Tools to Assist with Collection and Analysis of Ethical Reflections of Engineering Students

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Abstract

Ethical engineering practice is a global issue. However, cultural norms and social realities may result in differences in points-of-view on ethical practice. The present project seeks to facilitate discussion and analysis of ethical practices between undergraduate engineering students at our university and peers in partnering countries. Three major goals of the project are to develop a readily accessible website for student interactions, to develop partnerships with global participants, and to develop machine-based tools capable of identifying major topics in student contributions to the website and analyzing characteristics of students' ethical reasoning. An undergraduate ethics course for engineering majors and the website http://reflectivechoices.ttu.edu are currently the primary channels through which this project is being developed and implemented. The results describe steps in developing the website, which is currently operational, progress developing partnerships and in recruiting participants, and an analysis and discussion of students' submissions to the website from the first several months of operation.

1.0 Introduction

The present project arose out of an interest at our university, Texas Tech, in better preparing students to communicate in a global society. This paper describes the effort that is being carried out through a multi-disciplinary collaboration with psychological sciences and engineering in the U.S. and several universities abroad. One goal is to create and populate a digital platform for the exchange of reflections on the ethics of engineering practices in the U.S. and abroad. The second goal is to develop machine-based tools to analyze the ethical reflections submitted to the website. These two goals are elaborated next.

1.1 A Platform for the Exchange of Ideas

Social media are web-based means of communication that allow individuals to share information and communicate with one another. Social media include academic platforms for connecting individuals and groups in areas of academic research and discourse, like Academia.edu https://www.academia.edu/, Github https://github.com/, LinkedIn https://www.linkedin.com/, and ResearchGate https://www.researchgate.net/. Social media allow groups and organizations to co-create, share, and discuss content on the organization's website, thereby building a sense of community, identity, and shared purpose. These virtual formats are accessible through the world wide web and thereby often cross political and geographical boundaries by users motivated in the pursuit of mutual goals and interests. There is little doubt that the nature of communication is changing with the emergence and growing influence of social media. Communication is in many ways more immediate, interactive, and more frequent. Because social media are digital and machine-based, they readily allow for storage and access to archival data from the website, providing opportunities to assess the current mindset of groups and to track changes in thinking over time.

In the internet application described here, we have added interactive technology to an undergraduate engineering ethics course at Texas Tech University. The technology is being used to connect engineering students in this course with students abroad. Course objectives are geared toward promoting discussion and learning around issues involving ethical choices facing practicing engineers in the U.S. and elsewhere. The major task is to kindle reflective analysis of present-day engineering and technology dilemmas from different perspectives – e.g., an U.S. student reflecting on a dilemma facing an engineer in India; an Indian student reflecting on an engineering decision faced by a U.S. engineer. The undergraduate engineering ethics course and the website http://reflectivechoices.ttu.edu are the primary channels through which this project is being developed and implemented. The project combines traditional pedagogical theory with cutting-edge instructional and assessment technology. The intent is to internationalize the curriculum of this course and provide an interface for university students to learn about and benefit from cultural differences associated with ethical thinking.

1.2 Machine-Based Tools to Analyze User Submissions

A premise that characterizes thinking in multiple domains is that the language that a person uses reveals much about the person. Pennebaker and King [1] proposed that "the way people talk about things reveals important information about them" (p. 1297). The linguist, Edward Sapir, believed that "language and our thought-grooves are inextricably interwoven, [and] are, in a sense, one and the same" (in [2], p. 43). Machine tools for analyzing the content of language productions are based on this premise. These machine tools operate according to a fundamental computational principle in current machine-based learning systems: *There are highly probable markers (cues, features) in the input (e.g., student essays) that characterize key constructs in the input.*

In this paper, three machine-based tools were tested for their ability to analyze the comments students posted to case studies on the website: LIWC (Linguistic Inquiry and Word Count) http://liwc.wpengine.com/, MEH (Meaning Extraction Helper) https://meh.ryanb.cc/ , and LDA (Latent Dirichlet Allocation) [3]. LIWC uses carefully crafted dictionaries to score individuals' essays in terms of up to 80 variables, including analytic thinking, confidence, openness, and emotion. MEH calculates n-grams frequencies (e.g., frequencies of single words, 2-word sequences, 3-word sequences) across multiple documents. LDA uses the document-term frequencies output of MEH in order to identify the topics in the documents (e.g., student essays) that it is analyzing.

The next sections will provide background for this project by drawing on the literature in engineering ethics, will briefly describe the development of the website and recruiting efforts, and will provide some preliminary results of the machine-based analyses of users' contributions to the website.

2.0 Background and Literature Review

One can glean some of the major themes dominating ethics instruction in the U.S. from a review of the literature. The mainstay themes include professionalism, following an

ethical code, and doing no harm [4] [5] [6]. More recent considerations of ethics have emphasized the importance of being socially aware and responsible, following a care ethic [7], and working from a perspective of empathy [8]. Recommendations in the literature run from ideas on how students learn ethics [9] [10] to effective content for classroom instruction [11] to demonstrations of how ethics can be learned and practiced in real-world contexts [12].

Globalization potentially affects the perspectives that engineers take on ethical issues. Lynn and Salzman [13] suggest that the notion of stakeholders has been a basic element of consideration in engineering ethics. Globalization has significantly changed who the stakeholders are in any given situation, and has affected affiliations and allegiances that engineers hold to a specific country and culture. According to Lynn and Salzman, attempts to preserve former U.S. domination in science and technology through nationalistic and isolationist policies are counter-productive. The goals, rather, should focus on accepting diversity in the workforce, forming collaborations with other countries, and participating in global innovations.

The notion of stakeholders runs through the book series *Engineering, Technology and Society* [12] [14] [15]. The guiding questions in the series are not only what benefits and what costs will arise from an engineering project, but whose benefits and whose costs? The focus is on the need for social justice, fairness, and equality from a global perspective in matters involving engineering decisions. Responsible and well-designed engineering projects, according to Baillie [14] are sensitive to the economic, social, and political factors at local and global levels.

3.0 Developing and Populating the Reflective Choices Website

Review in the previous section of current practical and theoretical perspectives on ethics shows both the depth and breadth of engineers' responsibilities to their profession and the communities that they serve. By what means can students be enabled to reflect on and critique the ethical issues in current engineering principles and practices? How can students exercise their ethical reasoning and voice their perspectives on current engineering ethics?

The overall principle behind the present project is to include interactive multicultural exchanges as part of ethics instruction for undergraduates. This principle is being implemented by developing an open platform for the discussion of ethical principles and practices in engineering that might not be readily available in classrooms. Rather than directly teaching ethics, the interest is to discover what students think about these issues, and how they may benefit in developing their own ethical reasoning from the sense of openness, independence, and empowerment that social media may provide. In the present context of globalization, the goal is to bring students from different cultures, orientations, and from different countries together, to share their perspectives on ethical practices.

A major challenge in creating cross-institutional discussions is incentivizing students to participate. Our approach thus far has been to contact colleagues at academic institutions in India, Ukraine, and Chile as a first step in identifying potential sources of student participants.

We have begun to develop collaborations with faculty abroad who lead ethics courses for engineering majors. Beyond students who actually contribute comments to the website, we expect a larger number of individuals who visit the website, but do not contribute to it. The results described in Section 3.2 below are consistent with that expectation.

3.1 Methods

Development and implementation of the *Reflective Choices* http://reflectivechoices.ttu.edu website began in spring of 2017 as a collaborative effort between the College of Engineering and Department of Psychological Sciences at Texas Tech University. Successfully launching the website depended on significant assistance from the Texas Tech Office of Information Technology. A senior faculty member in the College of Engineering developed the original content for the website consisting of five case studies and three featured articles (essays), related to engineering practice. This faculty member also teaches a required engineering ethics course to undergraduate engineering majors. This engineering ethics course is the primary source of U.S. participants in the website activities. A senior faculty member in Psychological Sciences assisted in the development of the website and has been responsible for the assessment of student contributions to the website. Current advisory board members are faculty representing Texas Tech University and Manipal Institute of Technology in Karnataka India.

The website was launched in September 2017. The home page and articles and case studies on the *Reflective Choices* website are open to the public.

3.2 Results

In Fall 2017, there were 293 unique persons visiting the website and 828 visits to the articles and case studies on the website. Fifty-nine individuals joined the website as registered members: one senior philosophy professor from Texas Tech (in addition to the two website developers), one faculty member from India, one from Ukraine, and one from Chile; 44 U.S. students; and 9 international students from partnering institutions. In Fall 2017, the five case studies and three featured articles were expanded through an additional featured article that was posted by a senior faculty member in philosophy. Twenty-two students commented on the case studies and articles on the website. These archival data are posted to the website.

By mid-spring of 2018, 20 additional engineering students from Indian institutes of technology joined the website as registered members, as well as four U.S. students. A case study and featured article were added to the website by Indian faculty. In this way, the website is expanding in the anticipated direction, drawing the interests of students and faculty from abroad to a common platform where ideas can be shared and exchanged with U.S. students.

3.3 Discussion

The initial phase of the project involving developing and initiating the website has been generally successful. To fully achieve the intended goals of the website, there is a need to further build partnerships. Efforts in the coming year will be to more aggressively recruit

- foreign faculty partners who teach engineering ethics, in order to develop a common

cross-cultural base for the exchange of ideas among students
- foreign students to analyze and comment on articles and case studies on the *Reflective Choices* website, in order to develop a knowledge base regarding how students abroad reason about ethical engineering practices
- U.S. and foreign faculty to author articles and case studies to post to the *Reflective Choices* website, in order to expand the corpus of informed theoretical and practical dilemmas that may face engineering students doing internships and professional engineers in daily practice.

4.0 Analyzing Comments to the Reflective Choices Website

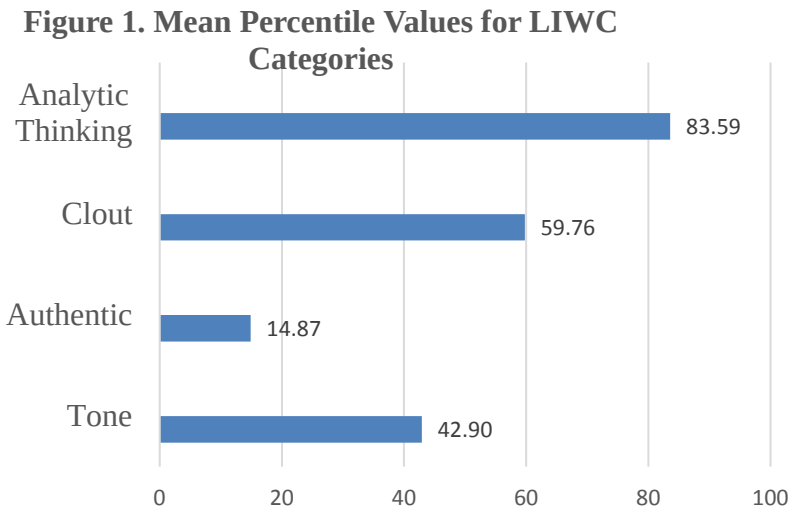
Students' current submissions to the Reflective Choices website consist of comments on articles and case studies that are available on the website. There are no definitive right and wrong answers. Instead, evaluating the submissions requires a capacity for evaluating students' analytic thinking, their confidence in their positions, and their affective and personal commitments to the topics. Course instructors are certainly capable of assessing these facets of a composition. The present analyses, however, assess the capacity of a machine to carry out comparable analyses. From a pedagogical perspective, the motivation is to enhance instructors' ability to provide students with fast and effective feedback, especially in courses like engineering ethics which may have high enrollments and which may involve a significant amount of qualitative writing.

The data consisted of 22 comments to case studies and articles that were available at end of the Fall semester and posted to the website. These 22 students each submitted a single comment. The first test used LIWC software to assess the ability of machine analysis to identify differences in students' thinking and behavioral dispositions. The second test using MEH software assessed the ability of machine analysis to discriminate the key concepts in the comments. The third test using LDA software assessed the ability of machine analysis to organize the concepts in the comments into coherent topics.

4.1. Results Applying LIWC

The analysis using LIWC quantified four variables that are defined as follows in the LIWC Manual [16]:

- **Analytic Thinking -** A high number reflects formal, logical, and hierarchical thinking; lower numbers reflect more informal, personal, here-and-now, and narrative thinking.
- **Clout -** A high number suggests that the author is speaking from the perspective of high expertise and is confident; low Clout numbers suggest a more tentative, humble, even anxious style.
- **Authentic -** A higher number is associated with a more honest, personal, and disclosing text; lower numbers suggest a more guarded, distanced form of discourse.
- **Tone** - A high number is associated with a more positive, upbeat style; a low number reveals greater anxiety, sadness, or hostility. A number around 50 suggests either a lack of emotionality or different levels of ambivalence.



Values for these variables are computed by LIWC in terms of percentiles, based on extensive prior research by Pennebaker and colleagues [17], making these variables especially attractive for small-sample analyses, as in the present case.

Figure 1 shows the mean percentile values for the four variables averaged across the corpus of students' comments. Because these are percentile scores, the scales are normed to a mean of 50. In the present sample, students clearly excelled in analytic thinking (mean 83.59) and were quite guarded and impersonal in their positions (mean 14.87). Their sense of confidence (mean 59.76) and emotionality (mean 42.90) were somewhat above and below the mean, respectively. Two sample submissions provide examples of contrasts in these variables, and provide informal evidence of the validity of the LIWC results. Student A excels in analytic thinking and is confident, but distant and not self-disclosing (e.g., through the use of pronouns like "I"), and expresses little affect regarding the issues. In contrast, Student B is lower on analytic thinking, but high on self-disclosure (readily using pronouns like "I" and "me") and affect toward the issues.

Student A: Analytic Thinking: 91; Clout: 62; Authentic: 3; Tone: 20; Word Count: 257; Words per Sentence: 33

> *Cathy is being asked by Henry and upper management to sacrifice potentially harming the environment and surrounding community in order to preserve the company's profit margins and public reputation. Although engineers are required by NSPE Code of Ethics to "act for each employer or client as faithful agents or trustees", they also shall "hold paramount the safety, health, and welfare of the public." Thus, Henry's demand that the company hold off installing new water treatment equipment until data shows that an actual violation occurs. However, should a violation occur, the company will lose the public's faith that they are acting to preserve the natural environment and their safety as well as occur more financial consequences than had they simply installed the new equipment from Cathy's first recommendation. Cathy is justified in submitting a report and stating that next quarter a violation may occur since "engineers shall be objective and truthful in professional reports, statements, or testimony." Altering her report to the State Department of Natural Resources would clearly violate this duty. Cathy is serving the prime purpose of engineers by seeking to preserve the welfare of the general public, which is more important than obeying orders from a money hungry plant manager and other members of upper management. Henry's threat that Cathy will lose her job should her job should the next quarterly report is a gross violation of the NSPE Code of Ethics, and Cathy should consider resigning from the sinking*

ship in favor of an employer who values ethics in practice, not just on paper.

Student B: Analytic Thinking: 71; Clout: 50; Authentic: 25; Tone: 80; Word Count: 201; Words per Sentence: 18

This article allowed us as engineers to better understand the importance of professionalism and how it ties in with being an ethical engineer in the workforce. Some people might not have thought that being unprofessional is also unethical. I was guilty of not knowing this myself. The article began with defining what exactly is a professional and what is ethics. Next, in the article, the author essentially explains why an ethical engineer must be professional. Lastly, he inserted The NSPE Code of Ethics to further show how they both work together to make one the best engineer that they could possibly be. I found this article to be very enlightening. Also, this article allowed me to really think about the importance of being professional and ethical at all times. The author also included the NSPE Code of Ethics to further prove the point that being professional is just as important as to be an ethical engineer. Being professional, comes from being able to handle situations in a rightful and fair manner no matter the consequences on you or your company. It is important to have something such as The NSPE Code of Ethics in place to prevent making unethical decisions.

LIWC also calculates basic parameters of texts, using a Word Count statistic, and a Words Per Sentence statistic. One question related to the LIWC measures in Figure 1 was the extent to which the strength of those variables was dependent on the length of students' submissions – i.e., are measures of analytic thinking a reflection of submission length. Another question is the extent to which the LIWC measures are associated with the complexity of students' ideas. To the extent that students qualify the topics in their sentences with adjectives, phrases, relative clauses, and other grammatical devices, the sentences will convey more complex thoughts. In order to address these questions, correlations between the LIWC variables in Figure 1, Word Count, and Words Per Sentence were calculated using Spearman's correlation statistic [18]. The correlations are shown in Table 1 and are considered significant if their *p*-value is less than .05, which is the standard cutoff in the research literature. The results show that Analytic Thinking is not significantly associated with Word Count, but is positively and significantly associated with Words Per Sentence. Simply, the length of students' submissions is not associated with analytic thinking, but the complexity of their sentences is associated with analytic thinking. Another significant correlation is between Tone and Words Per Sentence. The association is negative and significant, indicating that students who express more affect tend to use shorter sentences. The correlations with sentence complexity are supported by the negative and significant correlation of Analytic Thinking with Tone. Basically, the more Analytic a students' comments, the less emotional or affective. Overall, these patterns

Table 1. Spearman Correlations for LIWC Variables (N = 22)

	Clout	Authentic	Tone	Word Count	Words Per Sentence
Analytic	-.31	-.02	-.50 *	.40	.45 *
Clout		-.44 *	.50 *	.35	-.32
Authentic			-.19	-.14	.11
Tone				.01	-.43 *
WC					.17

* $p \leq .05$ (two-tailed)

suggest interesting research questions for future study regarding the relationship between grammatical structure and the communication of critical thinking compared to emotion or affect.

4.2. Results Applying MEH

In addition to the assessment of analytical thinking, dispositional, and affective reactions to the articles and case studies, it was important to analyze the main concepts and topics that students developed in their comments. MEH extracts word and phrase data from text data and calculates n-gram frequencies (e.g., frequencies of single words, 2-word sequences, 3-word sequences). In order to identify and extract the key concepts in a text, MEH deletes function words (e.g., *the, a, in, on*) and pronouns (e.g., *he, she, they*). In order to provide a more general description of the concepts in a text, MEH converts words to lemmas. This allows MEH to identify key concepts in the sample of texts. Table 2 shows the most common lemmas in students' comments, ordered by frequency. Nearly half of the students commented on the case study involving Hurricane Katrina, which explains the high-frequency emphasis on hurricanes, levees, and (New) Orleans. Cathy was the main protagonist in a case study that received comments from over one-quarter of the students, which explains the high frequency of that name.

Table 2. Frequency of Occurrence of Concepts in Students' Comments

Concept	Total_Frequency
engineer	65
Cathy	31
company	28
hurricane	28
ethic	22
ethical	22
report	22
system	20
disaster	19
levee	19
Orlean	19
public	19
people	18
professional	18
code	17
work	17
article	16
flood	16
Katrina	15
sure	15
safety	15
standard	14
future	14
design	14
project	14
natural	14
code ethic	14
issue	14
situation	12
great	12

4.3 Results applying LDA (Latent Dirichlet Allocation)

LDA is a software program for statistical text analysis. LDA is based on the assumption that a set of documents have a latent semantic structure that can be statistically inferred from correlations between words, across a sample of documents. LDA uses a document-term matrix that is generated by MEH in order to identify topics across a sample of written texts. Technically, a *topic* is a set of words that occurs consistently across a sample of texts in a particular context. LDA was originally developed by Blei, Ng, and Jordan [3] and has generated many computational variations. LDA is being applied extensively in marketing analyses, but less so on open-ended text data like those analyzed here.

The concepts associated with three main topics that LDA identified across the corpus of students' comments are shown in Table 3 along with their weights, expressed as probabilities. Topic 2 captures the fact that nine of the students' commented on the case study involving

Hurricane Katrina, and therefore that topic was highly represented in the comments overall. The other two topics focus on the ethical standards to which companies are held (Topic 1), and on the ethical code to which engineers are held (Topic 3).

These results provide some preliminary evidence that LDA is able to extract the characteristic topics across a corpus of student submissions. In order to build a more detailed conceptual structure of students' reasoning, the LDA topic concepts could potentially be used to re-construct students' submissions in linked conceptual networks. Exploration of that possibility awaits future work. Overall, LDA may be able to provide a means of reliably tracking changes in students' ethical focus and reasoning across a semester, as well as in longitudinal analyses over longer periods of time.

5. Conclusions

The Reflective Choices website http://reflectivechoices.ttu.edu provides new directions for expanding instruction in engineering ethics. The analytic tools presented here provide significant resources to faculty and students to analyze the cognitive, semantic, and affective elements in the ethical reflections. The combination of archival digital data and machine tools holds the promise of the ability to analyze students' ethical thinking over time.

Table 3. Main Topics in Students' Comments with Most Closely Related Concepts and Probabilities (Prob) Associated with Concepts

Topic 1: Ethics and Company Standards		Topic 2: Engineers and the Katrina Disaster		Topic 3: Engineers and an Ethical Professional Code of Public Safety	
Concept	Prob	Concept	Prob	Concept	Prob
company	.047	engineer	.046	engineer	.055
ethical	.037	hurricane	.043	Cathy	.049
standard	.024	disaster	.029	report	.035
future	.024	levee	.029	ethic	.031
situation	.020	Orlean	.029	public	.030
great	.020	system	.028	professional	.028
change	.019	work	.025	code	.027
order	.017	flood	.025	safety	.024
time	.017	Katrina	.023	issue	.022
job	.017	design	.022	plant	.019

Goals for the project going forward are to increase foreign faculty and student participation in *Reflective Choices,* and to further develop and apply machine-based tools for the analysis of students' website submissions. Analytic tools can aid in determining the extent to which engineering students are tuned into the principles and practices of ethical engineering, as expressed and advocated in the current literature on engineering education in ethics. In a related

project [19], we are developing machine-based tools to aid students in improving their communication skills. Offering these tools to website participants may provide an added incentive to participate in the online submissions, especially for foreign students who may be concerned with the mechanics of good writing.

Finally, for this project to succeed, there is a need to develop collaborations with faculty at universities outside the U.S. At the same time, we welcome and encourage contributions from U.S. faculty that discuss ethical theory, ethical dilemmas, and ethics in professional practice. Information on how to submit an article can be found at http://reflectivechoices.ttu.edu.

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