Bringing Engineering Ethics Education into the High School Curriculum

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Abstract

This paper presents the progress made in the first two years of a five-year NSF ER2 (Ethical and Responsible Research) project on ethical and responsible research and practices in science and engineering undertaken at a large public university in the southwestern United States. Overall objectives of the project include: **1)** conduct a survey of incoming freshmen college students to assess their ethical research competency and self-efficacy at the beginning of their tertiary education and during their senior-level capstone course; **2)** evaluate the ethical research competency and self-efficacy of university students and identify any significantly contributing factors to develop an intervention plan to improve their ethical research competency (ERC) and ethical research self-efficacy (ERS) levels; **3)** develop learning materials on topics related to ethical STEM research and practices and integrate them into undergraduate curriculum in multiple engineering disciplines; **4)** provide enrichment experience in ethical STEM research and practices to high school teachers.

Prior research shows that there is a lack of empirical work done with respect to engineering ethics education at the tertiary level. There is an even greater lack of ethics at the secondary level. According to a prior study, the authors saw significant improvements in ethical judgement and epistemological beliefs related to ethics as a result of incorporating ethics content into a high school course; these improvements were assessed using essays in response to ethical prompts. Other studies revealed a significant lapse in ethical practices in students' work at the high school level. Researchers also point out that students who are able to make ethical decisions in schools are more likely to perform better academically than their peers. To that end, the objective of this paper is two-fold. First, it presents a snapshot of survey results of freshmen, seniors, and the capstone courses as stated in the above-mentioned objectives. Secondly, it discusses the summer enrichment program for high school teachers. A self-efficacy assessment of teachers (pre- and post-enrichment experiences) is presented in detail. In addition, the teachers' work during the summer, including their sample lesson plans are discussed. Lastly, the paper also includes the challenges with the current survey instrument and how the research team is modifying the instrument to aid the overall objectives of the project.

1. Introduction

Prior research suggests that the ethics education in schools especially at secondary levels is mostly an unplanned, unstructured and informal learning exercise imparted by teachers in the form of value education in everyday learning of school students. Without a common benchmark for required knowledge and understanding on the ethical issues and dilemmas, it is difficult to comprehend how effectively teachers can impart knowledge on ethics to students and make them capable of making ethically correct decisions [1]. In a survey conducted among American upper secondary students, although most of the students claimed to be aware of the ethical course of action in various situations, most of them were not able to choose a correct ethical alternative even

when posed with situations that were easy to comprehend [2]. A very high proportion of high school and undergraduate students were found to be engaging in academic dishonesty considering different motives and possible outcomes. Even other kinds of unethical behavior were found to be present among school students, which demanded establishment and education of a common set of socially acceptable standards on morality among students [3,4]. Past research also hints at students at the tertiary level lacking basic understanding of ethical education. In their case, delivering ethics through discussion and feedback on ethical dilemmas resembling the ones faced by them in their profession proved to be an effective approach [5].

Research also points at teachers noticing a significant improvement both in willingness to engage in dialogue and in making correct ethical decisions when presented with various situations containing ethical dilemma once students were educated on ethical and moral values. In one instance, situations with ethical dilemmas were used as course content in a senior high school English class, which lead to both better involvement of students in the English class and the selection of personal stances by students considering the situations and actions of characters in the literature being discussed [6,7]. Another study compared the possibility of unethical behavior among students before and after imparting ethical education, and noticed significant improvement after imparting ethical education [8]. Researchers have also commented that the students or individuals that displayed a higher amount of intellect in academia and creativity displayed a higher amount of intellect in aspects of ethical evaluation and decision making as well. This can be understood from the onset of thought, realization and questions on moral and ethical issues at an early age compared to their peers [9]. A study conducted in the past did reveal that the schools with teachers having good leadership qualities and interpersonal relations witnessed fewer incidents of cheating. Also, cheating was more prevalent among students having lower grades compared to their peers [10].

This project aims at a multifaceted approach in evaluating and improving ethical research competency and ethical self-efficacy of undergraduates. Furthermore, the project is providing high school STEM teachers with summer research and curriculum development experience. For undergraduate students, the project aims to identify the factors that contribute significantly to the ethical research competency and self-efficacy through surveys at the freshmen level and then develop intervention plans to address the identified contributing factors in the upper level courses such as Capstone or senior design project courses. For the secondary education level, this program aims to provide teachers with research experiences through laboratory activities in addition to lectures on related topics with an aim of making teachers capable of and confident in addressing ethical dilemmas of their students.

This paper presents a review on initiatives taken by the project during the past year and consists of summary and findings from Enrichment Experience in Engineering for High School Teachers (E3) program for STEM teachers at K-12 level conducted in the year 2023. The section on E3 program highlights the lectures delivered, research experiences provided, and the deliverables sought from participating teachers. A survey was conducted among participants pre- and post-E3 program aimed at recording confidence levels and improvements in confidence levels of teachers

in their capacity to educate their students on engineering ethics, the results of which are also shared in the paper. This paper also contains a section on analysis of responses recorded from previous years student questionnaire and how the recorded responses and results highlighted limitations of the current questionnaire influenced changes in questionnaire for the current year.

2. Enrichment Experience in Engineering for High School Teachers

The Enrichment Experience in Engineering (E3) program offered by TAMU is a three-week enrichment program for high school science and engineering teachers aimed at providing the participants with a research and professional/curriculum development experiences in engineering. This program intends to enhance the ethical awareness of high school teachers and help them develop curriculum plans in order to address the issue of engineering ethics in their classrooms.

The first cohort of summer research experience for teachers started in 2023. The detailed schedule of 3-week long E3 program is shown in Table 1. Per the project plan, three teachers were recruited for summer 2023 cohort; one high school teacher did not attend citing personal reasons, so only two teachers participated in the program. As shown in Table 1, the program is structured so that all teachers spend some time in "lab research" paired with curriculum and professional development activities. For our instructors, "lab research" consisted of reading assignments, daily conversations with philosophy faculty with expertise in science and engineering ethics, visits from engineering faculty, and lesson plan development. In the first half of the program, readings were assigned to develop a general understanding of ethics of science and technology [11], engineering ethics [12], and research ethics [13, 14, 15], and which then led into materials designed to help the instructors apply these ideas in the high school classrooms [16]. The first part of the program also included a presentation by a university librarian, to help them do independent research as they constructed their lesson plans, and one by Jacquelyn Huff, teaching professor from Penn State's School of Engineering Design and Innovation who has experience teaching high school students. The second half of the program consisted of independent research, guided by the philosophy faculty member, oriented toward lesson plan development. During this period, they also spent some time discussing the general objective of professional ethics courses [17].

As a part of the E3 program, the participants were required to prepare a classroom curriculum plan on engineering and research ethics for their class and submit it for evaluation by external evaluators. Out of two participants, one participant developed a fourteen-day course for 9th and 10th grade students aimed at defining methods to address engineering ethics and helping students understand and implement the delivered content first using case studies and later using engineering projects that they develop in future. The first two days consist of building on the notion of "in the public's best interest" and understanding the applications of the notion to the world of engineering design. Between the third day and the seventh day, students will study selected cases where unethical decisions were made, identify those, and will be made aware of the possible better

Table 1: E3 2023 Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
12-Jun	13-Jun	14-Jun	15-Jun	16-Jun
2:00-6:00 Check-In to TAMU Lodging **6:00-7:30** Welcome Dinner **7:30-8:30** Campus Tour	**9:00-1:00** Breakfast w/ Faculty Mentor, Introduction and Pre- Survey **10:00-3:00** Lab Research **3:00-4:00 (Zoom)** Dr. Karan Watson	**9:00-10:00** Library Session **10:00-2:00** Lab Research **11:00-12:00 (Optional Zoom)** T3 - Dr. Jessica Ramella, FIU **2:00-2:45** ISEN Lab Tour **3:00-4:00 (Zoom)** Engineering Design Process **Assignment 1 Due**	**9:00-10:30** Research Seminar **10:30-3:00** Lab Research **3:00-4:00 (Zoom)** T1-Dr. Samuel Mabbott	**9:00-3:00** Lab Research **3:00-4:00 (Zoom)** TeachEngineering Exploration
17-Jun	18-Jun	19-Jun	20-Jun	21-Jun
9:00-5:00 Lab Research **3:00-4:00 (Zoom)** TeachEngineering Exploration **Assignment 2 Due**	**9:00-5:00** Lab Research **3:00-4:00 (Zoom)** Photography in Labs	**9:00-3:00** Lab Research **11:00-12:00 (Optional Zoom)** T3 - Dr. Ashok Veeraraghavan, Rice University **12:00-1:00 (Optional Zoom)** Effective Research Presentations **3:00-4:00 (Zoom)** Poster Training	**9:00-11:30** Lab Research **11:30-1:00** Research Seminar/Lunch with TAMU Engineering Professor **1:00-3:00** Lab Research **3:00-4:00 (Zoom)** Video Presentation Tactics	**9:00-10:30** Lab Research **10:30-11:30** ETID Lab Tour **11:30-3:00** Lab Research **3:00-4:00 (Zoom)** Lesson Plan Check-In **Assignment 3 Due**
22-Jun	23-Jun	24-Jun	25-Jun	26-Jun
9:00-10:00 Lab Research **10:00-11:00** Leadership Seminar on Ethics in Education: Challenges and Opportunities **11:00-3:00** Lab Research **3:00-4:00 (TAMU Only)** eSAIL Expectations	**9:00-5:00** Lab Research	**9:00-3:00** Last Day in Lab **3:00-4:00 (TAMU Only)** Poster Printing **Assignment 4 Due**	**9:00-12:00** Lab Tours **12:00-3:00** Teacher Work Time **3:00-4:00 (Zoom)** Mel Tenant-Booyna, FIU	**9:00-10:30** Poster Session **11:30-1:00** Luncheon with Faculty and Lab Staff **Assignment 5 Due**

consequences in case ethical decisions had been made. This exercise will be performed in a group of two to three students. For the next week, the students will leave their original group and join new groups with different students to discuss how they feel different choices in decision making would have led to different consequences.

The other participant developed a small project aimed primarily at 10th grade students where students are required to design and develop a bridge capable of bearing certain loads. The students are provided with a choice of adhesives, an expensive one and a cheaper one. Also, the constraints on the budget of the bridge are kept strict and a penalty is imposed on the students who exceeded the allocated budget. This tradeoff between not receiving a penalty and making an ethical decision that is in the best interests of the public is meant to be the learning objective from the project.

A survey was conducted before and after delivery of the program aimed at identifying the level and change in level of confidence that the participating teachers had in their ability to address questions related to engineering ethics in the classrooms. Since there were only two participants for the first year of the program, the data analysis of the surveys collected from the participants is inconclusive because of the small sample size.

Even with the small sample size, based on the responses of the collected surveys, the participants found ethical issue exposure, case study learning, and faculty collaboration to be extremely helpful aspects of the program. In terms of confidence in teaching ethics, although the participants were very confident in delivering lectures, addressing questions, and designing curriculum on ethics before the program, the level of confidence slightly decreased among the teachers after attending the program in the aspects of teaching and answering questions. The teachers were still confident of their ability to address ethics in classrooms. In terms of preparedness on teaching various aspects of ethics in responsible research and conduct as engineers, the teachers felt that they were well prepared to educate their students.

3. Survey of Senior Undergraduate Students to Identify Factors Influencing Ethical Self-efficacy and Ethical Competency

A survey was conducted among senior year engineering students participating in capstone design course during the Fall 2023 semester. The survey conducted for this year differed from the previously conducted surveys for the project. A section on ethics case studies was removed from the survey as results of data analysis on previously conducted surveys were inconclusive. This paper focuses on the two research questions listed below.

RQ1. What is the self-efficacy level of students on ethical research and practices in engineering?
RQ2. Are there any underlying factors that may explain the variability in ethical self-efficacy levels across the different student populations such as student demographic and socioeconomic attributes, academic attributes (e.g., major), professional experience attributes (e.g., level of involvement in extracurricular activities, prior exposure to research, industry internship, nature of work experience)?

For the fall 2023 Semester, over 284 responses were collected to the questionnaire from senior year capstone design students majoring in Engineering Technology and Industrial Distribution (ETID) and Industrial and Systems Engineering (ISEN) departments at a major Southwestern University. Of these, 84 responses were discarded because of inconsistency in responses (e.g., not being able to respond correctly to questions framed to check awareness of a participant). Out of the recorded valid responses, 79% responders were male and 20% were female. In terms of race and ethnicity, 17% belonged to Hispanic and Latino origins and 1% of responders did not wish to disclose their ethnicity. 68% of the respondents were from ETID discipline, while 32% belonged to ISEN. Also, out of all the respondents, 59% of students had previously taken or were currently taking a course on engineering ethics when this survey was conducted. These demographic data are summarized in Figure 1.

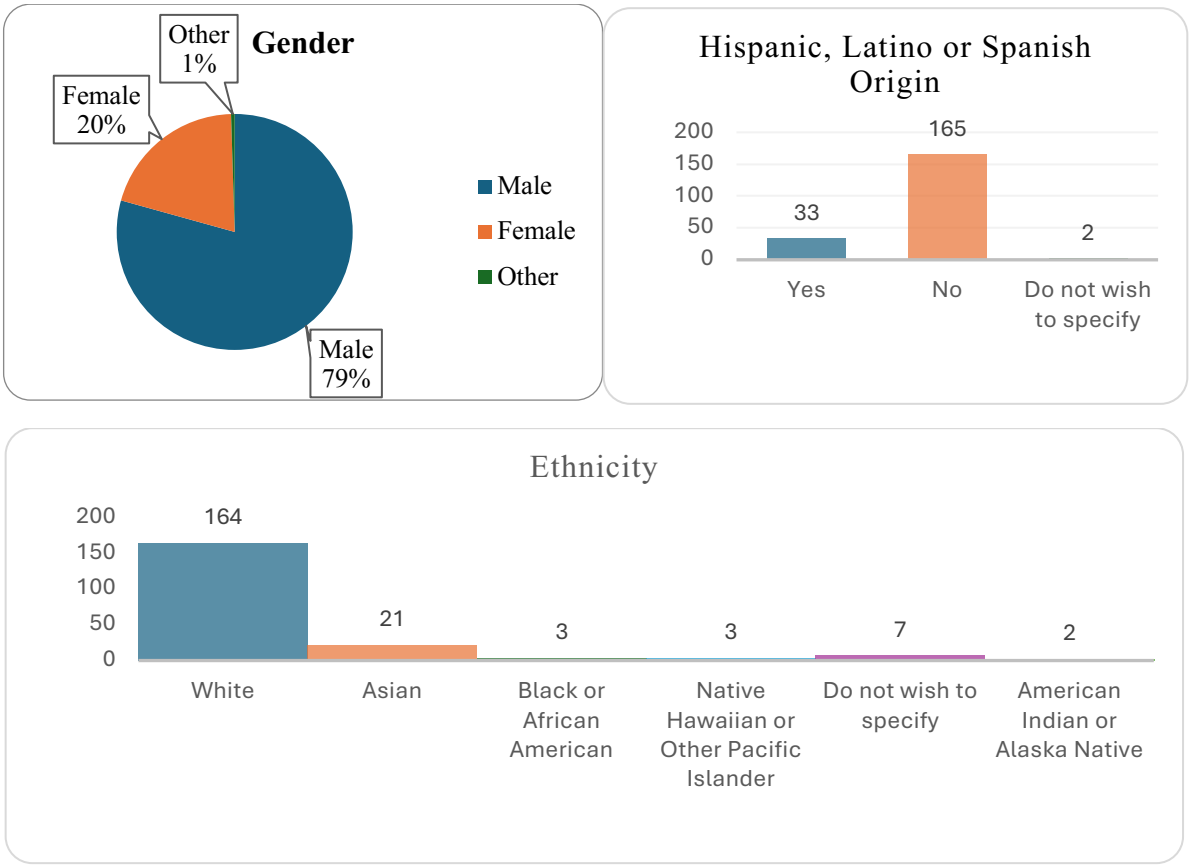

Figure 1: Demographic attributes of participants

The survey questions posed to the students and the results of *t*-test performed on the received responses on the basis of demographic factors and high school experiences are described below. It may be noted that this paper only discusses results of the ethical-self efficacy section of the survey (see questions below).

Table 2: Comparison of self – efficacy scores with high school experiences

High School Education Questions	Occurrences	D1 (Mean)	D2 (Mean)	D3 (Mean)	D4 (Mean)	D5 (Mean)	D6 (Mean)
Q1. Emphasized to follow accepted procedures in science experiments	Never & Once	5.83	2.83	5.83	4.17	5.00	4.50
	Occasionally & Frequently	5.72	3.13	6.46	5.81	5.33	5.68
	p-values	**0.80**	**0.67**	**0.11**	**0.00**	**0.54**	**0.01**
Q2. Encouraged to accurately report results regardless of outcome	Never & Once	5.33	3.89	5.56	5.11	5.56	5.11
	Occasionally & Frequently	5.74	3.09	6.48	5.79	5.31	5.68
	p-values	**0.28**	**0.16**	**0.00**	**0.05**	**0.58**	**0.12**
Q3. Importance of doing own work and recognizing the contribution of others	Never & Once	5.20	4.20	6.00	5.40	5.60	4.80
	Occasionally & Frequently	5.74	3.10	6.45	5.77	5.40	5.68
	p-values	**0.28**	**0.15**	**0.30**	**0.43**	**0.71**	**0.07**
Q4. Grades for group work based on the individual contribution	Never & Once	5.45	3.40	6.00	5.55	4.95	5.45
	Occasionally & Frequently	5.73	3.10	6.47	5.77	5.37	5.68
	p-values	**0.28**	**0.45**	**0.03**	**0.35**	**0.16**	**0.37**
Q5. Taught to welcome and work with people from different backgrounds	Never & Once	5.56	3.31	5.92	5.28	4.85	5.10
	Occasionally & Frequently	5.76	3.07	6.56	5.88	5.44	5.80
	p-values	**0.32**	**0.42**	**0.00**	**0.00**	**0.01**	**0.00**
Q6. Teachers interested in student's development and growth	Never & Once	5.32	3.61	6.00	4.93	4.96	4.82
	Occasionally & Frequently	5.79	3.05	6.51	5.90	5.38	5.79
	p-values	**0.04**	**0.10**	**0.01**	**0.00**	**0.12**	**0.00**
Q7. Teachers treated me and my classmates with respect	Never & Once	6.00	4.00	6.33	5.67	5.67	4.67
	Occasionally & Frequently	5.71	3.11	6.44	5.76	5.40	5.66
	p-values	**0.66**	**0.36**	**0.85**	**0.88**	**0.71**	**0.11**
Q8. Taught to think about my role requiring to make decision that was not in my (or family) interest	Never & Once	5.55	2.83	6.25	5.58	5.18	5.37
	Occasionally & Frequently	5.82	3.28	6.52	5.85	5.39	5.80
	p-values	**0.12**	**0.08**	**0.05**	**0.09**	**0.29**	**0.01**
Q9. Taught to think how individual actions affect community	Never & Once	5.46	3.18	5.89	5.25	5.25	5.32
	Occasionally & Frequently	5.77	3.12	6.52	5.84	5.33	5.71
	p-values	**0.18**	**0.86**	**0.00**	**0.00**	**0.76**	**0.07**
Q10. Taught to consider choices that can affect environment	Never & Once	5.48	3.20	6.20	5.28	5.24	5.04
	Occasionally & Frequently	5.76	3.11	6.47	5.83	0.85	5.74
	p-values	**0.24**	**0.81**	**0.18**	**0.01**	**0.74**	**0.00**

D1: I am certain that I would respond correctly if I were choosing a vendor or making another professional decision that could make my family, my friends, or me better off financially.
D2: I am concerned that I will be unable to respond effectively if my client pressures me to accept a flawed engineering solution.
D3: I feel that I am prepared to work effectively with co-workers from different racial, ethnic, and disciplinary backgrounds.
D4: I am sure that if my boss asked me to complete a task that I did not feel like I had the education or experience to do, I would respond appropriately.
D5: I feel prepared to address interpersonal tensions that arise between my coworkers.
D6: I know how to balance the interests of my employer, myself, and the public, and how to explain my decisions.

Furthermore, survey results are organized based on the level of exposure to ethical education in high school (see Table 2) and demographic attributes (see Table 3).

As shown in Table 2, in general, the students with greater exposure to ethical education in high school showed higher self-efficacy than those who were "never or once" exposed to ethical education. A t-test on difference in mean scores (*Occasionally & Frequently* versus *Never & Once*) at 95% confidence level showed significant difference for multiple self-efficacy questions. For example, the students who were occasionally and frequently education "Taught to welcome and work with people from different backgrounds" showed significantly higher self-efficacy score for question D3, D4, D5, and D6. Similarly, students who had "Teachers interested in student's development and growth" scored significantly higher mean score in almost all self-efficacy question.

Table 3: Comparison of self – efficacy scores with demographic attributes

Demographic Factor	Student Population Groups	Self-Efficacy Questions (p-values)					
		D1	D2	D3	D4	D5	D6
Gender	Female / Male	0.49	0.55	0.08	0.99	0.07	0.70
Major	ETID / ISEN	0.64	**0.00**	0.21	0.59	0.95	0.58
Origin	Hispanic / Non-Hispanic	0.82	0.51	0.81	0.34	0.49	0.95
First Generation College Student	Yes / No	0.44	0.13	0.88	0.54	**0.03**	0.87
Taken TAMU Course in Ethics	Yes / No	0.17	**0.04**	0.47	0.45	0.97	0.12

Similarly, Table 3 illustrates the survey findings concerning demographic attributes. As shown in Table 3, the mean self-efficacy scores for various student populations were not significantly different except for a few questions. More specifically, our data showed there was significant difference in mean self-efficacy score for Question D2 based on the major ("I am concerned that I will be unable to respond effectively if my client pressures me to accept a flawed engineering solution"). In other words, Industrial and Systems Engineering students demonstrated a greater self-efficacy level for question D2 than their peers in Engineering Technology and Industrial Distribution. We also saw the similar difference for question D2 between the student groups based

on if they had taken any engineering ethics course in their curriculum. In addition, mean self-efficacy scores for first-generation students was significantly lower for Question D5 (": I feel prepared to address interpersonal tensions that arise between my coworkers") than that for non-first-generation students.

Conclusion and Future Scope of Work

The activities conducted in the past year provided a solid platform for testing the instruments developed by the project and built on the previous findings of the project, and measures determined by the project to address the same. The E3 program conducted for high school teachers, although with a small number of participants, revealed the ability and confidence of the participating high school teachers to deliver ethics education to students. It highlighted the benefits that the individual aspects of the E3 experience brought in enhancing ethical knowledge and ability to deliver the same among high school teachers.

The survey conducted among senior year engineering students revealed some new insights on the relationship between ethical self-efficacy of the students, their demographic attributes and their high school experiences. Although the demographics of students did not have any largely statistically significant effects on the ethical self-efficacy of the students, it was observed that students belonging to ETID majors demonstrated a lower self-efficacy about not being able to respond effectively to pressure for accepting a flawed engineering solution. This is an interesting observation, which requires further investigation to determine the cause for the difference in average scores of the students in the two departments. Furthermore, the ethics education in high schools proved to be relevant to only some aspects of ethical self-efficacy among the senior year capstone design students. The results did highlight the need for ethics education in some aspects in order to improve the ethical self-efficacy among the students.

The project team plans to conduct a direct assessment through longitudinal studies of students across the different engineering disciplines to assess the impact of ethical education at different points across the engineering curriculum. The project team would like to increase the scope of the survey of undergraduate students by deploying the survey to a few other majors in the college of engineering. Such an exercise will provide a larger sample size and is likely to provide a basis for comparative analysis between students in different majors for the different survey questions.

The project anticipates expanding the scope of the E3 program by recruiting a higher number of high school teachers and provide them training in developing ethics curriculum for their students along with relevant practical examples so that a larger number of prospective first-generation students can receive exposure to the education required to help improve their ethics self-efficacy.

Acknowledgement: *This work was supported by the National Science Foundation's Ethical and Responsible Research (ER2) grant (**SBE** # 2124888**). Any opinions, findings, conclusions, or recommendations presented are those of the authors and do not necessarily reflect the views of the National Science Foundation.*

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