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Ethical Preparedness, Self-Efficacy and Challenges in Engineering Education – A Quantitative Study

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Abstract: Academicians and practitioners in engineering focus on promoting ethical behaviour in their field. Engineering ethics are essential for maintaining public faith in the field and its professionals, especially as engineers rapidly face global and socially complicated issues that involve technical and ethical challenges. Unethical engineering exposes companies to legal action, financial constraints, and decreased effectiveness. To enhance ethical awareness about one's own ethical self- efficacy, ethical preparedness and the associated ethical challenges, ethical instructions are to be developed among students successfully. With this as the motivation, an attempt is made in this study to develop a survey instrument to capture the freshmen engineering students' understanding related to ethical preparedness, ethical challenges, and ethical self-efficacy. Considering these three aspects, a survey instrument was created and distributed at an affiliated (autonomous) college in south India (Hyderabad Institute of Technology and Management) during spring 2021 to the freshman engineering students. Exploratory factor analysis was conducted to determine the factor structure of the survey instrument and it results in three factors as hypothesized. The factors had a minimum and maximum loading of 0.56 and 0.90 and Cronbach's α ranged from 0.83 to 0.88. This instrument could be used by institutions willing to assess students' current levels of awareness regarding engineering ethics and decide next steps accordingly.

Keywords: ethical challenges, ethical self-efficacy, engineering ethics, freshman engineering students

1. Introduction

Needless to say, times have changed. Owing to rapidly changing technology and environment around, ethics is and should be the core of engineering. Engineering ethics is the field of system of moral principles that apply to the practice of engineering. The field examines and sets the obligations by engineers to society, to their clients, and to the profession. Engineering ethics comes under branch of applied ethics.

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Ethics as a course in engineering has increasingly drawn attention in the past decade and has ended in a field of research and teaching which is popularly referred as engineering ethics [1]. The field of engineering ethics has made significant progress over the past decade. A variety of strategies and methods of teaching engineering ethics have been researched and experimented [2]. The ethical decisions and moral values of an engineer need to be considered because the decisions of an engineer have an impact on the products and services they provide for the benefit of the people [3]. Contrary, engineering failures due to ethics are not new. From the sinking of Titanic in 1912 to the Fukushima Daiichi nuclear disaster in 2011, engineering failures have been caused by problems in design, construction, and safety protocol. The blame can often have learned from the wrong ethical decisions that were made [4].

Due to the unethical behaviour of employees working in an organization, serious consequences for both individuals and organizations can be observed. Engineers must perform under a standard of professional behaviour that requires adherence to the highest principles of ethical conduct. Professionalism and ethics in the workplace are the guiding principles that an individual or the company has established [5]. For employers a key point is to know how college students are perceiving ethics at their undergraduate courses which will help them to take potential hires to make ethical decisions when confronted with moral dilemmas in the real world. Hence, it is understandable why many firms today are placing the ability to make ethical decisions in the real world first and foremost on their lists of desired qualifications for new hires [6].

Decision making is an important part in ethics irrespective of the discipline or field. Some of the common examples of decision-making used in the engineering education which do not directly relate to ethics involve some sort of optimization techniques, which requires to eventually making decisions based on different attributes [7-12]. However, ethics in engineering is not as evidently present as other decision-making methods in engineering. A few exceptions include engineering ethics courses established by National Society for Professional Engineers, IEEE, Accreditation Board for Engineering and Technology (ABET), and at Texas A&M university where they address the need for ethics in the engineering curricula [13].

Moreover, many engineering programs are under pressure to train learners for the expected ethical dilemmas that will arise in the workplace. Many foreign universities have continued to stimulate a sense of ethics, accountability, corporate social responsibility, and environmental sustainability through teaching, classroom discussions, research, institutional best practices, as well as active social conscience [14]. Recent study has focused on the impact of moral behaviour on ethical education and the challenge is to understand whether ethical education is beneficial or not which eventually affects the behaviours of future engineers [15].

Ethics education must be included in engineering curriculum and professional training courses. The evaluation of ethics training programs will be based on psychological variables that are relevant to them. An improvement in ethical self-efficacy could imply that the instruction was beneficial [16]. The present study is focused on investigation of students understanding on the different aspects related to engineering ethics such as ethical preparedness, ethical self-efficacy, and ethical challenges of freshman engineering students. A survey instrument was developed and administered to students enrolled of Hyderabad Institute of Technology and Management (HITAM).

2. Literature

The supporting literature for this study explores the freshman student perception of ethics using various dimensions of ethics in engineering. In this research, ethics is formally defined as “the discipline dealing with what is good and bad and with moral duty and obligation”. It is not easy to teach professional ethics or to motivate students on ethical values fully [17].

It is recommended to teach ethics for undergraduate students in four aspects of academic dishonesty, punctuality, judgment, and moral behaviour. In a study [18], the impact of gender and academic disciplines on these four moral processes is explored and discussed about possible connection with each other and other connections to perceptions of ethics involving gender, age, and engineering education. Codes of ethics play a crucial role for guiding ethical values in engineering education [19]. In other words, if students perceived that such codes of ethics are being enforced properly, they will consider these codes to be effective and place a high moral expectation on the ethical culture and members of the academic institution. However, an enforced code of ethics is not the only element found to influence individuals’ perceptions of ethics.

In engineering education, some studies have actually underlined the importance of students' academic self-efficacy. As a result, when engineers are unable of producing anything of worth or of professional growth within their chosen profession, we all too frequently go for the problem elsewhere rather than critically scrutinizing the processes within our own classroom [20]. Due to multiple psychometric and sociological aspects, few studies claim that "grades represent, at best, a compromised measure of success." [20]. Self-efficacy, which is simply described as one's opinion of one's own competence, has been demonstrated to be a key mediator in cognitive motivation. Few studies suggested role of the professor, theories of motivation, the role of self-efficacy in motivation, and guiding principles can be used to enhance self-efficacy in engineering students [21].

According to a few authors in the awareness process, a person's ability to identify that there is a moral concern in a certain scenario function as a sort of triggering mechanism that starts the ethical decision-making process [22]. Moral awareness entails role-playing, but it's also important that the person understands that breaking a moral rule or allowing unethical events to occur might "impact the needs, beliefs, health, and expectations of others." Engineers and future potential engineers must adhere to strict work ethics and be aware of the ethical risks they face. As a result, it is timely to investigate whether engineering students ready to enter the workforce are prepared to confront such issues [23].

As the scope of engineering is becoming more global, academicians and industry stakeholders have long recognized the importance of engineering graduates being able to collaborate effectively with colleagues from various national and cultural origins. These characteristics that improve undergraduate engineering students' global preparedness are essential for engineering graduates to be capable of working across national boundaries in order to successfully "encounter worlds of professional practice that are progressively global in nature [24]. While most of the engineering students have basic knowledge of ethical principles, they just need more practice to understand and deal with the complex and subtle problems of professional responsibility in engineering before they encounter ethical problems in the real engineering world [25].

As suggested from above ethical dimensions researchers concluded that ethics instruction can indeed be taught, and training effectiveness may increase ethical self-efficacy which can have an impact on students’ personal beliefs and behaviours. Ethics education is a key component of engineering student curriculum and professional training programs, ABET’s engineering criteria 2007 requires engineering program exhibit that their graduates have a considerate professional and ethical responsibility but teaching engineering ethics is still not a high priority in engineering education [26].

Despite these important advances, the present study attempts to examine the awareness of students’ perception in terms of their understanding of ethical issues in the profession, their readiness to deal with them, and their confidence in their ethical abilities (ethical preparedness, ethical challenge, and ethical self-efficacy) at freshman engineering level by collecting and analysing data quantitatively.

3. Methods

The length of the paper inclusive of figures, tables etc., should not exceed a maximum of 8. Based on the literature study the survey instrument was developed [27], few modifications were done keeping in mind the sample population. The data was collected during spring 2021. The instrument is comprised of three factors (Table 1). The

factors in the instrument align with the dimensions or constructs of the participant's opinion and are intended to capture student preparedness, self-efficacy, challenges related to their ethical values in engineering environment. The instrument also includes a separate demographic section with questions about students' personal background characteristics such as gender, discipline, board, and highest qualification of parent to know how educational background impacts ethical values. The author developed 16 interdependent items for the three factors to determine freshmen students' understanding of ethics, requesting information pertaining to the students' perception of ethical preparedness, challenges, and self- efficacy.

Table 1 provides information about the item development for each factor, including, the intended meaning of the construct and example items. Response options for all constructs were arrayed on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) [28]. The students' responses to these questions allowed the author to analyse the students' perception on ethical preparedness, self-efficacy and challenges faced during engineering education.

Factor 1 Ethical preparedness

It includes six items which focus on student's perception of being prepared to respond, recognize, and make decisions related to ethical dilemma during four years of engineering education. In addition, it also describes students' awareness of ethical guidelines of their field and prepared to act ethically during engineering.

Factor 2 Ethical challenges

This factor includes five items which speaks about the ethical challenges that students might come across during their engineering which could basically include ethical dilemmas in which the right response to an ethical dilemma in engineering is unclear and there will be times in career when they will be asked to act unethically, besides it will be challenging to make ethical decisions for them.

Factor 3 Ethical Self-Efficacy

It includes five items were student's self-efficacy showcases how confident are they in their ability to deal with ethical challenges towards acting ethically during four years of engineering career and how confident are they in taking ethical decisions in their engineering career or profession.

4. Data Collection

The data for this study was collected from freshmen engineering students at an autonomous institution HITAM in South India. The evidence for the face validity of the survey instrument was obtained by asking three potential participants to review the questions on the survey and provide their feedback on wording and phrasing of the questions. The students did not find any unfamiliar words or confusing phrasing of the survey questions. Hence, the survey instrument did not require any revisions. A total of 229 participants responded the survey and after cleaning the data 220 participants remained in the final dataset. Participants who did not respond to more than 50% of the questions on the survey were not included in the data. Also, participants who selected the same option for all the questions were deleted from the data. The missing data was handled using group mean substitution method.

Table-1 Overview of factors within the survey instrument

Factors	Definition of construct	Example items
Ethical preparedness	Student's individual perceptions on awareness about the different aspects of ethics in engineering.	- I am prepared to respond to ethical dilemmas during my four years of engineering. - I am aware of ethical guidelines in engineering field.
Ethical challenges	Students' facing challenges or disputes when they individually come across deciding on some things following ethics.	- It will be challenging to act ethically at times during my four years of engineering career - It will be challenging to take decision which is unethical
Ethical self-efficacy	Students' individual's confidence in their ability to act ethically in a given situation.	- I am confident in my ability to deal with ethical challenges - I am confident in my ability to act ethically during my four years of engineering career

Table 2 presents the participants' demographic information including gender, engineering discipline, board of study, and parent's qualification. The data was collected during Spring 2021. The participants provided their consent before starting to respond to the survey. In total, the survey takes approximately 6 minutes to complete. A five-point Likert type scale was used in the survey – strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. The students were sent a reminder after 3 days to complete the survey if they had not already completed.

5. Results

Table 3 provides the descriptive statistics of all the items used in the survey. An exploratory factor analysis was used in this study. Bartlett's test for sphericity was used to test the suitability of items for factor analysis ($p<0.05$) and Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was used (KMO > 0.8) was used to check the variance of the extracted factors [29]. The suggestions for factor analyses were considered through parallel analysis, scree plot and Kaiser's criterion. The parallel analysis and

suggested three factors, scree plot and Kaiser's criterion suggested 2 factors. Three factors were chosen as it matched the hypothesized number of factors. As the correlations of the factors were greater than 0.33, Promax rotation was used [29].

The final factor loadings for all the three factors are shown in Table 4. Three factors (items 3 and 16) had factor loading of less than 0.4 on at least two items and one factor (items 9) cross-loaded on more than one factor [30]. These three items were removed from the analysis resulting in a total three factors with 13 items. The factor loadings for factor 1 ranged from 0.61 to 0.84, 0.56 to 0.88 for factor 2, and 0.75 to 0.90. The reliability coefficient for internal consistency (Cronbach's α) ranged from 0.83 to 0.88 showing a strong reliability of the factors [31].

Table 2. Demographic information of the participants

#	**Category**	***n***	**%**
	Total	220	100
1	*Gender*		
	Male	144	66
	Female	76	34
2	*Engineering discipline*		
	Electronics and communication engineering	29	13
	Mechanical engineering	13	6
	Electrical and electronics engineering	20	9
	Computer science engineering	46	21
	AI and ML	6	3
	IOT	27	12
	CS	35	16
	DS	44	20
3	*Board of study*		
	CBSE	34	15
	SSC	186	85
4	*Parent's qualification*		
	Below 10th grade	31	14
	10th grade	38	17
	12th grade	55	25
	Bachelor's degree	71	32
	Master's degree	21	10
	Ph.D.	4	2

Table 3. Descriptive Statistics of the five factors

#	Measure	*Mean*	*SD*
	Ethical Preparedness		
1	I am prepared to respond to ethical dilemmas during my four years of engineering.	3.5	0.9
2	I am prepared to make decisions related to ethical dilemmas during my engineering	3.6	0.8
3	I am confident that I will be able to recognize ethical dilemmas during my engineering	3.7	0.8
4	I am aware of the ethical guidelines of the engineering field.	3.5	0.9
5	Ethical decisions in engineering education are usually easy to make.	3.3	0.8
6	I am prepared to act ethically during my engineering	3.7	0.7
	Ethical Challenges		
7	At times, the right response to an ethical dilemma in engineering is unclear	3.5	0.8
8	It will be challenging to act ethically at times during my four years of engineering	3.5	0.8
9	There will be times in my career when I will be asked to act unethically	3.4	0.9
10	It will be challenging to take a decision that is unethical	3.5	0.9
11	It will be challenging to give judgment on unethical things during my four years of engineering	3.5	0.9
	Ethical Self-Efficacy		
12	I am confident in my ability to deal with ethical challenges	3.7	0.8
13	I am confident in my ability to act ethically during my four years of engineering	3.7	0.8
14	I am confident in my ability to deal with solutions to problems ethically	3.7	0.8
15	I am confident in my ability to take ethical decisions during my four years to engineering.	3.7	0.8
16	I am confident in my ability to make judgments ethically during my four years of engineering	3.7	0.7

Table 4. Final factor loadings of the survey instrument

#	Measure	*F1*	*F2*	*F3*
	Ethical Preparedness (α=0.88)			
1	I am prepared to respond to ethical dilemmas during my four years of engineering.	0.61		
2	I am prepared to make decisions related to ethical dilemmas during my engineering	0.84		
3	I am aware of the ethical guidelines of the engineering field.	0.68		
4	Ethical decisions in engineering education are usually easy to make.	0.72		
5	I am prepared to act ethically during my engineering	0.69		
	Ethical Challenges (α=0.83)			
6	At times, the right response to an ethical dilemma in engineering is unclear		0.88	
7	It will be challenging to act ethically at times during my four years of engineering		0.56	
8	It will be challenging to take a decision that is unethical		0.74	
9	It will be challenging to give judgment on unethical things during my four years of engineering		0.63	
	Ethical Self-Efficacy (α=0.85)			
10	I am confident in my ability to deal with ethical challenges			0.77
11	I am confident in my ability to act ethically during my four years of engineering			0.90
12	I am confident in my ability to deal with solutions to problems ethically			0.75
13	I am confident in my ability to take ethical decisions during my four years to engineering.			0.83

6. Conclusions

The design and development of a survey instrument to capture the freshmen engineering students' perceptions related to ethical preparedness, ethical challenges, and ethical self-efficacy were presented. A total of three factors emerged from the exploratory factor analysis as hypothesized. The factor had a minimum and maximum loading of 0.56 and 0.90 and Cronbach's α ranged from 0.83 to 0.88.

This survey instrument could be used by any educational setting to understand students' understanding and knowledge levels related to engineering ethics. Based on the outcome of the survey, appropriate interventions can be made in the curriculum such as organizing a webinar on ethics, conducting workshops related to ethics, including elements of ethics in the curriculum, introducing elective courses related to engineering ethics, etc.

7. Future Work

In future, the author would like to collect evidence for content validation of the survey instrument. Examining the influence of the different demographic variables (gender, engineering discipline, board of study, and parent's highest qualification) on all the ethical preparedness, ethical challenges, and ethical self-efficacy could be a direction for potential future work. Collecting more data and conducting a confirmatory factor analysis to further validate the survey instrument could also be done in future. Future research would even involve students' quantitative survey to collect data from the students of all the four years of engineering and their ethical perspective in engineering education which will help to better understand how to incorporate ethics in curriculum [32-34]. Further research will be carried out by conducting qualitative interviews that can be designed to investigate deeper understandings and perceptions of ethics in engineering [34-38]. Qualitative research studies can also be conducted to investigate the perceptions or opinions of the faculty members' perspectives on engineering ethics. Concept assessment tools can also be created and used to assess students' understanding and knowledge in applying their learnings related to engineering ethics under different circumstances [39-42].

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