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A Module on Ethics and Social Implications of Computing for Introductory Engineering Computing Courses

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Introduction

Documentaries like *The Social Dilemma* [1] and *Coded Bias* [2] present ethical and social implications of computing to the public, increasing awareness of these critical concerns. The latter features several researchers who have been investigating algorithmic bias and how different groups of people (with respect to race, class, and gender) are harmed more by artificial intelligence and technology. Given these impacts on society and considering that computing and engineering continue to merge as advanced technologies are developed, a need has been established for ethical reasoning in technical curricula [3- 6]. Previous work presented a collaborative lesson plan that integrated science fiction and principles of ethical engineering design in an introductory engineering computing course [7], which could be used and adapted by engineering and computer science faculty.

Given established needs to diversify the technical and engineering workforce as well as initiatives to mitigate biases in algorithms and technology, the need for diversity, equity, and inclusion in computing education [8 - 9] and engineering education [10,11] have been established. This has resulted in the development of the Cultural Competence in Computing Program [8] and equity-centered engineering education initiatives [10,11]. Moreover, engineering deans from universities in the Big Ten Academic Alliance recently submitted an open letter of support to the Accreditation Board for Engineering and Technology, Inc. (ABET) regarding the addition of diversity, equity, and inclusion requirements to its accreditation process [12].

This work provides a first step towards addressing ethics and cultural/social implications in an introductory engineering computing course. Specifically, it expands upon the previously developed module [7] by incorporating ethical theories, group discussions via case studies, and interactive activities to cultivate student awareness of current social and cultural implications of computing. The module remains rooted in its collaborative and interdisciplinary approach, as the lectures are taught by an engineering professor (instructor of record for the computing course), a philosophy professor, and a librarian specializing in digital liberal arts. The culminating activity for this module, a podcast presentation, was revised to ensure these new topics were addressed in student presentations. Assignments were assessed using rubrics, developed by engineering faculty at the institution, for the following ABET Student Outcomes [13]: 2 (Design), 3 (Communication), 4 (Ethics), and 7 (New Knowledge). In addition, students completed surveys before and after completing the module, to provide the instructors with insight on student attitudes and opinions concerning the roles and responsibilities of engineers with respect to computing ethics. The post-module survey contained additional questions to capture students' understanding of computing ethics and cultural/social implications of computing.

Course structure and lesson plan overview

Prior work [7], piloted in Fall 2020, presented a module consisting of three consecutive 80-minute lecture periods. Students watched the 45-minute episode of Doctor Who titled *Oxygen* [14] and answered guided questions prior to attending the first lecture. However, when this approach was repeated in Spring 2021, some assignments reflected a misunderstanding of events in the episode and connections to the course concepts. Also, some students did not understand why science fiction was being used as a means to teach ethics in the course. To provide further clarity and address these concerns, the module was revamped to include one additional lecture period. Lectures were conducted in the following order: Introduction (watch episode and discuss connections to computing), Ethics in Engineering Computing, Social and Cultural Implications of Computing, and Introduction to Podcasting (Science Communication). The first and third lectures were taught by the engineering computing professor. The second lecture was taught by the philosophy professor and the fourth lecture was taught by the digital liberal arts librarian. This approach was piloted in Fall 2021 with all three sections of Engineering Computing.

Introduction (Lecture 1): The lecture began with a brief discussion on different methods to teach ethics in undergraduate courses and the case for using science fiction as a hook was made by referencing recent literature on its application to ethics across disciplines [15 - 16], including engineering and computer science [3 - 5, 17 - 18]. Students then screened the episode. A brief synopsis of it is as follows. The characters are on a futuristic mining station whose owners have monetized access to oxygen. To do their jobs, miners must purchase smart robotic spacesuits to access this oxygen; and as their oxygen levels deplete workers become more inefficient. Once enough workers become inefficient, the company causes the suits to deactivate, turning its user into a zombie. While watching the television program, students completed the guided questions individually. The final 15-20 minutes of the lecture period were used to engage the entire class in a discussion to share their answers and ask additional questions. The engineering instructor asked students to share the first thing that they think of when they hear the word “robot.” The results of these associations would be discussed in the lecture on social and cultural implications of engineering computing (Lecture 3).

Ethics in Engineering Computing (Lecture 2): The pre-lecture assignment was to review the IEEE Code of Ethics [19] and the ACM Code of Ethics [20] and compare and contrast the two codes. The first part of this lecture focused on the importance of studying ethics, the source(s) of ethical decision-making (e.g. ethical intuitions and theories), key ‘levels’ within the discipline of ethics (meta-ethics, normative ethics, and descriptive ethics), and main ethical theories (Consequentialism, Deontology, and Virtue Ethics). Students were then asked to draw connections between this content and the *Doctor Who* episode (e.g., ‘which ethical theory do you think each of the characters in the episode was most closely following?’). The second part of the lecture focused on the IEEE and ACM codes of ethics and how to understand the importance of ethical learning in connection to these codes. For example, it addressed the importance of using ethical theories to clarify vagueness in some of the principles (e.g. ‘avoid harm’), think through the scope of some principles (e.g. ‘honor confidentiality’), and address potential conflicts between principles (e.g. instances in which a duty to ‘honor confidentiality’ conflicts with one to

‘avoid harm’). Finally, students were then asked to apply their learning so far to a couple of ethical case studies or scenarios obtained from the Markkula Center for Applied Ethics [21], including that presented in the *Doctor Who* episode. Students were asked to specifically focus on the issues of ‘scarce resources’ and ‘narrowly-defined purposes’ as they were relevant to the ethical dimensions of this scenario.

Social and Cultural Implications of Computing (Lecture 3): To formally address ethical decision making with respect to the impact of engineering [computing] solutions in from a societal context (ABET Student Outcome 4) [13] and cultivate student awareness of contemporary social and cultural issues in engineering design and computing, a new lecture was added to the module. This lecture focused on students assessing their own culture, activities to foster appreciation of diversity, and furthering student knowledge of diversity, equity, and inclusion. As a pre-lecture assignment, students created a culture box, which is a collection of random objects that define one or one’s social identities [22 - 23]. Students were asked to reflect on why they selected those particular items and how those items represent who they are now. Culture box presentations served as an ice breaker for the lecture, creating an open and welcoming environment for the rest of the lecture. Due to time constraints and class sizes, students were challenged to select their top three items for presentation and were given a maximum of two minutes for their presentation. Students had the choice of presenting physical objects or a PowerPoint with pictures and quotes. The purpose of the activity was for students to cultivate an awareness of their own culture and worldview, understand their life story and who they are today, learn to appreciate diversity and other cultures (by listening to the presentations of their classmates and the instructor), and learn how culture, social norms, and history are encoded in technology. Additional reflection questions posed after this activity were:

- How do your background and experiences inform your choices, especially about technology, computing, and engineering design?
- How do your background and experiences inform how you interpret the decisions others make, especially about technology, computing, and engineering design?

Next, there was a short discussion on the two main methods to program computers using algorithms: sending step by step instructions via a program (how they are taught in class) and sending the computer data and training it to perform tasks given that data set (artificial intelligence). To provide students with further context on the latter, since it is not a topic covered in the introductory course, students conducted an interactive activity using Google™ Image Search. Students typed the word “engineer” into the search bar and commented on the images they most frequently saw in the results. Students were also asked to reflect on whether or not they saw themselves or their engineering concentration represented in those image results. This led to a discussion on how the algorithm was likely designed to reflect what the developers’ associations as to what engineers look like and the type of work they perform. This discussion also covered explicit and implicit attitudes and stereotypes [24], and how they may contribute to algorithmic bias in current technology. To further illustrate these ideas and apply them to computing, students were asked to search for images of robots. The instructor presented a slide with images composed of the students’ associations with the word “robots”, as mentioned during

Lecture 1. Students compared what they noted in the online image search results to the slide prepared by the instructor. The "image results" based on class association not only included industrial and commercial robots, but also robots from popular culture (movies and dance styles). It was noted that the images in the slide had more breadth as to what was considered a robot, compared to the Google™ Image search. The instructor noted that this breadth in associations was likely due to the diversity in experiences of the students in the classroom, compared to the algorithm developers.

Shifting the conversation to the *Doctor Who* episode and its connection to contemporary social and cultural implications of computing, excerpts from *Race after Technology* (Benjamin) [25], *Automating Inequality* (Eubanks) [26], and *Algorithms of Oppression* (Noble) [27] were presented. These books were referenced due to their selection for a book club led by the institution's Data Analytics and Science Working Group. These works present critical perspectives of researchers who have been exploring issues in technology and how race, class, and gender are not only impacted by technology development, but also by who gets selected by companies to create technology.

Robotics and Social/Cultural Implications: Students learned that robots are typically used for the 3Ds: dull, dirty, and dangerous tasks. Connecting these ideas with those presented in Benjamin's work [25], students also learned that robots represent a way to discuss dehumanization- they can be controlled and are considered disposable. For further discussion, students were asked the following:

- How were the miners controlled by the company?
- How were the miners dehumanized by the company?
- How did the company treat the miners as if they were disposable?
- How did the company and the suits treat the miners when their oxygen levels reached critically low levels?

Additional real-world engineering examples from Benjamin's work [25] were discussed, to provide students with a contemporary context of these implications due to race and ethnicity.

Technology and its Distribution Across Socioeconomic Class: Special emphasis was placed on socioeconomic status, connecting ideas from Eubanks' work [26] to the experiences of the miners in the *Doctor Who* episode. An example from the book was also discussed to provide students with a contemporary context for algorithmic bias due to socioeconomic class.

Lack of Government Regulations for Algorithms and Bias in Search Engines: Noble's work [27] was introduced to discuss the need for public policy to mitigate algorithmic bias. Since algorithmic bias from search engines was not featured in the *Doctor Who* episode, the interactive

image search activity was created to teach students about Noble's work on search engines and how algorithmic bias in search engine design can negatively impact various social groups.

After presenting these critical concerns, there was some discussion on current ways researchers and technologists are mitigating algorithmic bias. For this portion of the lecture, design justice [25, 28] and algorithmic accountability [25, 29] were addressed. The lecture concluded with the presentation of the "Oath of Non-Harm for an Age of Big Data", developed by Eubanks [26].

Introduction to Podcasting (Science Communication, Lecture 4): Students completed a pre-lecture assignment, which entailed listening to two short podcasts and answering guided questions about what they learned, what was interesting and what was disinteresting. This lecture, taught by one of the campus librarians, began with a class discussion around the short podcasts the students listened to prior to class. With a think-pair-share exercise, students first were challenged to reflect on three primary questions:

1) What did you like/dislike about the podcasts listened to for class today?

2) How did they (podcasters) make it engaging (or not) to listen to?

3) What characteristics can you emulate in your podcast?

Students were then asked to discuss their thoughts on these three questions with someone nearby and then we reflected upon answers as a group. Through this exercise, students began to engage in best practices of podcasting and were encouraged to think of themselves as a consumer of information [30, 31]. From there, five best practices of podcasting were presented and elaborated on in the lecture. Students were encouraged to provide examples of how they had or had not seen these best practices done in their homework assignment. This conversation was followed up by introducing students to campus technology and support resources. Students were encouraged to take advantage of library technology and support resources to ensure that their project was successful. Next, podcast formatting options, project management suggestions, and copyright law for finding outside content were discussed in detail. This lecture ended with tutorials of the softwares Audacity and Garageband for the creation of podcasts [32].

Podcasting and Science Communication Skills

As discussed in previous work [7], the culminating assignment for the module is a student developed podcast. Briefly, students had the opportunity to work alone or in groups of no more than three to create six to eight minute podcasts discussing the ethical issues in the *Doctor Who* episode, with respect to at least 3 principles in the ACM Code of Ethics. In addition, students proposed three alternative coding or design solutions for the smartsuits, to mitigate the violations to the Code of Ethics. Students also identified and explained instances of algorithmic bias or social implications of computing in the original design of the smart suits and addressed how their solution minimized these instances. To prepare for the podcast, students completed four outlines, each addressing a different component of the podcast. The objective of the outlines was for

students to think through the project and work on the assignment in small chunks. The engineering instructor provided feedback on the outlines, which was also a way to reinforce material and concepts taught in the module. The last lecture for the course was used as a free period to work on the podcast projects. The engineering professor and the librarian used the class periods as open student hours to clarify material or project instructions and troubleshoot technical issues with podcast recording or submission to the JSTOR Forum.

Assessment

The final project grade was based on the pre-lecture assignments, the podcast outlines, and the submitted podcast. The submitted podcast was graded according to the rubrics, developed by the institution's Engineering Department, for ABET Student Outcomes: 2 (Design), 3 (Communication), 4 (Ethics), and 7 (New Knowledge). Specifically, the podcast discussion on the redesign of the smart suits was assessed using Outcome 2. The discussion on ethical violations and the mitigation of those violations was assessed with Outcome 4. In addition to the lecture slides, students were provided with excerpts from texts referenced during Lecture 4 [25 - 27, 29]. Students could also conduct their own research to supplement the lecture notes. The ability to synthesize these sources to address algorithmic bias and social implications of computing with respect to their design approach was assessed with Outcome 7. In alignment with the introductory ethics assignment (completed when students take Engineering Statics) and the mastery ethics assignment (upper level course in the students' engineering concentration area), the rubric for ABET Student Outcome 4 was used to assess ethical reasoning and decision making. The overall structure of the podcast and communication of ideas were assessed with the rubric for ABET Student Outcome 3, with the exclusion of Domains 1 (composure and confidence via body language) and 4 (use of visual aids), as well as a rubric provided by the librarian (which was modified by the engineering instructor, to better meet the objectives of the assignment). Students were provided with the detailed rubric when the project was assigned.

Pre and Post Module Surveys

To understand student opinions and attitudes towards ethics in computing before and after the module as well as capture the impact of the new lecture on social implications of computing, the engineering instructor conducted a study with two surveys. The pre-module survey consisted of seven statements about ethics in computing and responsibilities of engineers, to which students selected a response according to a 5-point Likert-type scale. One question asked about awareness of codes of ethics for engineering and computing professionals and was measured on a 3-point scale ("Yes", "No", "I don't know"). The post-module survey consisted of the same questions as the pre-module survey, in addition to eight questions regarding content discussed during the lectures in the module. The study was approved by the Human Subjects research Board at Hope College. Since the engineering instructor was also the principal investigator of the study, additional steps were taken to avoid the appearance of coercion.-Participants were allotted approximately one and half weeks to complete each survey and they received at least one

reminder email before each survey closed. The pre-module survey was administered about a week and a half prior to Lecture 1; and the post-module survey was administered about a week after Lecture 4. The campus data center administered the surveys and maintained the study data during the semester, The principal investigator/engineering instructor was not provided with the deidentified survey data until after final course grades were submitted. Students who enrolled in the study were awarded extra credit on the podcast assignment. To provide an alternative for students who were interested in earning extra credit but did not want to enroll in the study, an engineering ethics case study was assigned. Students were given over a week to complete the assignment. Two students expressed interest in the alternative assignment, however they did not complete it.

There were three sections of Engineering Computing in Fall 2021 (all taught by the engineering instructor). A total of 41 students were enrolled in the course, across the three sections. Of those students, 21 completed the first survey. Of that number, 14 completed the second survey. The following findings reported are based on the participants who completed both surveys. Thus, the response rate was approximately 34%.

Given the small sample size and that the measures assessed with Likert-type scales represent ordinal data, nonparametric statistical tests were conducted to determine the effect of the module on student opinions on technology with narrowly defined purposes and whether engineers need to be concerned with ethics whenever they are programming. For both measures, the difference scores were approximately symmetrically distributed, as assessed by a histogram with a superimposed normal curve. A Wilcoxon signed-rank test (SPSS, IBM, Armonk, NY) showed that the module elicited a statistically significant median change in student opinion on the following statement ($z = 2.066$, $p = 0.039$): “Technology with narrowly defined purposes can lead to unintended consequences later.” Prior to the completing the module, 50% of participants responded with “Neutral”, “Disagree”, or “Strongly Disagree” to the statement; however after completing the module, those participants responded with “Agree” or “Strongly Agree,” resulting in 100% of participants selecting either response. The philosophy professor directly addressed the narrowly defined purpose of the smart suits as well as real-world examples of this situation in Lecture 2. In general, students were clear on the limitations of the suits. It is possible these science-fiction based and real-world scenarios helped students grasp this idea.

It is interesting to note that all participants either disagreed or strongly disagreed with the following statement, prior to completing the module: “When programming or computing, engineers do not need to be concerned with ethics.” However, after completing the module 69% of participants disagreed or strongly disagreed with the statement. A Wilcoxon signed-rank test showed that there was no statistically significant median change in opinion ($z = 1.14$, $p = 0.254$) on this matter after the module, compared to before the module. It is not clear what led to the change in student opinion on this matter. Moreover, prior to completing the module 29% of participants responded with “Strongly Disagree”, “Disagree”, or “Neutral” to the following prompt: “Ethics in computing is important for all engineers, not just computer engineers”. After completing the module 100% of participants strongly agreed or agreed with the statement. It is not clear why, after completing the module, participants perceived computing ethics to be

important for all engineers, but some participants indicated that engineers did not need to be concerned with ethics when programming or computing. Future work may further explore student opinions and attitudes on roles and responsibilities of different engineering disciplines, with respect to ethics, computing, and technology development.

Prior to completing the course module, about 57% of participants were aware of a code of ethics for engineering and computing professionals to guide their conduct and decision making, while 43% of participants were not sure if such a code of ethics was available. After completing the module, those who were originally unsure responded “Yes” to the prompt, resulting in 100% of the participants indicating their awareness of the codes of ethics for engineering and computing professionals. It is possible that those who originally responded “I don’t know” may not have taken Engineering Statics yet. In that course, students are first exposed to engineering ethics and codes of ethics in an introductory assignment. The ethics pre-lecture assignment entailed comparing and contrasting the IEEE and ACM Codes of Ethics, so whether students were previously exposed to professional codes of ethics or not, the module presented them with an opportunity to compare two different codes and extensively use the ACM Code of Ethics and ethical principles to guide their decision making.

Approximately 71% of the participants either agreed or strongly agreed that the ethics lecture improved their understanding of ethics. Anecdotally, during previous semesters in which different iterations of the module were included in the course, students who concurrently or previously took Engineering Statics indicated that the computing ethics module provided in-depth training in ethics, giving them a deeper understanding of the concepts. Thus, this finding is consistent with the anecdotal evidence. Moreover, approximately 93% of the participants indicated that they could identify at least one instance from current events of algorithmic bias and the groups of people negatively impacted by it. This question was only included on the post-module survey, so it is not clear what students knew about algorithmic bias and social implications prior to starting the module. Given the small sample size of the study participants as well as the class sizes in general, these findings are encouraging. They suggest that this collaborative and integrative approach may be successful in meeting the needs for addressing ethics and equity in engineering computing courses. Although this class size is typical at a small liberal arts institution, future work may seek to improve the survey response rate. This may be achieved by extending the window participants have to complete each survey and increase the number of email reminders sent to participants before the surveys close.

This work presents a module to address ethics and social/cultural implications of technology in an introductory engineering computing course. Although this module was not a standalone course in the curriculum, as recommended by Washington [8], it is a first step for addressing these topics in a standalone introductory engineering computing course. This approach may also be a viable model for faculty with limited resources and ability to create new courses in the curriculum. This work may not address all of the concerns raised regarding computing ethics, equity-centered design in engineering [10, 11], and cultural competence in computing [8, 9], but it does provide a foundation that could potentially be strengthened and reinforced in related upper level courses in an undergraduate curriculum. Future work may explore how to further

integrate these topics throughout the curriculum. For example, in Spring 2022, instead of the engineering professore providing the lecture on the social and cultural implications of computing, a sociology professor will present a lecture on race and socialization, highlighting its impact on computing. This same episode of Doctor Who has been used with the module since Fall 2020; so future work may explore other science fiction programs that can be used interchangeably to discuss the intersections of introductory computing concepts, technology, engineering design, engineering computing ethics, and social/cultural implications of computing. Science fiction may not be engaging for all students. Future work may also include clips from situational comedies that also address these themes. Moreover, "Oxygen" allows for an analysis of both social and cultural understanding of robotics and algorithmic bias with respect to class, but does not address issues of race and ethnicity. To address algorithmic bias with respect to race and ethnicity, Benjamin's work can further be discussed after viewing the "Racial Sensitivity" episode of *Better Off Ted* [33] (as discussed in [25]) or the self-titled pilot episode of *American Auto* [34]. Each episode features sensor technologies that are unable to detect dark skin tones and the consequences of these omissions in their designs.

Advice and Resources for Faculty Members

Collaboration across disciplines and resources from a campus book club were strengths of this module. It is acknowledged that not all faculty members have these same opportunities to collaborate or resources to replicate or modify this module. Therefore, access to module materials presented in this paper may be obtained by contacting the corresponding author. If access to the *Doctor Who* episode cannot be obtained via institutional resources, it may be streamed via various commercial streaming platforms. Ethics case studies, including the ones used by the philosophy professor, may be obtained from the Markkula Center for Applied Ethics [21]. For deeper discussions on Benjamin's work, Rachael Zafer created a resource with guided reading and discussion questions, which can be obtained from Benjamin's website [35]. In addition, documentaries like *The Social Dilemma* [1] and *Coded Bias* [2] may also be used to engage students. To gain a better understanding of social science topics and how they impact computing, faculty members may be interested in applying to be a Cultural Competence in Computing Fellow [36].

Conclusions

This paper builds upon previous work that presented an innovative approach to teaching ethics in an introductory engineering computing course. It leverages emerging ideas on the use of science fiction to engage students with computing ethics and introduces current research findings on cultural and social implications of technology with respect to race, gender, and class. In general, students reported having a greater understanding of ethics and expressed the ability to identify contemporary instances of algorithmic bias and the groups most negatively impacted by it. Assigning a student-developed podcast project allows for the assessment of student understanding of course content and development of skills, across four current ABET Student

Outcomes. This module now provides a first step towards addressing ethics and fostering awareness of diversity, equity, and inclusion in introductory engineering computing courses. It may be adapted to discuss these topics further in upper level courses in undergraduate engineering or computing curricula.

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