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Collaborating to Integrate Ethics in an Introductory Engineering Computing Course

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Introduction

Increasing attention, in both scholarly literature and the popular press, to the role of bias in algorithm design has highlighted the need for including ethical reasoning in technical curricula in higher education. At some institutions with technical computing curricula, the incorporation of ethics has been realized through collaborative instruction among faculty in Computer Science and Philosophy [1], [2]. Due to challenges with implementing ethics as a stand alone course, recent efforts have focused on integrating ethical reasoning in existing courses as students are learning technical concepts, to instill that ethical reasoning is needed while writing code and developing technology, instead of being an isolated activity [1], [3].

In developing a model for embedding ethics in the computer science curriculum at Harvard University, Grosz et al. [1] addressed ethics via software design and verification in introductory undergraduate programming courses. However, introductory engineering computing courses may not have these emphases and focus on using basic concepts to solve engineering-focused problems. One challenge in developing a collaborative and integrative model for engineering computing students is identifying an appropriate means to relate ethical content to technical applications that are germane to the introductory computing concepts taught in the course. Science fiction has emerged as an effective means to teach ethics to students in English [4], computer science [2], [5], [6] and engineering [2], [7] courses.

Inspired by the success of science fiction applications to ethics and integrative collaborative models for ethics in existing computing courses, this work presents a preliminary lesson plan, developed by an engineering professor and a philosophy professor at an undergraduate liberal arts institution, to introduce ethics in an introductory engineering computing course. In addition, it seeks to instill the importance of addressing ethics throughout the programming/coding process and engage students meaningfully with current trends in engineering education.

Course structure and lesson plan overview

This lesson plan was developed for an introductory computing course (Engineering Computing) for engineering students at a liberal arts institution. The course is offered each Fall and Spring semester and students typically take the course one semester during their sophomore year. In this course, students learn two programming languages/platforms: MATLAB (Mathworks, Natick,

MA)in the first half of the semester and C (via Code::Blocks) in the second half of the semester. This lesson plan, executed with a collaborative teaching approach, was piloted in Fall 2020, when only one section of the course was taught (17 students enrolled in the course). After completing the MATLAB portion of the course, one week (two 80 minute class sessions) was dedicated to discussing ethics in computing and introducing the culminating project. Students used the remainder of the semester to work on the project outside of class, with one additional class session during the last week of classes scheduled as free time to work on the project. Dedicating a week to ethics in between teaching the two languages was intentional, providing students with an opportunity to reflect on the basic computing concepts they learned in the first half and apply them to the lectures, connect them as they learned C, and apply them as they worked on the course project. This is also in accordance with previous work [1], [2] that integrates ethics in existing computing courses, emphasizing that ethics should be considered throughout the computing process and is not an afterthought.

Pre-lecture activities: Before attending the first lecture, students watched the episode "Oxygen" of the popular British science fiction television series *Doctor Who* [8]. In this episode, the Doctor and his companions travel to a space station in the future. This space station contains no oxygen, so the only way the miners can work is by purchasing robotic smart suits equipped with oxygen. Every activity performed by the miners is measured in breaths. When the miners deplete their oxygen credits and do not purchase additional credits, the suits receive messages to deactivate its organic components. Thus, the robotic suits are programmed to kill its users, rendering them in a zombie-like state, as they are more valuable to the company dead than alive at that point. This particular episode was selected for two reasons.

The first reason this episode was selected was because the programming of the smart suits could be directly related to major programming concepts (selection statements, iteration, functions/subroutines) taught in the course. For example, the programming needed for the suits to constantly track the miners' oxygen levels was connected to iteration. The suits' ability to decide which tasks to perform was related to selection statements. In addition, there is a scene near the end of the episode where the Doctor attempts to override the operating system for all suits by bypassing its subroutine. This was an opportunity to explain the difference between functions that return a result (which were the only functions students wrote in MATLAB) and subroutines (functions that do not return results, but rather execute statements), which students were exposed to in C programming. Based on this scene with the subroutine, it could be inferred that the code enabling the suits to perform different tasks were maintained in separate functions or subroutines. This was used to reiterate that computer programs should be written with modular designs, as opposed to one long script or program with many lines of code to perform multiple tasks.

This episode was also selected because the suits' ability to deactivate their wearer provided students with an ethical dilemma to discuss with respect to the design of the code/software. For an engineering student audience, it was important that the ethical dilemma be related to programming and/or technology. To focus students on the design of the technology and how it related to course concepts, students were provided with guided questions to answer while watching the episode.

Guided Questions

1. What is the significance of oxygen throughout the episode?
2. How do the robotic space suits operate?
3. Applying what you have learned in Engineering Computing so far, what scripting/programming features would you expect to see in the codes that control the operation of the space suits?

Moreover, this would better prepare students for the ethics lecture, which was geared towards how engineers could design well. Questions about engineering computing ethics and ethics in general were excluded from the list of guided questions to avoid priming the students about ethics. As a result, students only came to the lecture with their prior understanding about ethics. Currently, there is no required ethics course in the engineering curriculum. Students learn engineering ethics in Statics, which is also a sophomore level course; so students may have some exposure to engineering ethics prior to or while enrolled in Engineering Computing. However, the ethical content in the Statics course is focused on engineering applications, not computing. The Engineering Department is one of many departments at a liberal arts institution, so students may also have some prior understanding of ethics, if they previously took or were enrolled in a philosophy course while taking Engineering Computing.

Collaborative lecture (Lecture 1): This lecture was primarily developed and taught by a philosophy professor (with some assistance from an engineering professor to facilitate group discussions). The lecture briefly discussed ethics in general, codes of ethics for engineers, and made a case for why engineers need to be philosophers. Then, the rest of the lecture focused on how engineers could design well. This portion of the lecture addressed two main ethical topics derived from the *Doctor Who* episode: the problem of scarce resources, and narrowly-defined purposes and market failures. After each topic was introduced, each instructor facilitated group discussions. At the time, the course was taught with a hybrid modality, so the engineering professor facilitated discussions with in-person students, while the philosophy professor facilitated discussions with students attending the course online via Zoom.

Scarce resources: This topic addressed the suits' reliance on oxygen as an extreme example of an essential and scarce resource. To connect this topic with real world applications, it was stressed how engineers work with different types of resources, which exist on a spectrum of essential/non-essential resources as well as a spectrum of scarcity. Ethical distribution of

resources was also addressed. The discussion prompts and questions for this topic were as follows:

1. Come up with an example of each of these:
    a. An essential resource- very important or perhaps even necessary to common ideas about a flourishing life in contemporary society- that engineers might use.
    b. An inessential resource- perhaps useful or pleasant but unimportant to common ideas about a flourishing life in contemporary society- that engineers might use.
    c. A resource that engineers might use, that is somewhere in between very important and unimportant
2. Explain what sorts of designs or engineering projects require the use of these resources.
3. What sorts of policies, principles, or professional codes should guide how these resources are used or distributed?

Narrowly-Defined Purposes and Market Failures: This topic addressed the limitations of the suits, as they allowed the miners to work on the station, but could also kill the miners. This led to a discussion of other engineering successes and failures. For example, highways in cities provided access and travel opportunities, but also introduced noise pollution and disrupted communities, resulting in class and racial inequalities with respect to real estate and education. The discussion prompts for this topic were as follows:

Come up with an example of:

1. A previous "successful" design that had negative externalities that the designers should have taken into consideration.
2. A way in which successful designs can cause markets to fail to function through lack of information or other barriers to entry.
3. Policies or professional codes that can remove or mitigate these problems.

At the end of the session, students were informed that a podcast project would be introduced in the following lecture and that the campus Digital Liberal Arts Librarian would provide a guest lecture on how to create a podcast. To prepare for the lecture, students were given links to five short podcasts (2 minutes each) and were asked to listen to two of them.

Debriefing and introduction to podcasting lecture (Lecture 2): The first thirty minutes of the following lecture were allotted for the engineering professor to debrief the entire class about the *Doctor Who* episode and the ethics lecture. Answers to the guided questions (assigned with the episode) were reviewed, to ensure that students understood what happened in the episode and could make connections between course concepts and the design/operation of the smart suits. Students were also provided with a copy of the Association for Computing Machinery (ACM) Code of ethics [9] and the instructions for the podcast project.

For the remainder of the lecture period, the Digital Liberal Arts Librarian presented students with strategies to develop their podcast, and introduced them to software that could be used to record and mix their podcast. Students published the final versions of their podcasts of the JSTOR Forum and were instructed on how to complete this process. To adapt to the learning and safety needs posed by COVID-19, students were provided with recording options that were appropriate for those seeking in-person and socially-distanced interactions as well as those interested in recording remotely.

Instructions for the podcast project: Review the ACM Code of Ethics. Working alone or in a group no larger than 3, create a podcast that discusses ethics in engineering computing in 3 points. Use this podcast to discuss: 1) A summary of the "Oxygen" episode of *Doctor Who* and how the smart suits worked, 2) Discuss 1 or 2 general ethical principles from the ACM Code of Ethics that may have been violated with respect to the design and/or operation of the smart suits, and 3) propose alternative solutions with respect to the coding/programming to mitigate these violations.

Your podcast should include 1) outside research on the roles and responsibilities of engineers in computing (see Recommended Resources [11], [12] or do your own outside research and cite accordingly), 2) intro/outro music, 3) at least one quote (from the *Doctor Who* episode or ACM Code of Ethics), 4) a list of sources (including audio) turned in with your podcast. This podcast should be designed for an audience that knows nothing about ethics in engineering computing.

Podcast project checkpoints and rubric: Since students were learning computing concepts in C for the remainder of the semester, weekly project checkpoints were included to help students manage their time on the project as well as course homework assignments. Students had approximately six weeks to complete the assignment. The checkpoints were assigned as follows:

Podcast Project Checkpoints
Week 1: Submit list of group members
Week 2: Podcast Planning:

1. General Ethical Principle(s) Selected for Discussion
2. Podcast Format(s) Selected: Single vs. Group Conversation
   Scripted vs. Casual
   Interviews Read vs. "Live Interview"

Week 3: Submit draft podcast storyboard or script
Week 4: Submit revised storyboard or script
Week 5: One open class session to work on project
Week 6: Submit final podcast (publish on JSTOR forum)

Students were provided with a rubric that described how their podcast would be assessed. Due to formatting and layout of the rubric, it has been attached at the end of this document.

Work in progress

Two sections of the course are being taught by the same engineering professor in Spring 2021. This collaborative approach to introduce ethics in the course will be implemented again in each section, with a few changes to the assignments. In particular, students will be asked to submit their answers in advance of the debriefing lecture. To incentivize students submitting the assignment, the questions will be graded for completion and considered a homework assignment. This will enable the engineering instructor to determine how many students were able to make connections between course concepts and the *Doctor Who* episode. It is anticipated that this will lead to a more engaging debriefing session. In addition, the project rubric will be modified to clearly specify the engineering computing and ethics content expected in the submitted podcast.

In addition to these changes, a formal study to evaluate the effectiveness of this collaborative approach will be conducted by comparing student responses reported in pre and post lecture surveys. These findings will be used to refine our collaborative teaching approach and lead to a more formalized plan to integrate ethics in the existing engineering computing course. The Human Subjects Review Board at Hope College approved the research proposal and recruitment and enrollment of research participants has commenced. Future work will describe this study and present the initial survey findings. We intend to use pre and post lecture surveys to capture student understanding of ethical concepts and the ACM Code of Ethics. We hypothesize that student comprehension of the role of ethics in computing and comprehension of the ACM Code of Ethics will increase after the lecture.

Conclusions

The literature suggests that there is interest in incorporating ethics into existing technical courses. Several papers highlight collaborative approaches for existing approaches as well as how science fiction can be used to further engage studies. Inspired by this work, we present a complete lesson plan based on a collaborative approach to teach engineering computing ethics using science fiction and popular culture. Our lesson plan includes detailed information about a culminating podcast project that can be assigned to further engage students. The project also provides students with an opportunity to communicate what they have learned and apply technical and ethical concepts to propose solutions to technological problems. In particular, this lesson plan was developed for an introductory engineering computing course, which covers basic computing concepts. We anticipate that this lesson plan is appropriate for any introductory undergraduate programming courses.

Engineering Computing Ethics Podcast Project Rubric (100 points possible: 94 from table below + 6 for reflections)

	Excellent **20 points or 10 points or 4 points**	**Proficient** **13 points or 7 points or 3 points**	**Developing Proficiency** **7 points or 4 points or 2 points**	**Beginning** **4 points or 2 points or 1 point**
Digital Tool and Best Practices (20 points possible)	• Sound is clear and audible (no background noise or static) • Intro/Outro sound fades in/out • Audio is at the same levels throughout podcast	• Sound is somewhat clear and audible throughout entire podcast with minimal background noise or static • Intro/outro sound somewhat fades in/out • Audio is mostly at the same levels throughout podcast	• Sound is not clear and audible throughout entire podcast • Intro/Outro sound does not fade in/out • Audio is not the same level throughout the podcast	• Sound is inaudible at times • Intro/outro sound does not fade in/out or doesn't exist • Audio is at different volumes throughout podcast
Copyright (4 points possible)	• All of the audio is copyright free or the copyright license allows for the image to be used in a timeline • All of the audio is cited with their author and copyright license (if applicable).	• Most of the audio is copyright free or the copyright free license allows for the image to be used in a timeline • Most of the audio is cited with their author and copyright license (if applicable)	• Little of the audio is copyright free or the copyright license allows for the image to be used in a timeline • Little of the audio is cited with their author and copyright license (if applicable)	Audio is used that violates copyright law or failed to cite images.
Length and components (20 points possible)	Podcast is 4 – 6 minutes long Podcast contains **all** of these components: o Intro/outro music o External sources or interviews o Course Content	• Podcast is 3 – 4 minutes long • Podcast contains most of these components: o Intro/outro music o External sources or interviews o Course content	• Podcast is 2 – 3 minutes long • Podcast contains some of these components: o Intro/outro music o External sources or interviews o Course content	• Podcast is under 2 minutes • Podcast contains few or none of these components: o Intro/outro music o External sources and/or interviews o Course content

Research and Course Content (20 points possible)	• Course Content is appropriately and accurately represented • External research is appropriately and accurately represented and verbally cited within the audio of the podcast	• Course content is somewhat appropriately and accurately represented • External research is somewhat appropriately and accurately represented and verbally cited within the audio of the podcast	• Course content is inaccurately represented • External research is inaccurately represented and verbally cited within the audio of the podcast	• Course content is not used or extremely inaccurate • External research is not used or extremely inaccurate and not verbally cited
Bibliography (10 points possible)	**All** material used (including audio resources and additional sources) are turned in with the podcast in a bibliography	**Some** of the materials used (including audio resources and additional resources) are turned in with the podcast in a bibliography	Most materials used (including audio resources and additional sources) are NOT turned in with the podcast with a bibliography	No bibliography turned in
Creativity & Digital Story Telling (Digital Literacy) (20 points possible)	• Podcast is written creatively • Podcast expresses the course content in a succinct and clear way • Layman audience can clearly understand and interpret the course content • External interviews or content is seamlessly integrated into the story	• Podcast is written somewhat creatively • Podcast expresses the course content in a mostly clear way with slight moments of unclearness • Layman audience can somewhat understand and interpret the course content • External interviews or content is a little choppy when integrated into the story	• Podcast is generic and non-creative • Podcast expresses the course content in a convoluted way with slight moments of unclearness • Layman audience cannot understand materials presented within the podcast • External interviews or content is very choppy when integrated into the story	• Podcast is non-creative and possibly plagiaristic • Podcast expresses the course content unclearly • Layman audience cannot understand the course materials

Reflections (6 points, 2 points per question)

To be completed individually: Provide a reflection to the questions in this Google Form (Figure 1)

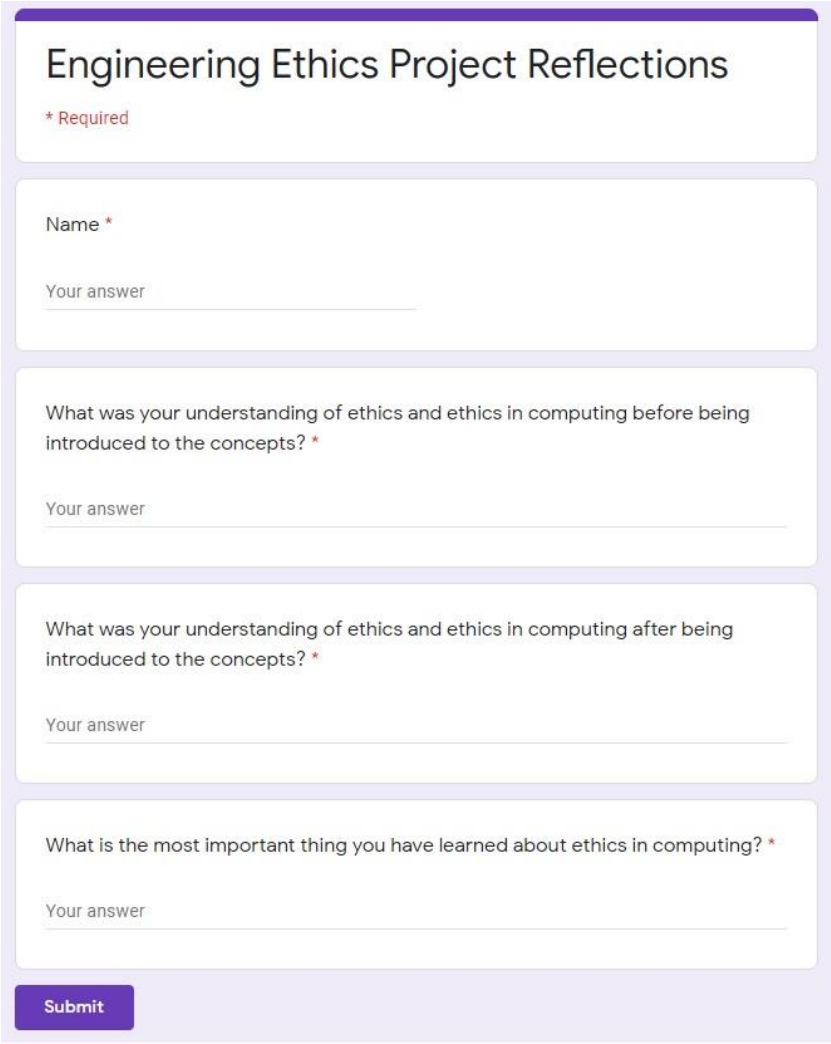

Figure 1. Screenshot of Google Form students used to answer the project reflection questions.

References

[1] B. J. Grosz , D. G. Grant, K. Vredenburgh, J. Behrends, L. Hu, A. Simmons, and J. Waldo, **"**Embedded EthiCS: Integrating Ethics Broadly across Computer Science Education," 2018. [Online] arXiv:1808.05686v1 [cs.CY] [Accessed August 3, 2020].

[2] E. Burton, J. Goldsmith, and N. Mattei, "Teaching AI Ethics Using Science Fiction," in *Proceedings of the Association for the Advancement of Artificial Intelligence*, 2015.

[3] V. H. Summet and R. A. Bates, "Science Fiction as an Entry Point for Ethical Frameworks in Engineering and Computer Science Education," in *Proceedings of the American Society for Engineering Education Virtual Conference*, June 22 - 26, 2020, Paper ID #29719.

[4] A. Pease, "Teaching Ethics with Science Fiction: A Case Study Syllabus", *Teaching Ethics*, pp. 75 - 81, 2009.

[5] R. A. Bates, "AI & Sci-Fi: Teaching Writing, History, Technology, Literature, and Ethics," in *Proceedings of the American Society for Engineering Ethics*, pp. 22.152.1 - 22.152.13, 2011.

[6] E. Burton, J. Goldsmith , and N. Mattei, "How to Teach Computer Ethics with Science Fiction," in *Proceedings of the Association for Computing Machinery Annual Conference*, 2008.

[7] R. W. Berne and J. Schummer, "Teaching Societal and Ethical Implications of Nanotechnology to Engineering Students through Science Fiction," *Bulletin of Science Technology & Society*, vol. 26, No. 6, pp. 459 - 468, 2005.

[8] J. Mathieson (Writer) and C. Palmer (Director). 2017, May 13. Oxygen (Series 10, Episode number 5) [TV series episode]. In Minchin, B. & Moffat, S. (Executive Producers), *Doctor Who*. British Broadcasting Corporation.

[9] D. Gotterbarn, B. Brinkman, C. Flick, M. S. Kirkpatrick, K. Miller, K. Vazansky, and M. J. Wolf M, ACM Code of Ethics and Professional Conduct, 2018.

[10] M.C. Loui and K. W. Miller, "Ethics and Professional Responsibility in Computing," In Wiley Encyclopedia of Computer Science and Engineering, B.W. Wah (Ed.)., 2008.

[11] B. M. O'Connell and J. R. Herkert, "Engineering ethics and computer ethics: Twins separated at birth?," *Techne: Research in technology and philosophy,* vol. 8, No. 4, pp. 36-56, 2004.