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Using the Web to Develop Global Ethical 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 ethical behavior. A basic instructional challenge is developing the ability of students to understand ethical practice and to facilitate discussion of ethical issues across regional and cultural boundaries. The present project seeks to facilitate discussion and analysis of ethical practices of undergraduate engineering students at our university, Texas Tech, and peers at universities in Ukraine and India, our partnering countries. An undergraduate ethics course for engineering majors and the website https://EthicalEngineer.ttu.edu are currently the primary channels through which this project is being developed and implemented. The paper describes i) steps in developing the website, which is currently operational, ii) progress developing partnerships and recruiting participants, and iii) results from preliminary tests of machine-assisted methods for analyzing students' submissions to the website. The Ethical Engineer is an emerging web-based innovation for facilitating cross-cultural discourse in engineering ethics.

Key words: Ethics; Social Responsibility; Critical Thinking; Written Communication; Content Analysis; Individual Assessment Tools

INTRODUCTION

Engineering is a highly regarded profession whose practitioners are expected to act with honesty and integrity, and to conduct themselves ethically in their professional work. In 1996-97, only about 27% of accredited engineering programs in the U.S. required all engineering students to take an engineering ethics or ethics-related course (Stephan, 1999). In that period, over 75% of engineering graduates obtained degrees from institutions that did not require exposure to ethics. In more recent times, ethics has become a fundamental topic in engineering education. In the U.S., an ethics requirement has been articulated and enforced. According to the U.S. accrediting board, ABET, engineering students should gain "an understanding of professional, ethical, legal, security and social issues and responsibilities"(www.abet.org) associated with being an engineer.

The rise in attention to engineering ethics has coincided with the globalization of engineering practice: "Ethical practice in engineering is critical for ensuring public trust in the field and in its practitioners, especially as engineers increasingly tackle international and socially complex problems that combine technical and ethical challenges" (Infusing Ethics Selection Committee, 2016, p. ix). The importance of global perspectives and skills and the urgency of incorporating them into engineering curricula was acknowledged over a decade ago at a national summit on educating students as global citizens (Grandin & Hirleman, 2009). According to U.S. academic and industry leaders, global competency includes the ability to deal effectively with ethical issues that arise due to cultural and national differences (Parkinson, 2009). An understanding of ethical differences begins in the classroom through exposure to national and cultural differences in engineering practices, and developing an ability to understand and respect perspectives different from one's own (Downey et al., 2006).

In this paper we describe an instructional implementation that expands on a traditional undergraduate engineering ethics course with three goals:

1. developing and launching a website open to students globally https://EthicalEngineer.ttu.edu
2. working with international partners to involve their students on the website
3. identifying and testing reliable machine-assisted methods for assessment and immediate student feedback.

In summary, through the present project we are extending the discussion of global ethics beyond students in a classroom, forming a network of international partners to expand the scope of the website and student participation, and developing the means of offering students a richer learning experience through automatic machine-based methods. These points are developed in more detail to follow.

BACKGROUND

Harris et al. (1996) suggest that we have little to teach students about ordinary morality. As young children, we already know that it is wrong to lie, to break promises, to cheat, to steal, and to kill. However, professional ethics is different. It relates to the professional behaviors expected of all members of the group. For Harris et al., ethics is tied closely to engineering practice: "Engineering ethics is part of thinking like an engineer" (p. 93). Haws (2001) proposes that engineering students need to gain "access to the common vocabulary of ethical articulation" and to "formulate and defend their personal resolution to the kinds of ethical dilemmas encountered by engineers" (p. 223). Students need to develop the "ability to reason through their own values, and select ethically appropriate courses of action" (p. 224).

An effective way to develop engineering ethics is through discourse, by giving students a chance "to make ethical judgments, explain them, and compare them with those other students make" (Harris et al., p. 94). Loui (2005) found that the two most influential activities in the ethics course he taught were the analysis of everyday scenarios and cases like the Challenger disaster, and the exposure to diverse perspectives about moral questions and problems. In considering objectives for engineering ethics instruction, Pfatteicher (2001) discourages giving students "firm answers" to ethical questions, but rather advocates developing students' analytical skills by encouraging them "to explore, define, and defend what it means to be an 'ethical engineer'" (p. 138). Further, in Pfatteicher's view, engineering students should be exposed to ambiguity, wrestle with uncertainty, and accept that there are not neatly defined answers to many problems. Cultural variation should be used "to spur study, investigation, and exploration" (pp. 140–141) of differences in ethical values.

The provisional thesis in the present work is that technology can assist in extending the impact of course instruction by connecting students from different cultural backgrounds and providing them with a means of verbalizing their perspectives on ethical issues. Evidence in support of, or in opposition to, this proposition will emerge over time as we engage students and probe their experiences when using instructional technologies.

The course innovation described here is a website https://EthicalEngineer.ttu.edu with associated assessment and feedback capabilities. The rationale and motivation for developing the website draws on recommendations in the engineering ethics literature to give students a voice, that is, to create contexts in which they can articulate their views on ethical issues and have opportunities to compare their views to those of other students (Harris, et al., 1996). Major websites for engineering ethics are currently accessible through the Online Ethics Center for Engineering and Science (https://www.onlineethics.org/) and the Center for the Study of Ethics in the Professions (http://ethics.iit.edu/). However, we are not aware of any websites that are attempting to create a cross-cultural exchange of student comments on ethics, like the Ethical Engineer.

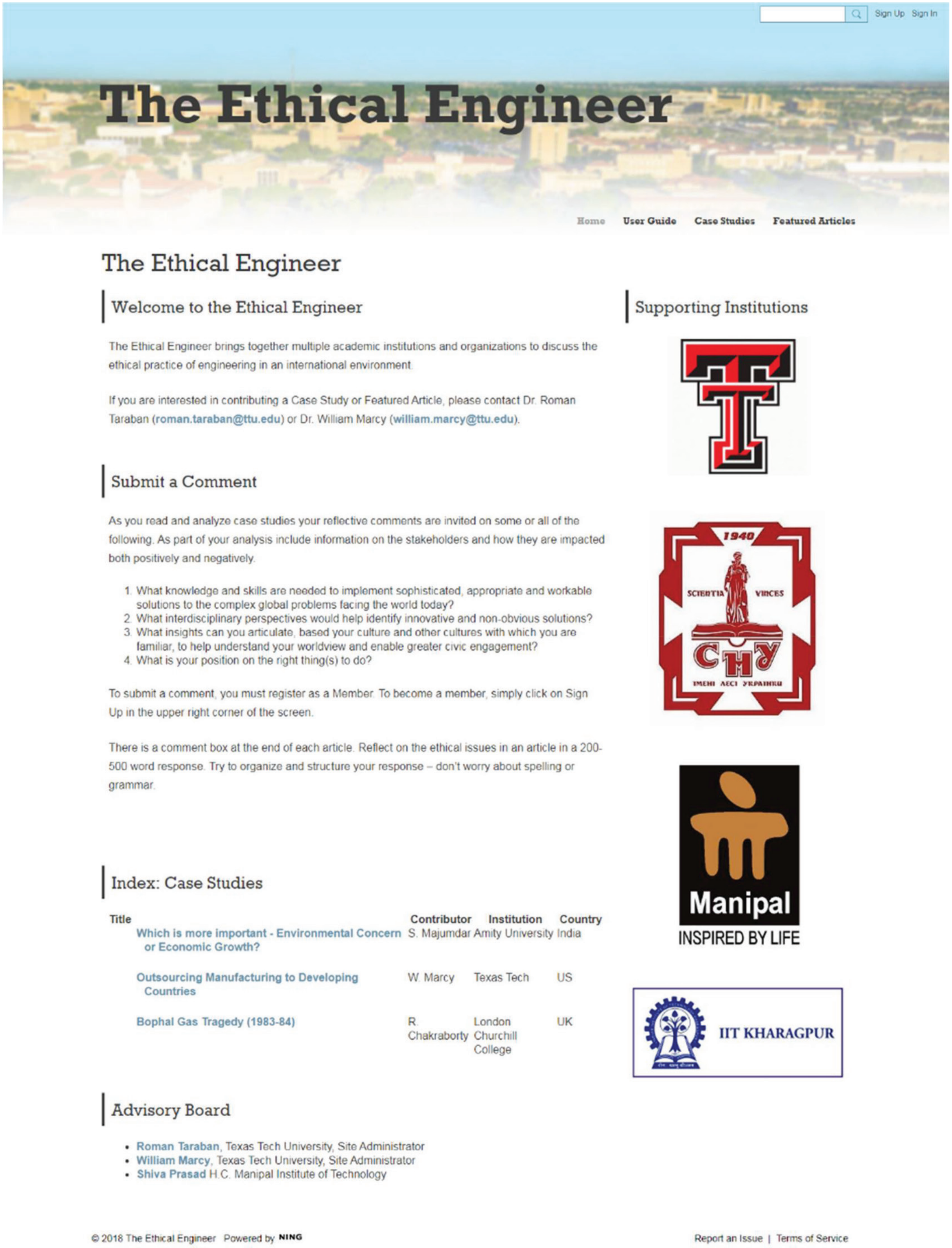

Figure 1. Website Home Page.

INSTRUCTIONAL CONTEXT

The website (see Figure 1) is a component of a sophomore-level course, ENGR 2392, Engineering Ethics and Its Impact on Society, that is required of most engineering majors at our university. This course develops ethical reasoning through an introduction to ethical theories and contemporary ethical issues in engineering, technology and society. Course materials and assignments consider *intuitionism*, which is a person's intuitive reaction to ethical issues, three ethical theories – i.e., *utilitarianism, respect for persons*, and *virtue ethics* – and the National Society of Professional Engineers Code of Ethics. Course activities require students to analyze and respond to ethical issues in contemporary social settings involving engineering dilemmas. A major course requirement is a term paper incorporating social impact analysis (SIA), which will be described in more detail later in the section on machine-assisted methods for assessment.

IMPLEMENTATION OF THE WEBSITE

The Ethical Engineer: Making Space for Student Voices

In many ways, ENGR 2392 is a traditional engineering ethics course. However, one aspect of the course that is novel is incorporating a publicly-accessible website into the course content and activities: https://EthicalEngineer.ttu.edu. Three case studies are currently posted to the website. These case studies subsume the contexts listed in ABET Criterion 3.4 for student outcomes: "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." (https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3) The cases are: "Which Is More Important – Environmental Concern or Economic Growth?" by Dr. Sudipta Majumdar (then Amity University Kolkata, India; currently, Faculty of Management Studies, ICFAI University, Jharkhand, India), "Outsourcing Manufacturing to Developing Countries" by Dr. William Marcy (Texas Tech University, U.S.), and "Bhopal Gas Tragedy" by Dr. Rhyddhi Chakraborty (London Churchill College, UK; https://londonchurchillcollege.ac.uk/) – See Figure 2.

The website is the result of several favorable factors at Texas Tech University and beyond, the most significant factor of which has been an institutional push, and financial support, by the Center for Global Communication (CGC) to help students become global communicators. (http://www.depts.ttu.edu/globalcommunications/) The CGC is helping to break through barriers to globalizing engineering students (Grandin & Hirleman, 2009), namely, curricular

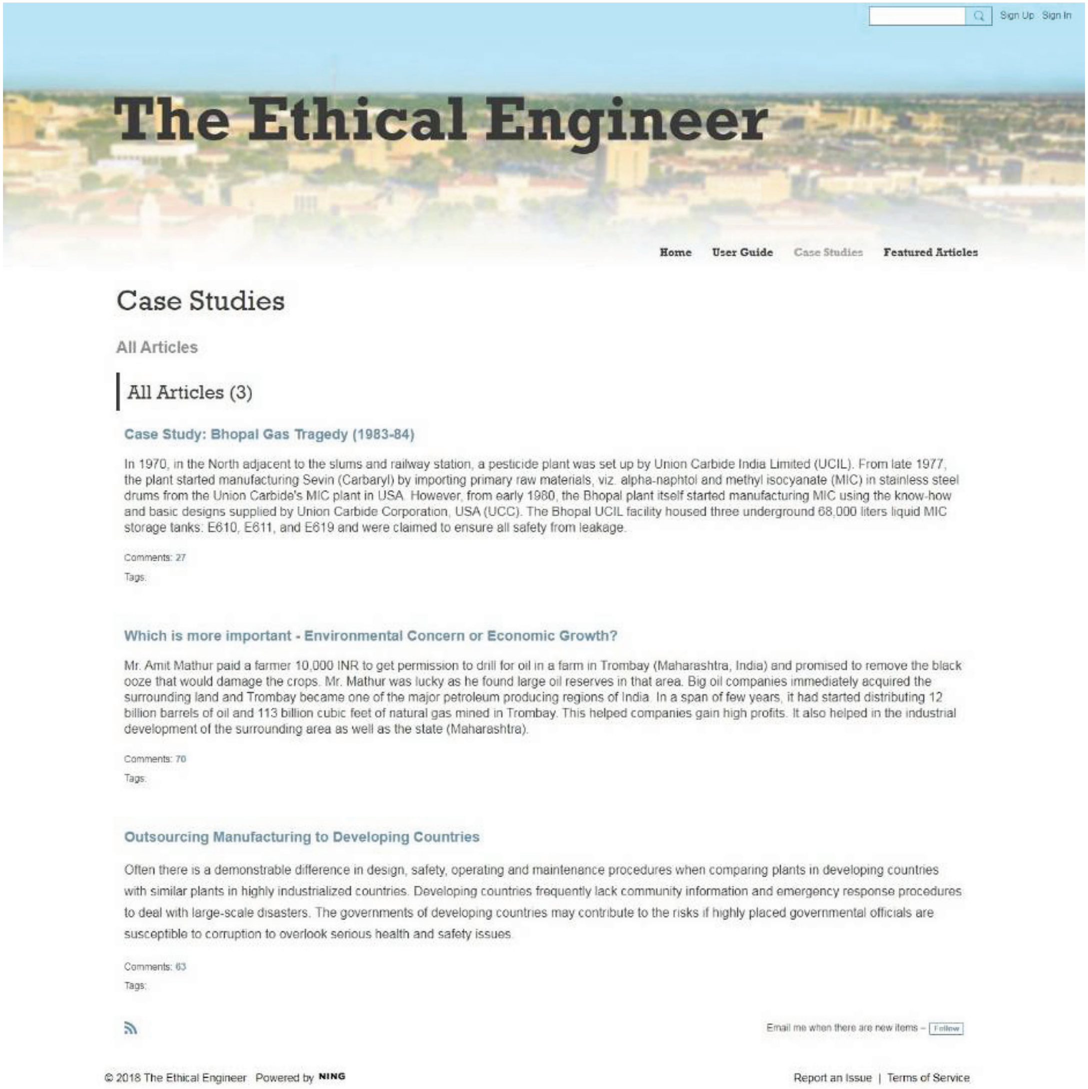

Figure 2. Lead-In Sections to Case Studies on the Website.

rigidity and lack of support for globalization from departments and colleges of engineering. Support was also received from the Office of International Affairs (http://www.depts.ttu.edu/international/) through its assistance in creating international partners, and from the Information Technology Division (http://www.depts.ttu.edu/infotech/) in its assistance in developing an open and secure website. The website is managed through interdisciplinary collaborations between the College of Engineering and Psychological Sciences at Texas Tech University, and through the participation of international partners in India at Manipal Institute of Technology (https://manipal.edu/mit.html), Amity University Kolkata (https://www.amity.edu/kolkata/), and NIT Rourkela (https://nitrkl.ac.in/); and in Ukraine at Lesya Ukrainka Eastern European National University (https://eenu.edu.ua/uk).

Worldwide Participation

The website has open access. One measure of success is the number of users – i.e., visitors. Figure 3 shows the distribution of website users by country, based on Google Analytics (https://analytics.google.com), which is a reporting utility associated with the website, and which was incorporated into the website in March 2018. Google Analytics identifies users by assigning unique IDs to clients logging in from different browsers. It then keeps track of the number of sessions originating from specific browsers. Table 1 shows the number of users and sessions by country, since the incorporation of Google Analytics.

Active participation in the website, as opposed to simply visiting the website, consists of reading and reflecting upon a case study and posting a comment. Posted comments are visible to website visitors. However, posting a comment requires a user to register as a member of the website. Website members post comments to these case studies under a pseudonym to protect

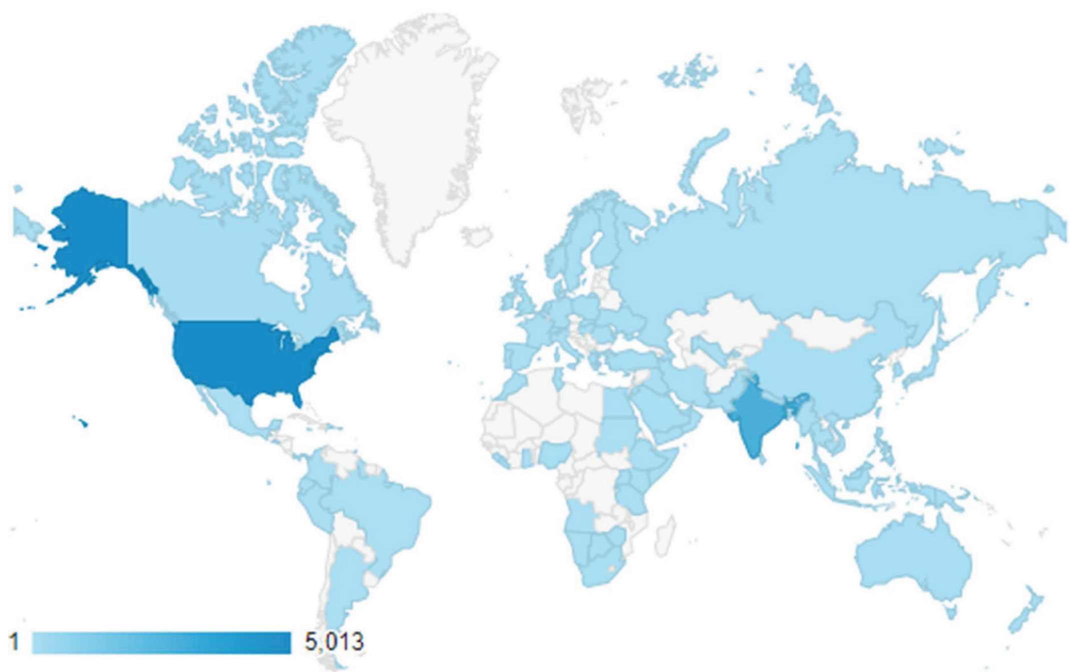

Figure 3. Distribution of Website Users March 2018 to May 2020 (retrieved from https://analytics.google.com).

Table 1. Number of Users and Sessions by Country, March 2018 to May 2020 (retrieved from https://analytics.google.com).

Country	Users	Sessions
United States	5,013	8,031
India	2,867	4,164
Malaysia	201	263
Canada	130	156
Philippines	108	148
Pakistan	98	108
United Kingdom	77	110
Bangladesh	64	72
Australia	55	65
China	55	62
United Arab Emirates	46	52
Kenya	40	49
Sri Lanka	29	32
Singapore	28	32
Indonesia	27	34
Lebanon	26	35
Turkey	26	32
Brunei	25	45
Saudi Arabia	24	31
South Africa	24	31
Japan	21	30
Puerto Rico	19	21
Nigeria	17	23
Nepal	17	27
Ukraine	17	29
Egypt	16	17
Botswana	14	15
Ghana	13	15
Myanmar (Burma)	13	13
Ireland	11	12
Zimbabwe, Netherlands, Spain, Hong Kong, Maldives, Brazil, Germany, South Korea, Portugal, Hungary, Rwanda, Thailand, Greece, Mauritius, Belgium, Bhutan, Columbia, Kuwait, Sweden, Trinidad & Tobago, Barbados, Ethiopia, France, Iran, Italy, Jamaica, Jordan, Mexico, Sierra Leone, Iraq, Qatar, Russia, Uganda, Vietnam, Bahrain, Switzerland, Cyprus, Liberia, Morocco, Norway, Oman, Peru, Romania, Sudan, Somalia, Tanzania, Uzbekistan, Antigua & Barbuda, Angola, Argentina, Azerbaijan, Denmark, Dominican Republic, Ecuador, Finland, Guyana, Cambodia, St. Lucia, North Macedonia, Macao, Namibia, New Zealand, Panama, Papua New Guinea, Poland, Slovakia	249	346
Total	9,370	14,100

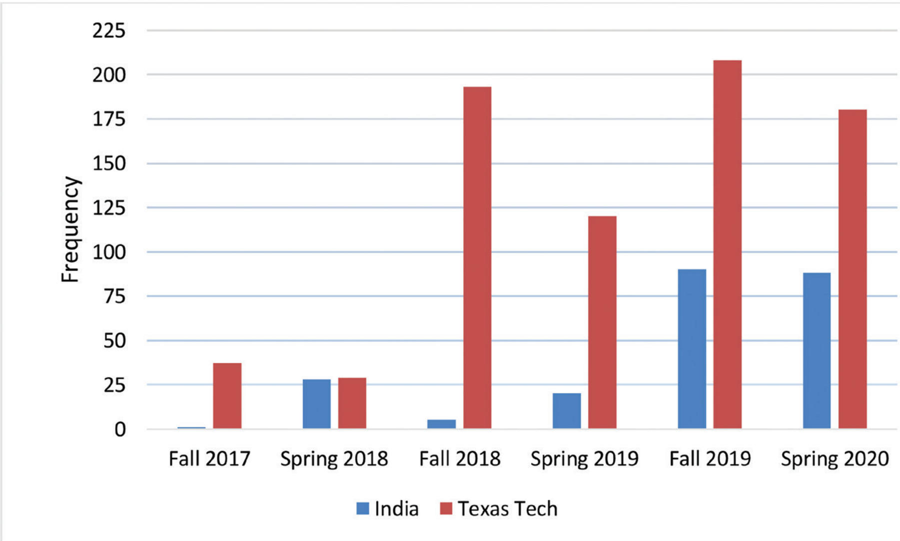

Figure 4. Number of New Registered Website Members, by Semester.

confidentiality. Figure 4 shows the growth in new members from the inception of the website in Fall 2017. It is clear that the primary membership is originating in ENGR 2392, however, there is active participation from students outside the U.S.

Figure 5 shows the number of students enrolled in ENGR 2392 and the number that contributed a comment to the website. Participation was slow in the first two semesters of implementation, but

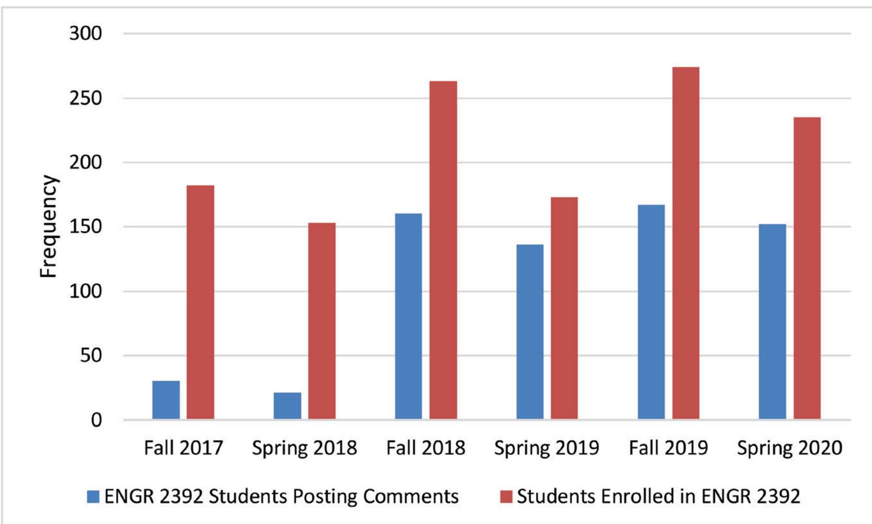

Figure 5. Number of Posted Comments and Students Enrolled in ENGR 2392.

has picked up dramatically in the latest semesters. It is important to note that students receive a homework credit (about 1.5% of their final grade) for submitting comments on a case study directly to the instructor. However, they participate on the website voluntarily. There is no extra credit for posting a comment to the website. The growing proportion of students voluntarily opting to present their views publicly satisfies, in part, our goal of bringing student voices to a global stage, and it bodes well for the future of the website.

Posting a Comment on the Website

Visitors to the website are invited to submit a comment to one of the case studies. Comments fall into five categories, which are implicit in the instructions to students on the website, as shown in the color-coded instructions below: i) stakeholders, ii) knowledge and skills required for innovative global solutions, iii) interdisciplinary innovative solutions, iv) cultural insights, and v) personal position regarding what is ethically right. (Instructions on the website are not color-coded.)

Submit a Comment

As you read and analyze case studies your reflective comments are invited on some or all of the following. As part of your analysis include information on the stakeholders and how they are impacted both positively and negatively.

1. *What knowledge and skills are needed to implement sophisticated, appropriate and workable solutions to the complex global problems facing the world today?*
2. *What interdisciplinary perspectives would help identify innovative and non-obvious solutions?*
3. *What insights can you articulate, based your culture and other cultures with which you are familiar, to help understand your worldview and enable greater civic engagement?*
4. *What is your position on the right thing(s) to do?*

These categories and associated case studies posted to the website are consistent with the focus in ABET Criterion 3.4 on "engineering solutions in global, economic, environmental, and societal contexts." Composition of the specific questions posed to students was guided by the global-communication student learning objectives of the Center for Global Communication and the instructor's learning objectives for ENGR 2392. It is important to point out that the implementation described here is not committed to specific categories or questions. Indeed, as we have developed the website since its inception in Fall 2017, we have modified the case studies and associated questions to fit the perceived needs of students and goals of the course. Other instructors, who may be interested in adopting a similar model, could readily tune their website to the specific needs of the context in which the website is implemented. For instance, the protocol could be modified to more closely reflect the rubric for assessing responses to engineering dilemmas proposed by Shuman et al. (2004) and others (Hess et al., 2014).

MACHINE-ASSISTED ASSESSMENT AND FEEDBACK

Using instructional tools that generate informal essays, like the Ethical Engineer, instructors may be inundated with submissions. For instance, in Fall 2018, 160 students submitted comments to the Ethical Engineer website, and in Spring 2019, 136 students submitted comments. Given high enrollments, it may not be possible for course instructors to provide timely feedback to submissions, if at all, and generally, immediate feedback would be more effective than delayed feedback. Indeed, delayed feedback may not have any benefit (Bitchener, 2008; Epstein & Brosvic, 2002; Epstein et al., 2002). With these issues in mind, we were motivated to seek out machine methods of providing feedback. After considering several possibilities, we settled on an application of naïve Bayes analysis. Preliminary results using naïve Bayes are discussed below, after briefly describing alternative computational approaches.

A well-known and commercialized approach to automated essay scoring (Franzke et al., 2005; Landauer et al., 2003) relies on an algorithmic method known as latent semantic analysis (LSA) (Landauer & Dumais, 1997). LSA projects the words from a submitted essay into a high-dimensional semantic database that quantifies the similarity of the submitted essay to the database. For instance, if a database codes highly frequent co-occurrences of words in a psychology text, then one can match the selection of words in a student's essay to the co-occurrence matrix of the database, in order to assess how similar the student's essay is to the database. One shortcoming of LSA is that the similarity between the target essay and database is reported in terms of vector similarity (i.e., cosine similarity) (Landauer et al., 1998), not in terms of the specific words (or lemmas) on which the similarity of essay to database is based. Other methods provide access to the most influential words used to classify essays, and may thereby provide useful information for instructors.

Another method of automated scoring uses pre-defined dictionaries (Pennebaker et al., 2015). According to this method, the software counts up the frequency of words (lemmas) that fall into specific categories, like positive emotion, cognition, biological processes, and so on. These frequencies can then be correlated with independent variables, like likelihood of academic success (Pennebaker et al., 2014; Robinson et al., 2013). The shortcoming of this method is the reliance on pre-defined dictionaries for categorical classification. Specifically, these dictionaries need to be constructed and maintained for specific contexts. If the dictionaries are not tailored to specific contexts, they are susceptible to missing relevant categorical information in a target set of essays.

The method that we are currently applying involves pre-training a machine classifier on a sample of essays and then applying the classifier to a new set of essays. The classifier gets increasingly better at its job as more and more essays are entered and can eventually provide specific feedback immediately and reliably. An advantage is that one can readily identify the words (concepts) that are most influential in the classifications. Our pilot tests were applied to students' papers from ENGR

2392 involving Social Impact Analysis (SIA). By way of a bit of background, the general purpose of SIA is to identify and analyze the positive and negative social consequences of engineering plans and projects. Students in ENGR 2392 identified and discussed a contemporary engineering technology (e.g., autonomous tractor trailers, fracking, drones). Students were required to incorporate knowledge from one or more of the ethical theories from the course into their analyses. Assessment of machine-based tools involved testing the tools' ability to accurately distinguish (classify) ethical and technical (non-ethical) statements in students' papers.

IBM Watson – Natural Language Classifier

Our initial work with machine-based classifiers tested the IBM Watson Natural Language Classifier (Watson-NLC), which is a paid service on the IBM Cloud that enables one to classify natural language texts. Given the success of IBM in implementing artificial-intelligent systems, we regarded Watson-NLC as providing a gold standard for classification. Watson-NLC learns how words relate to specific classifications. With sufficient training it can readily classify new instances. In a series of tests, we assessed Watson-NLC's ability to classify sentences from the SIA papers as related to ethics or to technical information (not-ethics).

The procedure for using Watson-NLC is straightforward. One creates a two-column comma-separated values (CSV) file, with the target sentences in one column and the classifications in the other column, as shown in the two columns in Table 2. The CSV file is used to train the classifier to discriminate ethics and not-ethics sentences. Once the classifier is trained, new sentences can be submitted to it for classification.

Table 2. Example of a Portion of a Comma-Separated Values (CSV) File for Training a Classifier Using Watson-NLC.

Example Input Sentences From Student Paper	Classifications
The fact that the United States was able to have large economic gains due to fracking made this a very viable route to phasing out coal power which is still very widely in use throughout the world.	Not Ethics
It is seen as a potential way to continue the growth in economy and electricity generation to eventually switch over to renewable resources, but for the time being has proven to not only be economically viable, but allowed the United States to gain influence over other countries who continue to develop and need new energy sources.	Not Ethics
Despite large benefits there have also been drawbacks.	Not Ethics
Possibly the largest concern about the use of fracking would be the effect it has on our fresh water supply; both contaminating it with chemicals creating more toxic water than water treatment plants can handle, and contaminating local water supplies.	Ethics
Since water is the main fluid being used in the process, this totals up to very large amounts of water being rendered unusable for drinking or farming.	Ethics

Table 3. Frequencies and Proportions of Agreement Between Watson-NLC and Human Classifiers, and Between Human Classifiers, for Ten Randomly Selected New Papers.

	Sentence Frequencies			Proportion of Agreement	
Student Paper	**Agreed**	**Disagreed**	**Total**	**Watson-Humans**	**Between Humans**
s71	65	17	82	0.79	0.87
s72	69	12	81	0.85	1.00
s73	70	13	83	0.84	0.96
s74	75	16	91	0.82	0.91
s75	53	15	68	0.78	0.98
s76	50	25	75	0.67	0.81
s77	79	11	90	0.88	0.97
s78	64	19	83	0.77	0.98
s79	97	23	120	0.81	0.96
s80	68	11	79	0.86	0.93
Average	69.00	16.20	85.20	0.81	0.94
SD	12.57	4.64	13.20	0.06	0.06

The Watson classifier is quite powerful. As an example, Table 3 shows results for training a classifier with 70 papers and testing the classifier on ten new randomly selected papers. The average percent agreement between Watson and the human classifiers was 81%, and the average initial agreement between pairs of human classifiers was 94%. Both levels of inter-rater reliability are acceptable, although the human classifiers showed more agreement.

In a second test, we were interested in Watson-NLC's ability to discriminate between kinds of ethical statements. For this test, the previously classified Ethics sentences from 40 random papers (814 sentences) were subjected to further classification into six possible classifications: 1) General Moralizing, 2) Utilitarianism, 3) Respect for Persons, 4) Virtue Ethics, 5) NSPE, 6) Unclassifiable. Only two instances were Unclassifiable, so those two sentences and the category were excluded from the analysis.

Human judges classified ethics statements into the five possible categories with 75% initial agreement. All disagreements were resolved through discussion. Twenty random papers were used to train Watson-NLC on the ethics classifications, and twenty new papers were used to test Watson-NLC. Agreement between Watson-NLC and human classifiers was 70%. Given that two humans agreed approximately 75% of the time on an initial classification, Watson-NLC was not too far off at 70% agreement. We know from other tests that Watson-NLC improves with larger training corpora. Similarly, human classifiers improve with increases in classification and resolution of differences. Therefore, use of larger corpora would presumably improve agreement.

IBM Watson-NLC versus a Naïve Bayes Classifier

Watson-NLC is closed-source software, that is, the source code is not available to users. In the following test, we compared Watson-NLC to a naïve Bayes classifier written in R code. R is an open-source language with many preprogrammed packages. The potential benefit of using a naïve Bayes classifier is that the computations are transparent to the user. The csv file used with IBM Watson-NLC constituted the input to naïve Bayes, which was implemented in R through R-Studio, using package e1071 and Laplace smoothing (https://cran.r-project.org/web/packages/naivebayes/naivebayes.pdf). Numbers, stop words (e.g., function words like *the, if, on*), and punctuations were removed, and stemming (e.g., reducing *trouble, troubles, troubling* to *troubl*) was applied. These are standard steps using naïve Bayes methods.

Table 4A summarizes the results shown in Table 3 for Watson-NLC. Table 4B shows the results using a naïve Bayes classifier over the same input data. In Table 4A, the predicted ethics sentences matched the human-rated ethics sentences in 185 out of 262 cases (22% of total sentences), and the predicted not-ethics sentences matched the human-rated not-ethics sentences in 505 out of 590 sentences (59% of total sentences), for a total accuracy rate of 81%. In Table 4B, the predicted ethics and human-rated ethics sentences match 21% of the time, and the machine-classified and human-classified not-ethics sentences match 59% of the time, for a total accuracy rate of 80%. The

Table 4A. Confusion Matrix Showing Frequencies (Percents in Parentheses) for Classification of Ten Papers (Same as those in Table 3) Using Watson-NLC.

IBM Watson-NLC Results			
	Human Classification		
Machine Classification	Ethics	Not Ethics	Row Total
Ethics	185 (.22)	85 (.10)	270
Not Ethics	77 (.09)	505 (.59)	582
Column Total	262	590	852

Table 4B. Confusion Matrix Showing Frequencies (Percents in Parentheses) for Classification of Ten Papers (Same as those in Table 3) Using a Naïve Bayes Classifier.

Naïve Bayes Results			
	Human Classification		
Machine Classification	Ethics	Not Ethics	Row Total
Ethics	179 (.21)	78 (.09)	257
Not Ethics	92 (.11)	503 (.59)	595
Column Total	271	581	852

results are nearly identical, suggesting that machine classification with open-source code is comparable to Watson-NLC, for present applications. A practical advantage of open-source R code is that it is easier to interface with the website, compared to Watson-NLC, and it comes at no cost.

Text Markup as Feedback for Website Comments

We are currently testing the ability of a naïve Bayes classifier to provide feedback to students immediately after they submit comments to the Ethical Engineer website. As one example of feedback, the sentence classification output from naïve Bayes can be used to mark up students' comments. One form of text markup is to use the most probable naïve Bayes classification of each sentence (i.e., addressing Culture, Interdisciplinary, etc.) to mark up a student's submission through color coding (See Figure 6). This form of markup can provide students and instructors with immediate visual feedback regarding students' coverage of the recommended points to address, as indicated in the website instructions for submitting a comment (shown earlier). The color-coded markup would immediately show how comments targeting specific topics (e.g. Culture, Interdisciplinary) are distributed within the essay. Further, the color coding of sentences in a student's comment can be supplemented by the Shiny application http://shiny.rstudio.com/ in R Studio with a bar graph and radar graph (See Figure 6), providing students with additional information about coverage of the points targeted in the instructions for submitting a comment.

We plan to test this form of feedback on the Ethical Engineer website in Fall 2020. Feedback could be binary (Yes/No), indicating to students whether they addressed a specific targeted issue. Feedback could also be on a gradient, depending on how well the comments addressed the targeted

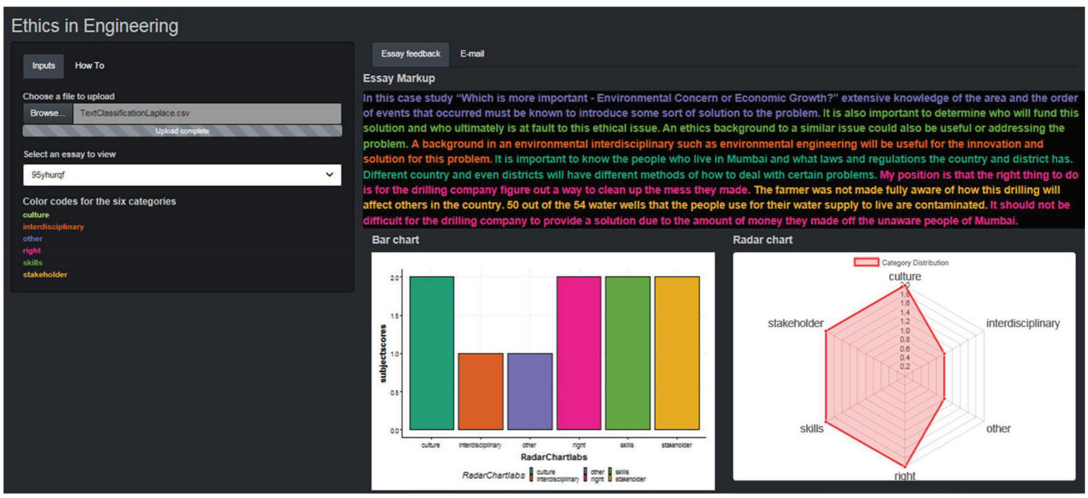

Figure 6. Example of Feedback Showing Most Likely Classifications of Sentences Based on Naïve Bayes Output and Mark Up Using Shiny App.

issues. This finer-grained level of feedback is possible using a Bayesian classifier because its output is in terms of probabilities that comments fit a classification, not simply in terms of a binary classification. Thus, one can establish cutoff values for Yes/No decisions or provide more fine-grained feedback based on the Bayesian probabilities.

General Method for Developing a Classifier for Website Feedback

Success in our ongoing work allows us to suggest a general method for combining traditional methods of classification (e.g. Hsieh & Shannon, 2005) with emerging methods of machine analysis. The overall goal is to provide students with constructive feedback related to specific prompts that an instructor could provide, for example, as in the instructions for submitting a comment to the website presented earlier. Our results so far suggest that using human classifiers to train Bayesian algorithms for classifications related to specific topical questions is currently the most promising method for providing large numbers of students with immediate feedback on their work. The general approach can be summarized as follows:

1. Select a sample of student submissions.
2. Use multiple human raters to classify sentences using a rubric developed for the writing assignment.
3. Train a classifier.
4. Apply computer code to parse new submissions into sentences.
5. Automatically classify sentences as relating to one of the classification categories.
6. Generate a weighted score for each category, based on the frequency and/or quality of sentences fitting each category.
7. Use the scores to inform students on the extent to which they adequately addressed the target issues.

LIMITATIONS AND FUTURE WORK

The Ethical Engineer project has overcome a number of significant hurdles as a course teaching tool, including developing a website that encourages global participation in a technically and individually secure manner, and aligning user activity with a number of academic, professional, and global issues related to ethical engineering practice. An ongoing challenge and current limitation to the website is attracting wider participation of engineering students representing other cultures and countries. In response to this challenge, we will continue to develop our partnerships in order to broaden the scope and diversity of comments submitted to the website. Further, we have identified and tested the means of providing simple feedback to students, indicating to them that they covered the relevant issues and, perhaps, the degree to which they covered those issues. However, it will still require human judgment to provide students with feedback on the depth, insights, empathy, and creativity of their responses. This is a machine-processing challenge that still remains. Finally, it was pointed out to us by a reviewer of an earlier version of this paper that there is no provision on the website for reactions to posted comments. We recognized this as a serious oversight, and we have revised the website to allow individuals to post reactions to comments.

CONCLUSIONS

The focus of the present web-based instructional tool is to provide engineering students with an outlet in which to reflect on ethical issues. As Haws (2001) has suggested, students need to learn the vocabulary of ethics, they need opportunities to speak to ethical issues, and they need to know what other students think about these issues. The website builds on ethical case studies, which have been found to be an effective instructional format (Loui, 2005; Pfatteicher, 2001).

The instructional and assessment paradigm suggested here provides an open-ended platform for instructors. Indeed, in the brief time that we have been developing the web platform, we have tried out a range of case studies and, importantly, variations of the guidance provided to students for submitting comments. Coincident with the affordances provided instructors to tailor content and writing requirements are the reliable and powerful methods that we describe here for developing and providing feedback to students on their contributions.

Students need a knowledge base on which to ground their ethical thinking. Programs like those focusing on Reflexive Principlism (Beever & Brightman, 2016) are well motivated by the philosophical and pedagogical literature. Calls for more attention to care (Warford, 2018), empathy (Hess et al., 2017), and inclusiveness (Eddington et al., 2018), among other topics, are also warranted. The present website is configured to the goal of developing global communication skills within a traditional engineering ethics course. However, the pedagogical, multi-media, and machine-assessment principles can be adapted to other content and activities.

Our ability as faculty to launch a website and to achieve the goals that motivated it depended on strong administrative and technical support locally, and committed support from our international partners. Present successes and future prospects have critically depended on a strong and consistent commitment from an engineering ethics instructor and researcher (WMM). Discovering what works best will take time.

U.S., Canadian, and Russian astronauts spent Christmas 2018 orbiting in the International Space Station (https://blogs.nasa.gov/spacestation/2018/12/21/international-crew-to-ring-in-christmas-50-years-after-first-moon-trip/). At the same time, Vladimir Putin took national pride in developing a nuclear missile that is "invulnerable" to U.S. defenses (https://www.irishtimes.com/news/world/europe/bullish-putin-unveils-invulnerable-nuclear-weapon-1.3742365). Efforts to connect students' voices across cultural and national boundaries on ethical issues are as important as ever.

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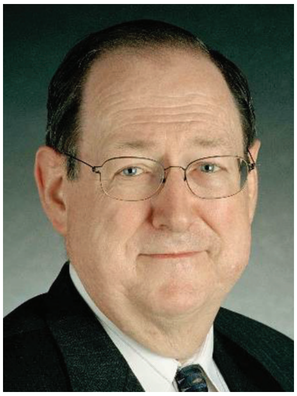

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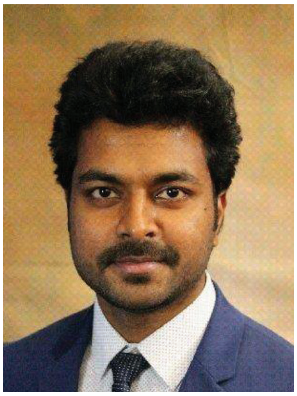

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