest technologies without thorough consideration of potential ethical issues and social consequences have caused various societal disturbances (Bynum & Moor, 1998). For instance, unethical use of technology—such as hacking, piracy, anonymity, confidentiality, conflict of interests, invasion of privacy, manipulation of information, and disruptive social implications of artificial intelligence (AI)—have recently and often been reported (Rekha & Pillai, 2014; Rigopoulos & Karadimas, 2006). During the COVID-19 pandemic, especially breaches of Zoom privacy, in the form of such attacks as "Zoom bombing" or "Zoom hacking," raised critical technical and ethical concerns for users highly dependent on the online conferencing tool for work performance (Gasser et al., 2020). Another well-known example is the distribution of malfunctioning computer microprocessors produced by Intel in 1994. Although Intel discovered the flaw long before the media reported it—and after an unflawed version was developed—the company sold the defective products until the stock of the flawed microprocessors was exhausted (Fleddermann, 2000).

Further, the ethical tensions of the current moment have roots in other well-known occurrences of technological misuse amidst periods of rapid, uncontended technological development and social change. In 1994, Intel discovered a flaw in their microprocessors before the media reported the error and proceeded to unquestioningly distribute the malfunctioning product even after an unflawed version was available. Intel sold the defective products until the stock of flawed microprocessors was exhausted. Next, the Volkswagen (VW) emissions scandal, a similar implicit disregard for

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consumer safety and interest, is a well-known willful corporate misconduct. VW installed defective devices and software in 11 million VW vehicles sold worldwide, even though the installation failed to comply with emissions standards dictated by the Clean Air Act. Because several engineers and leaders knew and even excused the defective technology, the VW scandal was considered intentional unethical misconduct (Trope & Ressler, 2016). This lapse of ethical behavior led to blatant disregard for social and legal requirements to keep the environment clean and safe. Numerous scandals involving unethical technology and engineering practices have established a need for education in ethics for individuals who are or plan to be in the technology and engineering fields (Bairaktarova & Woodcock, 2017). Insufficient ethical awareness and social responsibility among engineers, scientists, and technology leaders have accounted for severe social and environmental disasters beyond those mentioned above (Wang et al., 2015). To secure the safety and welfare of society, current and future engineers and technology leaders should require to acquire a strong awareness of ethical principles (Rigopoulos & Karadimas, 2006).

Given the substantial impacts of engineering practices on various aspects of society, ethics has been emphasized as an essential facet of work in technology-related disciplines (Park & Passmore, 2020). Therefore, professional engineering associations and societies have developed and continue to update their codes of ethics, providing ethical guidelines for professional engineers and a framework for engineering ethics curricula (Herkert, 2005; Spier & Bird, 2007).

As professional engineering societies and some undergraduate engineering institutions have recognized the imperative nature of ethical education and its integration into engineering practice, concerns have risen about low levels of understanding and actual implementation of ethics in engineering. Among young engineers, Buckeridge (2011) identified a lack of awareness and understanding of ethical principles and their effect on practice. In the same vein, Saat et al. (2014) reported that engineers seem more tolerant of unethical behaviors and are less likely to report ethical violations; these behaviors beg the question of whether engineers are tolerant of corrupt practice or are they genuinely lacking a heightened or mature awareness of what unethical practices are and their consequences. Michelfelder et al. (2013) speak to this question as they found how the overall level of ethical awareness in the engineering profession only translates to a perception of how to “do a thing right” rather than “do the right thing.” The ongoing interest in ethical perspectives for engineering and societal impacts speaks to how ethical considerations should be addressed early on, starting with undergraduate engineering education. Because the concept of ethics is highly socio-culturally bound and time is necessary to develop ethical awareness, engineering students should develop ethical awareness before they go into the field. It will ensure that students have enough time to consolidate their conceptualization and understanding of ethics (Herkert, 2000). Thus, introducing engineering ethics to undergraduate engineering students is critical to preparing engineers to perform best practices in engineering-related fields (Harris et al., 1996).

With the development of ethics education, the Accreditation Board for Engineering and Technology (ABET) states the necessity of ethics components in the criteria of engineering undergraduate programs, which include “an understanding of professional and ethical responsibility” and “the broad education necessary to understand the impact of engineering solutions in a global and societal context” (ABET, 1996). These criteria push for more integration of ethical awareness in engineering programs (Lattuca et al., 2006). The ABET’s efforts have led to recent increased attention to the ethical aspects of engineering education on top of traditional learning outcomes such as knowledge and skill acquisitions that make students feel and eventually become engineers. Studies have shown that learning ethics and developing ethical awareness are imperative for engineering students while they conceive of themselves as engineers through acquiring and demonstrating engineering knowledge and skills.

Engineering ethics education has undergone reforms to develop curriculum for future engineers grounded in ethics. A new paradigm has emerged to place greater emphasis on ethics education in the engineering curriculum (Clancy et al., 2005; Saat et al., 2014) the construct of ethical awareness is particularly stressed to prepare future engineers and engineering leaders because early awareness of ethical issues could mitigate the adverse outcomes before societal catastrophes (Herkert, 2000; Jimenez et al., 2005; Newberry, 2004). These events also have shown that engineers’ developing sense of ethical principles affects how they practice in their profession and how they conceive of themselves as professionals/engineers. And this is because ethics are socio-culturally bound concepts that involve, complicate, or exist in tension with one’s own experiences, histories, values, and beliefs. In future engineers’ developmental stages in undergraduate engineering programs, ethics education always involves engineers grappling with their perceptions of themselves and their identities. As such, an emergent interest is in cultivating students’ engineering identity in engineering education. Engineering identity as a construct has become a central factor in explaining the various motivations of engineering students and engineers (Anderson et al., 2010; Godwin et al., 2016; Prybutok et al., 2016; Tonso, 2006). Additionally, previous studies alluded to engineering identity is associated with collaboration, communication, and teamwork among engineers from diverse backgrounds and disciplines (McLean et al., 2020; McNair et al., 2008). Also, a consolidated one’s engineering identity nurtures creativity, curiosity, and a passion for innovation (Morelock, 2017).

Considering public trust is essential for the engineering profession, ethical awareness influences engineers to build and maintain their integrity, transparency, and accountability in their engineering work. Engineers’ ethical awareness ensures that engineers consider the ethical implications of their work and prioritize the well-being of society (Park & Passmore, 2020).

There is substantial literature containing assertions that current engineering education has contributed to one's engineering identity development. However, the ethical component has been underexposed in engineering identity related studies. Even if some literature explores how engineering students learn ethics and ethical awareness in the engineering curriculum, however, there are limitations in terms of the translational aspect of ethical awareness to engineering practices that relate to their engineering identity development. In other words, empirical research to investigate engineering students' ethical aspects has been sparse, too, due to ambiguity and difficulty in deciding what and how to measure ethics. These challenges require examining ethics and the niche in a translational aspect of ethical awareness to engineering identity.

The current study investigates the relationship between engineering ethics and engineering identity factors, the two critical themes for future professional engineers. In particular, the current study investigated the ethical and engineering identity development of undergraduate engineering students through ordinary least squares analysis to identify the intricate relationships between engineering students' ethical awareness and their engineering identity.

Literature Review

Engineering ethics stands at the intersection of professional conduct, societal responsibility, and moral decision-making within the engineering profession. Beyond regulatory frameworks and professional codes of ethics, scholars have sought to define and promote ethical awareness in engineering practice. Ladd's (1980) seminal work categorized engineering ethics into micro and macro issues, delineating individual and societal dimensions of ethical considerations. This categorization inspired further exploration by scholars like Herkert (2001), who identified technical, professional, and societal domains within engineering ethics. As professional engineering societies and government agencies established ethical standards and licensure requirements, the need for ethics education in engineering programs became increasingly apparent. However, the complexity of ethical dilemmas in engineering necessitates more than rote adherence to rules; it demands a nuanced understanding and application of ethical principles in real-world contexts. This study explores the evolution of engineering ethics education, its impact on professional identity, and the challenges and opportunities in preparing future engineers for ethical practice. By examining the relationship between ethical awareness and engineering identity, this study aims to contribute to the ongoing discourse on ethics education in engineering programs and its implications for the profession at large.

Engineering Ethics

In addition to professional codes of ethics or government legislation and licensure, there has been a continuous endeavor to conceptualize engineering ethics to promote ethical awareness and ethical practice in the engineering profession. Ladd (1980) categorized engineering ethics into micro-ethics and macro-ethics. Micro issues include autonomy, honesty, loyalty, responsibility, and whistleblowing, whereas macro issues concern the status of the engineering profession, product liability, and public safety (Van de Poel, 2016). In other words, while micro-ethics concerns individuals and internal relations of the engineering profession, macro-ethics respects the shared social responsibility of the profession.

Ladd's categorization of engineering ethics inspired other scholars to conceptualize engineering ethics in a rapidly changing engineering industry due to technological advancement. Based on Ladd's categorization, Herkert (2001) introduced engineering ethics as three subcategories: (a) technical ethics, which deals with technical decisions; (b) professional ethics, which deals with employee/manager interactions; and (c) societal ethics, which considers the impacts of engineering projects on society. He claimed that professional engineering societies have a vital role in the ethics of engineers. The National Society of Professional Engineers has published and revised codes of ethics since 1946. The American Society of Civil Engineers has established and updated its codes of ethics since 1914 to provide basic rules of practice and professional obligations related to ethical standards and decision-making in engineering. As professional engineering societies have strived to establish ethical standards, government agencies have enacted legislation requiring engineer and surveyor licensure, contributing to the quality of ethical applications improving remarkably (McGuirt, 2007). At the same time, the code of ethics in professional societies, government legislation, and licensure in the engineering field have brought about the necessity of engineering ethics education in higher education.

Other than conceptual ethics, Martin and Schinzinger (2005) suggested two disciplines in engineering ethics. First, engineers' responsibilities and rights and their goals and commitments; the second area is ethically desirable decision-making, policies, and values that contribute to engineering practice and study. Haws (2001) also noted an ethical heuristics method of providing an organized and logical structure for the solutions to ethical problems. Despite these advances, limitations persist in established ethical codes for resolving ethical dilemmas and in methods for ethics education in the engineering profession.

At the same time, the code of ethics in professional societies, government legislation, and licensure in the engineering field have brought about the necessity of engineering ethics education in higher education. In addition, myriad viewpoints exist about the preferred content for engineering ethics education. Herkert (2000) asserted that, because the concept of ethics is highly socio-culturally bound, engineering students should receive training in ethics before they enter the field to ensure that they have enough time to understand and consolidate ethical principles and practices to apply codes and guidelines for ethical engineering practice in the field. Harris et al. (1996) echoed the importance of teaching engineering ethics to undergraduate engineers to improve engineering practice, claiming that engineering ethics should be highlighted as a fundamental facet of engineering disciplines due to the significance and impact of engineering practices on society.

Engineering Ethics Education

Frequent unethical conduct among engineers was associated with a lack of a code of ethics and professionalism, which led to the rise of and need for engineering ethics education. However, due to the complexity of ethical dilemmas in engineering, ethics education should include much more than simply codes and rules to follow. Engineers should learn from the past to best secure the safety and welfare of the public. Early awareness of ethical issues could facilitate resolution before causing a significant impact and may even prevent problems or disasters before they arise. Thus, engineering undergraduate programs are uniquely positioned at the heart of developing future engineers who are both ethically and professionally grounded and committed (Bairaktarova & Woodcock, 2017; Clancy et al., 2005).

Rabins (1998) summarized ethics education investigated ethical decision-making processes in undergraduate engineering programs by answering “Why” (the driving force of increased efforts), “What” (the standard features and contents to be taught), and “How” (the overall approach to teaching ethics) questions. In the explanations, the major difference was identified between learning engineering, based on applying scientific principles, and learning engineering ethics. There is no single correct answer to ethical problems. Rabins explicitly listed common ethical issues in engineering, such as conflict of interest, handling of proprietary information, confidentiality, informed consent, risk and safety, health and the environment, and discrimination.

Although Rabins (1998) focused on the process of ethical decision-making based on questions involving why, what, and how, Harris et al. (1996) clarified the learning objectives of ethics education in engineering programs, which include: (a) stimulating students’ ethical imagination; (b) enabling students to recognize ethical issues; (c) enabling students to analyze fundamental ethical principles and concepts; (d) enabling students to deal with ambiguity; (e) encouraging students to take ethics seriously; (f) enhancing student sensitivity to ethical issues; (g) enhancing student knowledge of relevant standards; (h) improving students’ ethical judgment; and (d) enhancing ethical will-power. Newberry (2004) categorized the objectives into three levels: emotional level, intellectual level, and particular knowledge level. The emotional level requires students’ emotional engagement to recognize, care about, and resolve ethical issues, and ethical awareness plays an essential role in initiating this level of learning objectives. The intellectual level develops students’ understanding of moral principles and applies them to deal with ethical conflicts and ambiguity. The particular knowledge level aims to develop students’ knowledge of common ethical practices and familiarity with ethical precedent cases. Although many scholars and administrators attempted to provide guidelines of ethics education in engineering, including the previous researchers, the absence of precision has caused many engineering students to perceive ethics study as subjective and less rigorous (McGinn, 2003).

Recognizing these challenges, the ABET took the necessary steps to embed ethics education in the criteria of assessing outcomes of engineering education programs. The accreditation criteria of ABET Engineering Criteria (EC) 2000 delineated the ethical element of required student outcomes as an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts (Anderson et al., 2010). The ethical dimension reflects the social expectations for engineers, and there is a growing recognition for addressing real-world engineering problems (Jimenez et al., 2005). Thus, non-technology-oriented goals should be considered in the education of engineers by preparing the new professionals with more than technical skills but the ability to apply ethical considerations, acknowledging their decisions can have either helpful or harmful implications for society (Jimenez et al., 2005; Kiepas, 1997).

The ABET criteria are the primary driving force for the considerable investment of engineering programs to embed ethics education in the engineering curriculum to secure ABET accreditation (Troesch, 2015). Troesch (2015) confirmed that the learning outcomes of ethics education in contemporary engineering undergraduate programs appeared to be accreditation-driven, with most programs following the pedagogical framework of ABET. In a survey asking about the importance of ethical components required by ABET, engineering codes, and standards were ranked as most important, followed by manufacturability, ethical considerations, health and safety issues, and sustainability (Prybutok et al., 2016). Along the same lines, Bairaktarova and Woodcock (2017) reported that engineering ethics education primarily focused on introducing engineering codes of ethics and moral theories supplemented by the utilization of case studies. By applying learned moral theories and engineering codes of ethics, students must differentiate between ethical and unethical engineering practices and suggest ethical solutions in their future decision-making (Kulkarni & Wise, 2005).

Regardless of attempts to conceptualize engineering ethics, engineering ethics in the engineering field are rooted in professional codes of ethics, which are closely tied to the evolving ABET criteria for engineering program assessment, aiming to increase students’ awareness of ethical issues in engineering practices. The ideal learning outcomes should go beyond the engineering code of ethics and further establish students’ abilities to recognize the situations in which ethical dilemmas present, analyze the ethical issues from different perspectives, and finally make informed decisions (Huyck et al., 2008).

Moreover, ethics questions that engineering faculty consider most regularly in their classes may not always be ethical quandaries that engineers encounter in professional practice outside of academia. Hollander and Arenberg (2009) argued that ethics education used in one specific profession could not be converted and applied in another profession directly. For instance, teaching ethics in environmental engineering cannot be directly applicable to computer engineering. For these reasons, they suggested developing engineering instructors and faculty members who carry out ethics education in their areas of expertise. Further, they proposed to create an opportunity for engineering educators for professional development as engineering ethics educators, which includes workshops and training about ethics-related topics such as interdisciplinarity and cultural diversity.

Ethical Awareness

Ethical awareness, described as an ability to recognize how one's particular decision or action could affect others' interests, welfare, or expectations in a fashion that one or more ethical principles are conflicting (Butterfield et al., 2000), is a crucial attribute to ethical behaviors and ethical decision-making. It is also defined as the degree to which one can detect an ethical issue or the potential of an ethical issue to occur based on given information. Saat et al. (2014) explained ethical awareness through Rest's (1984) four-component model of moral development, which included moral awareness, moral judgment, moral intention, and moral character. Moral awareness refers to the ability to interpret situations that ethical dilemmas pose. Moral judgment occurs when people visualize the course of actions and the potential consequences and then justify their decisions in a moral sense. Moral intention refers to the degree of taking responsibility for the consequences of one's actions. Moral character underlines the personal will to persist with moral decisions.

Regardless of the common myth perceiving engineering as an ethically neutral science, the profession itself is less an isolated agent and rather more intertwined with decisions in solving a problem, designing a product, researching new methods or materials as well as the consequences to clients, companies, end-users, and broader society (Troesch, 2015). After all, the final products of engineering will generate social impacts when used in a particular social context, and therefore cannot be free from values (Brey, 2018). Therefore, engineers need to recognize the social consequences of day-to-day decisions in their professional activities and be prepared to take ethical responsibility (Didier, 1999). Thus, engineering programs should consider ethical awareness a key competency beyond those solely based on technical expertise when preparing future engineers.

Researchers advocate the imperative role of ethical awareness in engineering ethics education. For instance, Rabins (1998) argued that ethical awareness functions at the core of all aspects of engineering ethics education. Similarly, Bairaktarova and Woodcock (2017) suggested that developing ethical awareness is the first step to engaging engineers in ethical behaviors and ethical decision-making. However, although engineering educators depend heavily on ethical awareness to establish engineering ethics instruction, scant attention is paid to discovering the outcomes of enhancing engineering students' ethical awareness. Also, it is noted that existing efforts of ethics education in engineering programs lack reliable ways to measure its outcomes (Colby & Sullivan, 2008).

Engineering Identity

Tonso (2006) explained that students' engineering identity develops through a complicated cognitive process associated with individuals' thinking about themselves as engineers, their competencies as engineers, and being recognized as engineers by external agents. Choe and Borrego (2020) reported that engineering undergraduate students develop their engineering identity by participating in engineering projects, internship activities, and interactions with other students. This model is the most widely used for quantitative studies of undergraduate engineering identity and posits that engineering identity comprises three constructs: engineering performance/competence, engineering interest, and recognition as an engineer by others (Tonso, 2006). Performance/competence refers to belief in one's ability to perform engineering tasks and understand engineering concepts. Interest reflects one's desire to learn more about engineering, participate in engineering activities, and pursue engineering careers. Recognition means being recognized by others (e.g., instructors, friends, and family) as an engineer.

In addition, Meyers et al. (2012) reported that undergraduate students who identified themselves as engineers were likely to state they would continue their education and career in engineering-related fields. Godwin et al. (2016) similarly observed that undergraduate students who self-identify as engineers have a higher intention to complete their degree and are more likely to pursue an undergraduate engineering major or career. They also argued that the self-perception of being an "engineering person" is one way to examine students' persistence in engineering. In addition, Robnett (2013) postulated that engineering students' attrition and persistence are related to their engineering disciplinary identity development. Chemers et al. (2011) reported that the identity of students as engineers was a positive predictor of students' persistence and career choices in engineering fields.

Engineering identity is a potential outcome of teaching engineering students' ethical awareness, given the evidence linking ethical awareness with engineering identity found in a literature review. For instance, Harris et al. (1996) emphasized the importance of developing future engineers' ethical judgment skills, which form an integral part of engineering thinking and identity development. Jimenez et al. (2005) maintained that the ethical dimension reflects the social expectations for engineers, which is associated with individuals' thinking about themselves as engineers and being recognized as engineers by others. Finally, Downey et al. (2007) proposed that engineering identity refers to a "who" question of the profession, stimulating students' interest in learning engineering ethics. However, these assumptions have not been empirically tested. As such, the current study attempts to utilize empirical data to investigate the relationship between ethical awareness and engineering identity with the hope of providing more insights into evaluating the outcomes of ethics education in engineering programs.

In sum, the previous studies of engineering ethics often involve exploring the moral responsibilities and decision-making processes of engineers. It showed that individuals' ethical frameworks and dilemmas can shape an engineer's sense of professional identity and values. Engineering ethics education and training are integral parts of the socialization process for engineers. As individuals enter the engineering profession and undergo formal education and professional development, they are exposed to ethical standards and norms that help shape their professional identity. Discussions around ethical issues can foster a sense of belonging to the engineering community and reinforce shared values among practitioners.

Based on the literature, engineering ethics education influences how engineers navigate ethical dilemmas and make decisions in complex situations, which can influence their sense of self as professionals. It seems like engaging with ethical challenges and reflecting on the consequences of their choices can contribute to developing a strong professional identity grounded in ethical principles. These experiences can shape how engineers perceive themselves and their roles within the profession.

In addition, the current body of research on engineering identity primarily focuses on engineering identity as an outcome of engineering technical skills and interests in engineering education. The engineering profession's emerging need for engineering ethics was met in the engineering curriculum in higher education. However, the relationship between engineering ethics and engineering identity has remained underexplored. An inadequate study has been conducted on the translational aspect of ethical awareness (as a proxy for engineering ethics) to engineering identity. For these reasons, it is essential to investigate the ethical perspectives of engineering students and how these perspectives might be associated with developing their engineering identity. Literature is scant that supports the current study of the relationship between engineering ethics and engineering identity.

Current Study

There is significant literature suggesting that contemporary engineering education plays a significant role in developing students' engineering identity. However, studies on engineering identity overlook or insufficiently address the ethical dimension of engineering identity formation process. The literature alluded that engineering ethics and engineering identity development intersect in various ways, highlighting the interconnected nature of ethical practice, professional values, and identity formation in the engineering profession. By connecting with ethical principles, reflecting on moral dilemmas, and navigating complex decision-making processes can be influenced by engineers' cultivated strong professional identity grounded in previous ethical perspectives and integrity. Further, engineering students learn ethics and technical skills and knowledge in integrated or stand-alone courses in the same engineering curriculum while developing their engineering identity, however, it does not offer much in terms of the translational aspect of ethical awareness to engineering identity. Instead, both engineering identity and engineering ethics have been studied separately. Empirical research to investigate engineering students' ethical aspects has been sparse, too, due to ambiguity and difficulty in deciding what and how to measure ethics.

These challenges require examining ethics and the niche in a translational aspect of ethical awareness to engineering identity. The current study investigates the relationship between engineering ethics and engineering identity factors, the two critical themes for future professional engineers. The study was grounded in research traditions that prioritize early ethics education for developing ethical-savvy and responsible future engineers.

Research Questions

There are two major questions examined in this project:

1) Is ethical awareness correlated with the three constructs of engineering identity (i.e., engineering interest, engineering recognition, engineering performance/competence) among engineering undergraduate students?

2) What are the major demographic correlates of ethical awareness among engineering undergraduate students?

Methodology

Participants and setting

Participants in this study were 246 undergraduate engineering students enrolled in a Research I university located in the northeast U.S. Removal of 50 initial participants presenting missing data resulted in retaining 196 students (108 males; 87 females; 1 other) for further study. Most participants were Caucasian/European-American (70%), and 22% and 12% were Asian/Asian-American and Black/African-American, respectively. There were only eight Hispanic students (4%). However, this small number reflected the ratio of the engineering discipline in the institutional enrollment data. More than half of the participants (57%) were in their second year in engineering programs, and (22%) and (21%) were in their third year and first year, respectively. Participants were concentrated in mechanical engineering (30%), although participants majored in a variety of engineering disciplines, including biomedical (21%), civil (11%), and environmental systems (10%) engineering as well as materials science and engineering (11%). Only 12% of the participants were first-generation college students.

Measures and procedures

Data for this study were collected from participants using an online survey form supported by Qualtrics survey technologies. The use of human subjects in this study was reviewed and approved by the university's Institutional Review Board through which this study was conducted.

Participants responded to 18 survey items shown in Table 1 that were composed of scales of Ethical Awareness (six items) adapted from work by McGinn (2003) and Engineering Interest (three items), Engineering Recognition (three items), and Engineering Performance/Competence (six items) adopted from Godwin et al. (2016) and Prybutok et al. (2016) for the core factors of engineering identity. Participants assessed statements for each of the 18 items on a 5-point Likert scale (strongly disagree = 1, disagree = 2, neither agree nor disagree = 3, agree = 4, strongly agree = 5), with the stem question "To what extent do you agree or disagree with the following statements?" for each survey item. In addition, participants indicated their sex from a binary, male/female choice, designated their race among alternatives provided, reported their semester standing in their degree program, and specified whether they were the first generation in their family to attend university.

Table 1. Items Composing Scales of Ethical Awareness and Engineering Interest, Recognition, and Performance/Competence

Scale	Items
Ethical awareness	Ethical dilemmas have been discussed in any of my technical/science/engineering courses.
	My science/engineering instructors have discussed with us serious ethical dilemmas in professional practice.
	My science/engineering instructors have discussed specific situations about ethical practice in science/engineering fields.
	I expect to be faced with ethical dilemmas during my career.
	I have encountered a science-engineering-related deed, practice, or policy that I considered morally questionable or wrong.
	It might be useful to study ethical dilemmas as part of my science/engineering education
Engineering interest	I am interested in learning more about engineering.
	I enjoy learning engineering.
	I find fulfillment in doing engineering.
Engineering recognition	My instructor sees me as an engineer.
	My parents see me as an engineer.
	My peers see me as an engineer.
Engineering performance/competence	I am confident that I can understand engineering in class.
	I am confident that I can understand engineering outside of class.
	I can do well on exams in engineering.
	I understand concepts I have studied in engineering.
	Others ask me for help in this subject.
	I can overcome setbacks in engineering.

Variables derived from survey items for scales of *Ethical Awareness*, *Engineering Interest*, *Recognition*, and *Performance/Competence* were formed by computing the simple sum of item responses for each scale. A measure of the internal consistency and homogeneity of each scale was examined by calculating Cronbach's α, an indicator commonly applied to indicate the extent to which items in a scale measure a common dimension.

Analysis

Bivariate correlation and ordinary least squares (OLS) regression were conducted using SPSS 27. Although bivariate correlation examined the relationships among all variables, OLS regression accounted for how variations in *Ethics Awareness* were accounted for jointly by independent variables measuring *Engineering Interest*, *Recognition*, *Performance/Competence*, sex, race, semester standing, and first-generation status. All participant characteristics were dummy-coded, which included sex, race, semester standing, and first-generation status. We dichotomized the semester standing variable into lower (first and second year) and upper (third, fourth, and graduate). The reference groups of the dummy variables are male, White, upper-level class year, and non-first-generation college students.

For OLS regression analysis, first, we examined whether the set of all independent variables reflected a non-zero relationship with the dependent variable. Then, 95% confidence intervals were computed around each point estimate of the standardized regression coefficient calculated for each independent variable in the regression. An interval that did not span a zero value was considered to be related, positively or negatively, to the dependent variable. Before computing the regression model, statistical assumptions, including normality, linearity, and homoscedasticity, were confirmed. In addition, variance inflation factors (VIF) detected no multicollinearity issues in the regression model.

Results

Shown in Table 2 are the relationships among measures of ethical awareness, engineering identity, and personal characteristics for the 196 undergraduate engineering students who participated in this study. The Cronbach's α values for *Ethical Awareness*, *Engineering Interest*, *Engineering Recognition*, and *Engineering Performance/competence* scales are greater than .70, which is considered an acceptable level of scale internal consistency and homogeneity (Brace et al., 2012).

The bivariate correlations were conducted to check if *Ethical Awareness* is related to *Engineering Interest*, *Recognition*, and *Performance/Competence,* contributing to engineering identity. The results are shown in Table 2 with a significance level of $\alpha = .01$, indicating that ethical awareness had low positive correlations with *Engineering Interest* ($r = .28$), *Recognition* ($r = .39$), and *Performance/Competence* ($r = .34$) due to low coefficients that are between .3 and .5 [54]. The bivariate correlations among *Engineering Interest*, *Recognition*, and *Performance/Competence* provide construct validity as engineering identity. Although moderate positive correlations are evident between *Engineering Interest* and *Recognition* ($r = .57$) and between *Engineering Recognition* and *Engineering Performance/Competence* ($r = .62$), *Engineering Interest* and *Engineering Performance/competence* were highly correlated ($r = .74$). However, there was no multicollinearity detected, showing the two variables were not overlapped with each other.

Although some participant characteristic variables also had significant correlations, the correlations should be interpreted carefully because of low coefficients (smaller than .30) and small sample sizes. The negative correlations were observed between *Asian* and *Engineering Interest*, and correlations between Asian and Engineering Performance/Competence were low. *Hispanic* had correlations with *Ethical Awareness*, *Engineering Recognition*, and *First-generation*. However, the coefficients were low, along with the small sample size of *Hispanics,* which was only eight. Overall, the correlations between dependent and independent variables had low to moderate coefficients except for the strong correlation between *Engineering Interest* and *Engineering Recognition*. The r^2 value for the computed regression equation indicated a non-zero relationship between the set of all independent variables and the dependent. The collection of independent variables accounted for approximately 22% of the variation in the dependent variable, *Ethical Awareness*. Participants in this study were commonly male and white, in early academic standing in their majors, and *not* first-generation university enrollees. Two of the ten independent variables specified for this regression equation were related to ethical awareness. First, recognition by instructors, parents, and peers was positively related to ethical awareness. Second, being Hispanic rather than white was negatively associated with ethical awareness. None of the other independent variables examined in this study were related to ethical awareness.

Discussion

The significance of the societal impact of engineering practices has stimulated an ongoing effort to conceptualize engineering ethics, infuse instructional strategies for enhancing ethical awareness, and establish best ethical practices. To better prepare future engineers and engineering leaders, engineering educators have advocated the importance of ethical awareness. Early awareness of ethical issues could mitigate the adverse outcomes of willful ethical breaches before they cause societal catastrophes. Following codes of ethics established by engineering professional organizations, ABET EC 2000 emphasizes ethics education in undergraduate engineering programs (Hess & Fore, 2018). By ABET's initiation, the engineering education curriculum has integrated ethics education as a fundamental component of engineering programs. Ethics has been embodied in core courses rather than a stand-alone course. Adding additional credits to the degree program and providing further teaching resources is challenging (Cummings & Lo, 2004).

Table 2. Relationships Among Ethical Awareness, Engineering Identity, and Personal Characteristics of Undergraduate Engineering Students (n = 196)

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	r (Cronbach's α on diagonal)										
Dependent											
1. Ethical awareness	.779										
Independent											
2. Interest	*.281*[a]	.838									
3. Recognition	*.388*	*.566*	.717								
4. Performce/competence	*.344*	*.739*	*.616*	.889							
5. Female *v* male	.071	.025	-.020	-.128	--[b]						
6. Black *v* white	.018	-.027	-.049	-.086	.108	--					
7. Asian *v* white	-.113	*-.166*	-.101	*-.194*	.022	-.039	--				
8. Hispanic *v* white	*-.241*	-.055	*-.144*	-.067	-.080	-.018	-.083	--			
9. Multi-ethnic *v* white	.056	.051	.052	.097	.077	-.024	-.113	-.051	--		
10. Lower-level *v* upper	.099	-.024	.066	-.059	.077	.059	.027	-.018	-.124	--	
11. First-gen *v* other	-.070	-.078	-.122	-.131	-.071	-.032	.111	*.147*[a]	.016	-.023	--
M (*SD*)	23.255 (0.307)	13.469 (0.125)	12.148 (0.166)	24.960 (0.290)	0.444 (0.036)	0.010 (0.007)	0.168 (0.027)	0.041 (0.014)	0.066 (0.018)	0.694 (0.033)	0.117 (0.023)
b [95% CI][c]	12.717 [8.091, 17.343]	-0.070 [-0.556, .416]	0.443 [0.131, 0.754]	0.223 [-0.002, 0.448]	0.566 [-0.603, 1.735]	1.177 [-4.360, 6.714]	-0.796 [-2.326, .0734]	-4.109 [-6.969, -1.249]	-0.601 [-2.328, 2.206]	0.788 [-0.427, 2.002]	0.295 [-1.464, 2.053]

Source. Analysis of survey responses from undergraduate engineering students enrolled in a Research I university located in the U.S. Northeast.

[a] Entries italicized where $r \neq 0$, $p < .05$, based on hypothesis $r = 0$ after Fisher z-transformation of r.

[b] Reliabilities not available for dummy variables.

[c] Point and interval estimates of unstandardized coefficients from ordinary least squares regression ($r^2 = 0.223$, $F\ (10, 185) = 5.30$, $p < .001$).

There has been a growing recognition of the need to address real-world engineering problems. Recent advancements in AI, for example, have demonstrated remarkable capabilities that both amaze and, in some cases, alarm people. Instances of malicious use of AI, such as deep fakes and misinformation campaigns, which can create realistic images, voices, and even hallucinations, underscore the importance of ensuring the ethical and responsible development and use of technology (Chang & Ke, 2024; Knight, 2020). This responsibility begins with the education of engineers, who are the architects of these advancements.

The cultivation of engineers through education is crucial in instilling ethical values and a sense of responsibility. The three pillars of engineering identity—competence, interest, and social recognition—must not be overlooked. Although competent and interested engineers are essential, without considering the social component, such as engineering recognition, engineers may fall short of delivering positive outcomes for society. This social component aligns with the framework of socially responsible AI (SRAI) proposed by Chang and Ke (2024), which challenges the traditional emphasis on the functional and economic aspects of technology.

A truly socially responsible engineering practice should consider higher-level human values, including ethical, social, and even environmental considerations, to be able to benefit and make a better society and environment for all. The education of engineers needs to consider ethics and non-technology-oriented goals by preparing new professionals with technical skills and the ability to apply ethical considerations. Educators should acknowledge that their decisions can have helpful or harmful implications for society. Engineers are the silent leaders of modern society, shaping the world differently with their unique skills and ways of thinking. Instilling a sound understanding of both theoretical and practical engineering ethics in future engineers is key to ensuring students will uphold the profession's ethical values after graduation.

The purpose of this study was to empirically investigate the relationship between ethical awareness and engineering identity in undergraduate engineering programs. The study was grounded in research traditions that prioritize early ethics education for developing ethical-savvy and responsible future engineers. Still, it took its departure from these traditions of literature-based conceptual evidence to examine quantitative data to expand and enrich the small amount of initial research exploring how ethics education could be taught effectively within technical engineering education (Bairaktarova & Woodcock, 2017; Herkert, 2000; Michelfelder et al., 2013; Newberry, 2004). This study contributes to the practical value of engineering ethics education by affirming that what is taught in engineering ethics is beneficial and should be applied in practice. In other words, teaching engineering ethics is more than a required practice. It involves cultivating societal members who possess a potential impact on our society by developing professional identity and ethical agency.

The findings of this study offer insights into the relationship between ethical awareness and engineering identity. This relationship is elucidated by the correlation and a linear regression that showed how engineering students' ethical awareness is influenced during the development of their engineering identity. The results of bivariate correlation analysis showed significant findings: the three engineering identity development constructs were significantly correlated with *Ethical Awareness*. However, only *Engineering Recognition* became significant in the regression model, predicting *Ethical Awareness* positively. *Engineering Interest* and *Engineering Performance/competence* did not predict the variance of *Ethical Awareness*. This result is aligned with Newberry (2004), who found that the technical focus of engineering curricula, to some degree, may be self-defeating as it deters students from emotionally engaging with important non-technical issues such as ethics and interest in various socially engaged humanitarian topics.

Even though all three factors are related to each other as core components for building engineering identity, the recognition of identity is a more socially bounded construct. At the same time, *Engineering Interest* and *Engineering Performance/Competence* are self-claimed factors focused on technical skills. Regarding the influence of engineering identity on ethical awareness, this contrast between the engineering identity constructs sheds light on developing pedagogical approaches to how engineering ethics may be taught effectively along with traditional engineering content education. Based on the regression results, the inclusion of social recognition of a lack of morality and professionalism in engineering programs may be an effective pedagogical approach to teaching ethics. Furthermore, interests and competence in engineering may positively contribute to ethical awareness indirectly through recognition as an engineer because *Engineering Interest* and *Engineering Performance/Competence* are strongly related to *Engineering Recognition*. Thus, incorporating ethical elements with technical knowledge and skill acquisition may contribute to future engineers' professional identity development and career readiness as they become engineers with social and ethical responsibilities. For instance, those who are highly interested or competent in engineering can be aware of ethical issues to be socially recognized as engineers by family, friends, or faculty.

Another noteworthy point for effective ethics education is multicultural understanding due to the growth of multicultural teamwork in modern engineering industries and the international student population in engineering programs in the United States (Yutrzenka, 1995). The results of this study showed that Hispanic student status was negatively related to ethical awareness, even though there is a minimal sample size of eight. Asian student status was negatively related to interest and competence in engineering, which can influence ethical awareness through recognition as engineers. However, it is challenging to conclude that Hispanic and Asian students may have lower levels of ethical awareness in general. Because U.S. engineering ethics has been considered a global paradigm (Zhang & Zhu, 2021), non-American students may struggle to understand and integrate ethics in the engineering context.

Although this study did not find evidence of different levels of ethical awareness between lower and upper levels students, the contents of ethics education should be designed carefully based on their academic year. Selby (2015) asserted that customized ethics education is required to reflect students' needs, identifying the different needs of engineering students for their ethics knowledge from incoming first-year students through graduating seniors. Thus, curricular adjustments may be required periodically based on the needs of the present population of students. Considering the difficulty of learning ethics, especially for adults, the introduction of ethics to engineering students early on from the introductory courses in the context of social responsibility and social reputation might be helpful. Students may be interested in their discipline-specific ethical issues and codes of ethics for upper-level class year students.

Further, challenges remain to specify the content and instructional strategies for ethics education. Unclarity in what to teach and ambiguity about the amount of curriculum content required to satisfy the ABET's criteria were linked to difficulty in embedding ethics into the engineering curriculum (Colby & Sullivan, 2008). Because new technologies tend to be more complex than before and are more globally associated, developing international guidelines for engineering ethics education in a company with various ethical contents is imperative.

In sum, incorporating findings into ethics education and identity development in undergraduate engineering programs can have several benefits. Applying findings from the current study to ethics education in engineering programs can become more relevant and practical. Students can learn about real-world ethical dilemmas and how to navigate them based on empirical evidence and case studies so that students can develop critical thinking skills by analyzing ethical issues in a systematic way. Understanding the implications of different ethical decisions can also help students enhance their decision-making skills and become more aware of the ethical issues that are prevalent in the field of engineering. This awareness can help them make more informed decisions in their future careers. As this study showed how ethics plays a role in engineering can help students develop their professional identity, higher education engineering should help students learn about the importance of ethical behavior in the engineering profession and how it contributes to their overall identity as engineers. Further, incorporating findings into ethics education can help engineering students to promote ethics to consider the consequences of unethical actions, students are more likely to uphold ethical standards in their future careers. Overall, integrating research findings into ethics education and identity development in undergraduate engineering programs can produce an ethical and socially responsible engineering workforce.

Conclusions

There has been a growing recognition that to address real-world engineering problems, the education of engineers needs to consider ethics and non-technology-oriented goals by preparing new professionals with not only technical skills but also the ability to apply ethical considerations. Educators should acknowledge that their decisions can have either helpful or harmful implications for society. Engineers are the silent leaders of modern society, shaping the world differently with their unique skills and ways of thinking. Instilling a sound understanding of both theoretical and practical engineering ethics in future engineers is key to ensuring students will uphold the ethical values of the profession after their graduation.

This study contributes to the practical value of engineering ethics education by affirming that what is taught in engineering ethics is beneficial and should be applied in practice. In other words, teaching engineering ethics is more than a required practice, however, it cultivates societal members who possess a potential impact on our society by developing professional identity and ethical agency.

The findings of this study shed light on the intrinsic connection between engineering ethics and identity development, revealing that shared values and beliefs within the engineering profession intertwine these two aspects. Ethical decision-making in engineering hinges on principles of accountability, safety, sustainability, and public welfare, which form the foundation of both ethical practice and professional identity in the field. Engineers often rely on these values to guide their actions and decisions, shaping a core part of their identity as ethical practitioners. Educational background significantly influences ethical behavior and professional identity development, emphasizing the critical importance of acquiring ethical decision-making abilities during engineering higher education programs.

The societal impact of engineering practices emphasizes the necessity of integrating ethics education into engineering curricula. Initiatives such as ABET EC 2000 have prioritized ethics education as an integral component of undergraduate engineering programs, integrating ethical considerations into core courses rather than standalone modules. However, challenges arise in allocating resources to accommodate ethics education within existing programs. Recent advancements in AI underscore the importance of ethical awareness in engineering, given instances of malicious AI use. Ethical education is crucial in instilling values and a sense of responsibility in future engineers, focusing not only on technical competence but also on ethical considerations and societal impact. The relationship between ethical awareness and engineering identity shapes the future of engineering education, emphasizing the significance of incorporating the social component of engineering identity alongside technical knowledge and skill acquisition. Customized ethics education tailored to diverse student populations, along with clarity in curriculum content and instructional strategies, can enhance ethics education in engineering programs. Integrating research findings into ethics education can cultivate a more ethical and socially responsible engineering workforce, equipped to address real-world ethical dilemmas and contribute positively to society.

Although engineering education includes ethics and professional identity components, there is a need for a more comprehensive integration of students' identities, personalities, and real-world scenarios across the curriculum. Some programs may lack sufficient emphasis on these topics, leading to gaps in students' understanding and development. Therefore, fostering ethical awareness and a strong engineering identity is critical for preparing the next generation of engineers to address complex societal challenges and contribute meaningfully to society. Addressing the challenges and gaps in existing research can help enhance engineering education and promote a culture of ethical conduct, innovation, and social responsibility.

Ultimately, this research lays the groundwork for exploring the pedagogical approaches to teaching and fostering ethics within STEM disciplines across different academic contexts. Recognizing that engineering identity is not fixed but evolves over time through accumulated experiences, it becomes essential to examine the junctures at which students' ethical viewpoints become pivotal in shaping their engineering identity. Thus, this study highlights the importance of ethical perspectives that may stem from their prior educational experiences and the development of diverse identities.

Recommendations

A hope is that this study can inspire the development of effective pedagogical approaches to increase ethical awareness based on engineering identity constructs. To improve the effectiveness of ethics education, engineering instructors and faculty should play a critical role in carrying out ethics education alongside their areas of expertise, encouraging students to integrate empathy with the design, problem-solving, decision-making, and prototyping processes. In particular, motivating students to understand their ethical decision-making processes while participating in projects may yield a more positive experience during their academic and professional careers. Despite various pedagogical suggestions, several emerging challenges to teaching ethics effectively have emerged. First, the integration of ethics and technical education may require significant preparation of work for the instructors and faculty members to learn non-technical and non-expertise areas. Therefore, students can better understand ethical responsibility in their future profession by learning multifaceted aspects of engineering ethics introduced within the context of society, organization, and politics.

In the challenging situation of current ethics education, a conclusion drawn from this study is that the development of identity as an engineer has the advantage of framing ethical awareness for future engineers. The importance of combining the technical focus in the engineering curriculum and societal engagement with ethical issues should be emphasized in engineering education. Considering the impact of technological development on societal development and problems, incorporating ethics education supports developing future engineers and technology leaders. In particular, because recognition is a socially bounded construct and predicts ethical awareness, recognition as "ethical" engineering should be highlighted in society as well as in engineering education.

Lastly, future research may explore the impacts of engineering students' ethnicities on their ethical awareness with larger sample sizes for non-White populations such as African American, Arab-middle East, Hispanic, Asian, and multiple ethnicities. In addition, we envision future research on how engineering ethics motivates students' motivation for societal and communal goals and predicts career decision-making as humanitarian engineers. Moreover, future research could test the effectiveness of interventions designed to increase students' ethical awareness with their engineering identity development.

Limitations

This current study has several limitations. First, data was reliant on self-report responses. A limitation is that no independent validation is made of students' claims of their level of ethical awareness. Additionally, the instrument of ethical awareness was adapted from McGinn's (2003) questions, and a new instrument capturing contemporary ethical concerns periodically regarding new technology needs to be updated. Limited sample sizes cause another limitation for ethnic diversity. For the regression findings, *Hispanic* was significant at the marginal level, but this finding was based on a small sample size of only eight participants. The engineering program in the current institution has a meager Hispanic student rate of about 2%, and it is problematic to give unquestioned importance to this statistical result. Based on this preliminary examination for ethnicity differences, future research may explore the impacts of engineering students' ethnicities on their ethical awareness with larger sample sizes for non-White populations such as African American, Arab-middle East, Hispanic, Asian, and multiple ethnicities. In other words, future research on ethical awareness and engineering identity needs to address issues of diversity, equity, and inclusion within the engineering profession. There is a need to explore how different identities and perspectives influence ethical decision-making and professional development.

Lastly, this study targeted undergraduate engineering students. However, it is critical to note that ethical awareness development is best studied with a holistic perspective that considers previous life and educational experiences. There is limited research about ethical aspects taught in STEM classes for the K-12 setting. It will be critical to investigate how ethics related to STEM are taught and developed in that setting. Because engineering identity is not static but dynamic and developed through accumulated experience, it is imperative to investigate when ages or grades are critical for students to develop their engineering identity. Thus, ethics education, along with the STEM curriculum, should be developed. We envision future research on how engineering ethics motivates students' motivation for societal and communal goals and predicts career decision-making as humanitarian engineers. Moreover, future research could test the effectiveness of interventions designed to increase students' ethical awareness with their engineering identity development.

Ethics Statements

The studies involving human participants were reviewed and approved by the United Nations University. The participants provided their written informed consent to participate in this study.

Authorship Contribution Statement

M. Park: Conceptualization, design, analysis, writing. J. J. Park: Editing/reviewing, manuscript. Chang: Drafting manuscript and editing. Passmore: Editing and supervision.

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