A Course on the Societal Impact of Robotics: Preliminary Outcomes

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Introduction

A constant stream of stories appears in the academic and popular press about robots on our roads, in the skies, in our offices, restaurants, factories, and more. Robotics and automation play an increasing role in the lives of ordinary people. New developments in robotics raise a variety of social, economic, and ethical questions.

As consumers, workers, leaders, and citizens, we all are involved in some way in the decisions to accept, reject, or choose between new technologies. Most universities have recognized the need for a science and technology literate citizenry and have incorporated a requirement into the undergraduate curriculum that seeks to motivate students to be inquisitive about the broader implications of science and technology and to provide them with the tools to analyze the advantages and disadvantages of emerging technologies. This requirement is known as "Science and Technology in Society" (STS) at Clemson University.

We have developed and offered a new course, *ECE 1010: Robots in Business and Society*, which uses robotics as the topic for developing students' STS skillset. Robotics is especially fertile for this purpose, not only because the field is advancing rapidly and may increasingly impact our lives in the near future, but also because robots appear frequently in popular culture. Recently, an explosion of television shows and movies, such as "West World" and "Ex Machina,"" have explored questions surrounding robotics. These shows raise interesting issues that deserve exploration, but it takes clear thinking to separate fact from fiction.

Course Design

The course has been developed and co-taught by two faculty members in Electrical and Computer Engineering and one faculty member in History (the authors of this paper) at Clemson University. The three semester hours (45 contact hours) course is offered through the department of Electrical and Computer Engineering as *ECE 1010: Robots in Business and Society*, and satisfies the university's STS requirement. Undergraduates of any major and at any level are eligible to enroll. The course has been developed for online delivery and is offered as part of the established online course program at Clemson University. Course content is delivered using the Canvas course management system.

The course is divided into 11 modules, listed in the next section. Each module has six components: 1) assigned background material, 2) a list of supplemental resources, 3) a lecture video, 4) a faculty conversation video, 5) a multiple choice quiz, and 6) a written discussion assignment. The assigned background material ranges from third party videos describing a technology in more depth (such as [1]) to scholarly articles discussing related issues (such as [2]), to short stories illustrating relevant issues (such as [3]). A list of supplemental materials is posted along with the assigned background material. This list provides students with a starting point to dig further into a desired topic as well as find resources for the course project. The lecture videos are 20-40 minutes long, consisting of voiced-over Powerpoint presentations

intermixed with relevant video clips from third part sources. The conversation videos are about 20 minutes long and feature the instructors (the authors of this paper) discussing one or more open-ended questions related to the module topic. The conversation videos are intended to model the critical thinking skills that the students should apply in the discussion board assignments, exams, and course project. The multiple choice quizzes consist of 10 questions drawn from a question bank covering the assigned background material, lecture video, and conversation video. The quizzes are intended to focus the students on the provided materials in preparation for the discussion board assignment. The written discussion assignment is managed using discussion boards on Canvas. The assignment poses an open-ended question or statement to the students. The discussion assignment has two deadlines. By the first deadline, students are required to make a first post to the discussion board staking out their position on the discussion topic. A student cannot see other posts until his or her first post is submitted. Students have until the second deadline to discuss their positions with other students.

Modules

1. **Introduction.** History of robots. Introduction to ethics. Introduction to critical thinking.
2. **Robot Technology.** What is considered a robot? Robots are presented as a combination of computation, actuation, and sensing.
3. **Robotics and Business.** When is it a good decision to replace humans with robots? Will this lead to fewer jobs overall?
4. **Artificial Intelligence.** How do the fields of artificial intelligence and robotics overlap and how are they distinct? Does a robot require artificial intelligence? (Answer: No.)
5. **Robots and Transportation.** Driverless cars and trucks are already appearing on our roads. How should they be regulated and insured? What ethical decisions are involved in programming a robotic car? Should the public accept and trust such vehicles? What will happen to the millions of professional drivers?
6. **Security and Privacy.** Robots require computation, and anything with a computer can potentially be hacked. How do computer security issues affect the potential for robotics? How does the rich sensor data collected to allow robots to operate potentially risk our privacy?
7. **Robots in the Home.** We are already beginning to bring robotics into the home, such as the Roomba vacuum cleaner and “smart home” technology. How much could/should our surrounding physical environments become "robots for living in"?
8. **Healthcare Robots.** What are the advantages and disadvantages of robots as caregivers? What choices do we have regarding who/what cares for us? Why might different countries make different choices?
9. **Robots in the Military.** Drones are being used as a key element in today’s U.S. military strategy. What public consultation process, if any, has been adopted prior to deployment of this technology? Should military robots that make their own decisions rather than being remotely controlled by a human be allowed to carry weapons? What are the ethical considerations involved in arming robots?
10. **Space Robots.** Would it be better to send robots into space instead of people? To what extent are scientific spacecraft already robots? What can we learn from the space program about the potential of robots that partly make their own decisions and partly are remotely guided by humans?

11. **Our Future with Robots.** What could future human/robot worlds look like - should they come to pass? At what point should robots have rights? Will we become robots? How many robot parts can a human being have and still be human? Could/should our consciousness be "uploaded" into robots to extend our lives indefinitely? What would this mean for humanity? How accurate have fiction and futurists proved in predicting the future of robots so far? Is the direction in which technology develops inevitable, or do we have choices?

Grading

The course is graded on the scale ≥ 90 = A, 90-80 = B, 80 - 70 =C, 70 - 60=D, <60 =F. The course grade is the grades on the various activities as follows:

20% Participation
10% Surveys
15% Quizzes
20% Research Project (initial discussion 5%, research paper 15%)
15% Midterm exam
20% Final exam

The participation grade is based on the discussion boards, one per module. Grading takes into account engagement with other students, quality of responses, meeting the deadlines, and word count. Surveys assessing STS and critical thinking skills, described in further detail in the next section, are graded based only on completion, not performance. The 10 question multiple choice quizzes are delivered on Canvas and cover the background material, lecture video, and conversation video for the corresponding module. The Research Project is a 6-8 page paper providing a technology assessment of a student-chosen robot. The paper must address the questions:

1) CHOICE: What choices are made in development of the technology?
2) ACCESS: Who will have access to the technology?
3) RISK: What are the risks involved?
4) COST: What costs (economic, environmental, social, etc.) are involved?
5) RESPONSIBILITY: Who is responsible for any harm that may result?
6) BENEFITS: Who will benefit from the technology?

The midterm and final are electronically submitted take-home exams. These exams present the students with a number of position statements about robots, and students are asked to agree or disagree with the statement and defend their position. Students are graded on their ability to use facts to defend their position and their ability to understand and consider potential criticism of their position.

Assessment

The goal of the course is to develop students' STS skills and critical thinking skills through study of the issues surrounding the topic of robotics. We use two assessment tools to evaluate the effectiveness of the course to this end, the modified Views on Science-Technology-Society (VOSTS) survey and the California Critical Thinking Skills Test (CCTST). The tests are administered at the beginning and end of the course in order to assess the growth in students' abilities. The specific test results do not count toward the course grade, and results are only used in aggregate.

The original VOSTS survey contains over 100 multiple choice questions in seven categories [4]. The modified VOSTS survey [5] used here has 13 questions spanning 6 categories. The modified VOSTS survey is administered using Canvas.

The California Critical Thinking Skills Test (CCST) [6],[7] is administered using the website https://www.insightassessment.com/. The test is "an objective measure of the core reasoning skills needed for reflective decision making concerning what to believe or what to do." [6]

Initial Offerings and Course Modifications

The original concept for the course included a hands-on component using Lego Mindstorms. The original conception also restricted the course to non-engineering majors [8], largely because engineering majors were thought to have a considerable advantage working with the Lego Mindstorms. The hardware requirement imposed severe constraints on another important course goal, online delivery. Ultimately we decided not to implement the hands-on component. That had the side benefit of allowing us to open the course to all majors, including engineering majors. The course discussion boards have benefited from having a mixture of students with engineering and non-engineering majors. We have increased the emphasis on critical thinking skills, which ties in with Clemson University's Thinks^2 Quality Enhancement Plan (http://www.clemson.edu/assessment/thinks2/), which aspires to transform student learning and faculty teaching across the curriculum and in the disciplines.

The course was first offered during the second 5.5-week session of Summer 2016 [9]. The initial offering had 7 students enrolled. To fit the compressed time frame, the course covered a module roughly every other weekday. The course is currently being offered a second time in Spring 2017, a 15-week semester. During this longer semester, one module is covered per week, with one week each set aside for the midterm, project, and final. The Spring version of the course has 31 students. All seats in the Spring 2017 offering filled in the first day of scheduling, suggesting the course has generated some excitement. The course is scheduled to be offered a third time during a 5.5-week session in Summer 2017.

Several modifications have been introduced to the course based on our experience with the first offering:

- In the first offering, some students spent very little time completing the VOSTS and CCTST assessment devices. Since they were graded only based on completion, some of the students rushed through the complicated questions on the VOSTS test in just few minutes, as indicated by Canvas statistics. The low quality of a portion of the data combined with the tiny number of students in the first offering makes it difficult to reach any conclusion based off of the assessments. In the second offering, we have spent more time explaining to the students why, as stakeholders in the development of the course, it is important to take the assessment devices seriously. With the larger class size and more motivated students, we hope to have more statistically relevant results after Spring 2017.
- In the first offering, some students seemed to confuse the supplemental material with the core course material, leading to less focused discussions. The multiple choice quizzes were added in the second offering in order to require the students to engage with the core material before beginning the discussion.

Conclusions

We have described a new undergraduate course, ECE1010: Robots in Business and Society. The course uses the topic of robotics to develop STS and critical thinking skills in students from both engineering and non-engineering majors. The ongoing second offering of the course has a larger number of students, 31, and will provide better assessment statistics for evaluating the effectiveness of the course. Qualitatively, the students seem enthusiastic about the topic of robotics.

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References

1. Urmson, Chris, "How a driverless car sees the road," https://www.ted.com/talks/chris_urmson_how_a_driverless_car_sees_the_road, accessed February 12, 2017.
2. Richards, Neil M., and William D. Smart. "How should the law think about robots?," https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2263363, accessed February 12, 2017.
3. J.G. Ballard, Thousand Dreams of Stellavista, Short Story, 1963.
4. Aikenhead, G. S. and Ryan, A. G, "The Development of a New Instrument: Views on Science—Technology—Society (VOSTS)" Sci. Ed., Vol. 76, 1992, pp. 477–491.
5. Mack, P.E., Campbell, T. and Abd-Hamid, N.H., "Issues in Survey Assessments of STS courses", Bulletin of Science, Technology, and Society, October 2008, Vol. 28, pp. 408-413.
6. California Critical Thinking Skills Test, http://www.insightassessment.com/About-Us/California-Critical-Thinking-Skills-Test-Family , accessed February 12, 2017.
7. P.A. Facione, "*Using the California Critical Thinking Skills Test in Research, Evaluation, and Assessment*", 1991.
8. Burg, Timothy, P. Mack, I. Walker, R. Groff, "Building and Assessing a Hands-on Learning Experience for Robots in Business and Society" in Proc. of ASEE Zone III Conference, 2015.
9. Walker, I.D., P.E. Mack, and R.E. Groff, "A Novel Approach to Teaching Undergraduates the Societal Impact of Robotics," International Conference on Humanities, Society, and Culture, September 2016.