Who's Driving?: Using Design to Engage Learners in the Ethical Dimensions of Autonomous Vehicle Technology

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Tanner Vea

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Introduction

Imagine you are driving down the freeway in the middle lane, when you suddenly realize that a mechanical problem has caused your breaks to go out. About 10 seconds ahead of you, you see stalled traffic. Cars are piling up, but you have no way to slow down. You are surrounded by other vehicles. To your left is a truck full of cows, to your right is a family with two young children in the back seat, and ahead in your lane you can just make out a driver with gray hair. A collision is imminent, but how you choose to act (or not act) in the coming seconds will shape the consequences not only for you, but also for the lives around you. How do you weigh the harms? Perhaps you think the lives of seven cows are worth less than one human. Perhaps you think the lives of the children should be preserved over a lone, older driver.

Now suppose that the car you are riding in is an autonomous vehicle, and it is going to make this decision without your input. This scenario is not so farfetched. Google's self-driving car prototypes are already on the road, as are a number of vehicles with more limited driver assistance features. Commentators have argued that software programmers will necessarily be faced with making judgments that allow autonomous vehicles to algorithmically respond to ethically difficult scenarios (Lin, 2013), particularly as sensing technologies become more sophisticated. Some people may not trust a software engineer at Google or another firm to make such decisions on their behalf, especially in light of the diversity challenges Silicon Valley continues to face (The Editorial Board, 2014).

In February 2016, the first collision caused by an autonomous vehicle occurred when a Google self-driving car struck the side of a bus in Mountain View, California. The director of Google Auto LLC, Chris Urmson, filed a report (Urmson, 2016) to the DMV, describing how the accident occurred as the car in autonomous mode moved to turn right from El Camino Real onto Castro Street:

> The Google AV [autonomous vehicle] then moved into the right-hand side of the lane to pass traffic in the same late that was stopped at the intersection and proceeding straight. However, the Google AV had to come to a stop and go around sandbags positioned around a storm drain that were blocking its path… After a few cars had passed, the Google AV began to proceed back into the center of the lane to pass the sand bags. A public transit bus was approaching from behind. The Google AV test driver saw the bus approaching in the left side mirror but believed the bus would stop or slow to allow the Google AV to continue. Approximately three seconds later, as the Google AV was reentering the center of the lane it made contact with the side of the bus.

What's striking in this account is the way in which Urmson avoids talking about the car's algorithmic decision-making process, which led to the accident, by instead narrating the incident from the test driver's point of view. He writes about what the driver "believed" as if the driver had made a reasonable, if fallible, human decision given the complex dynamics of driving with other humans. However, the reality is that the test driver was not acting as a driver at all in the moment, and instead the decision was made by an algorithm, which made no such public disclosure in this report about its own evaluation of the situation.

Given the present-tense reality of self-driving vehicles, questions about the algorithmic ethics of autonomous driving cannot be deferred. This set of questions, however, is just the tip of the iceberg. Other potential ethical issues with driverless cars include data privacy and surveillance, liability issues, the potential for higher insurance rates for people who cannot afford the technology, and the economic impact of losing driving-based jobs.

In this brief research report, I first discuss the importance of engaging diverse learners in ethical questions about emerging technologies; review some previous approaches to incorporating values, ethics, and pro-social concerns in STEM education efforts; and review the role of design in STEM learning settings. Next, I describe the design of a pilot study to probe high school students' technology and ethics learning in an "ethical design" challenge related to self-driving cars. Finally, I report on preliminary findings from the pilot study and discuss future directions for this ongoing work.

Diversity in STEM Fields

Students of color face a number of challenges in formal STEM education. In K-12 schools, students from non-dominant communities often find cultural and linguistic barriers to their own STEM-relevant knowledge and practices being valorized in the classroom (Civil, 2016). By the time they reach college age, many students of color have already lost interest in STEM fields or have become discouraged.

According to a report from National Science Foundation and the National Center for Science and Engineering Statistics (2015), Whites received 60.2 percent of U.S. bachelor's degrees in science and engineering. Meanwhile, Hispanics/Latinos received 9.9 percent, American Indians and Alaska Natives received 0.6 percent, Asians received 9.3 percent, and Blacks and African Americans received 8.4 percent. Compared to census population estimates (U.S. Census Bureau, 2015), Hispanics/Latinos (17.4 percent of the U.S. population), American Indians/Alaska Natives (1.2 percent), and Blacks/African Americans (13.2 percent) are seriously underrepresented among STEM degree recipients. I note that such categories provide only rough understandings of the overall picture, do not account well for people's complex self-identifications, and gloss great diversity of background and experience within them. Thus, even though as a totalized group, Asians achieve bachelor's degrees at a higher rate than their presence in the overall U.S. population, some subgroups remain dramatically marginalized in STEM and in higher education more broadly (see Museus et al., 2011 for further discussion). Despite such limitations, these data demonstrate the need for further efforts in diversifying the population of STEM practitioners.

In the case of Google, the company whose efforts in self-driving technology have been most touted so far, the underrepresentation in bachelor's degree programs is further exacerbated by hiring practices. The company reports (Google, 2016) that as of January 2015, its technology-related workforce is 82 percent male, 59 percent White, and 35 percent Asian. Only 1 percent identify as Black, 2 percent as Hispanic, 3 percent as 2 or more races, and less than 1 percent as others.

These figures beg the question of whether important perspectives on the ethics of emerging technologies are missing from the room when crucial decisions about the shaping of sociotechnical arrangements are being made. Just as who's asking the research questions in scientific endeavors inherently shapes what knowledge will be sought and uncovered (Medin & Bang, 2014), who's asking the ethical questions in technology design shapes what kind of technological future we all will share (Feenberg, 1999). This is a challenge for educators because it gives a moral urgency to the issue of diverse representation in the STEM fields.

Values, Pro-Social Concerns, and Ethics in STEM Education

Some STEM education researchers have investigated the importance of values in learning. For example, in mathematics, families make math useful in accomplishing everyday goals by drawing upon cultural resources and values (Esmonde et al., 2012; Pea & Martin, 2010). From a science education perspective, Roth and Barton (2004) push for a vision of education that places issues of power, politics, and ethics at the center. Pushing back on the prevalent human capital motive for science education, they argue that many of the "advances" promulgated by scientists – including weapons, genetic modification, and pharmaceuticals – have had ambiguous to negative effects on society. They write:

> Conventional approaches to scientific literacy, knowing, and learning are based on an untenable, individualistic (neo-liberal) ideology that does not account for the fundamental relationships between individual and society, knowledge and power, or science, economics, and politics. (p. 3)

Rather than coercing students to engage in the practices of professional scientists, Roth and Barton push for a different model. They argue that the kind of science that people need in everyday life does not look like the science that happens in a lab. In place of the human capital view, they see a future world where "individuals with different expertise co-participate in resolving the complex problems that their communities, countries, and humanity as a whole face today" (p. 13). Extrapolating from this work to STEM fields more broadly, individuals must be ready to participate in STEM as a site of struggle over what is valuable, worth building, and worth preserving on a local and global level.

Other scholars have connected STEM education to pro-social concerns through service learning programs (Coyle, Jamieson, & Oakes, 2005; Payton et al., 2015; Sanderson & Vollmar, 2000). Payton and colleagues (2015) found that in computer science, a long-term, curriculum-integrated service learning program was effective for engaging diverse learners in college. Students across multiple universities in the U.S. gathered for an annual conference where they developed project plans in local teams. Upon returning to their home institutions, they implemented their service projects over the course of at least one semester. These projects included things like installing computers for community members or running a robotics club in a K-12 setting. The researchers found that participating in the program led to significant increases in students' self-reported computing commitment and computing efficacy, meaning they saw themselves as more likely to persist in their computer science degree programs and felt more capable of succeeding. They also found that students from underrepresented groups in the early years of their degree programs seemed to benefit most from the program in terms of computing efficacy. Programs like this show promise for approaches that integrate content-area learning within the context of value-laden and pro-social projects.

Designing for Values and STEM Learning

The incorporation of design activities in education settings has been shown to be an effective strategy for supporting students' learning about their values and about STEM domains. For example, Bers (2006) examined a multiuser virtual environment for positive youth development that engaged learners in exploring personal, moral, and community values by designing objects and spaces in a virtual city. As students learned to use the virtual environment and its design capabilities, they were encouraged to reflect on the values that mattered to them. Bers found that students learned technology skills, including three-dimensional design, programming, and debugging. They also learned to express their personal values, as they were invited to attach values-oriented statements to the objects they designed in the virtual space. Students reported in interviews that in the course of everyday life, they did not often have occasion to reflect on or share the values that mattered to them, or to think about the values embedded in objects and the world around them. This affordance of the virtual environment gave them opportunities to do that.

A prominent strand of research in design and STEM learning is the Learning by Design (LBD) project (for an overview see Kolodner et al., 2009). The project engaged middle school students in science through a series of design-and-build challenges. For example, in earth science, students designed and modeled a mechanism for dealing with erosion on a hillside. Compared to matched classrooms that did not engage in LBD curriculum activities, students in LBD classrooms learned science content knowledge as well or better according to multiple-choice tests. They also performed better in collaboration, metacognition, and science skills (such as designing tests and explaining mechanisms) in performance tasks.

Another strand of work has approached learning in STEM through the lens of design thinking. Design thinking is a method for creating innovative products, services, and experiences by putting human needs at the center of the endeavor. In the design thinking process, designers start with empathic research into the needs of "users," individuals who might benefit from their designs. Research in the Stanford REDlab has used design thinking to help interest middle school students in STEM learning and other curricular goals (M. P. Carroll, 2014; M. Carroll et al., 2010). In recent studies of middle school students engaging in a design thinking and integrated STEM curriculum, students interviewed classmates, educators, and community members about their needs related to STEM-relevant topic areas such as energy, water, or shelter. We found that framing engineering as a way of helping others and solving real societal challenges helps students see the value of STEM in their lives (Goldman, Vea, Bullock Zielezinski, Bachas-Daunert, & Kabayadondo, 2015).

These projects suggest that learning environments based on design may provide a compelling context for learning about autonomous vehicle technology and exploring the complex, value-laden judgments and social ramifications of its development and use.

Research Objectives

The overarching objective of the pilot research described in this report was to demonstrate the viability of a design-oriented approach to learning about autonomous vehicle technology and associated ethical questions, and to field-test a set of research methods for understanding learning in this context. The research questions of the larger project are:

1. What do students engaged in an "ethical design" challenge learn about the STEM content related to autonomous vehicles and about ethics and ethical questions?

2. Does engaging diverse students in an "ethical design" challenge help them see themselves as people who can participate successfully in STEM fields?

3. How do learners collaborate and negotiate with one another regarding the design task and the ethical issues involved?

4. What are the differences in student learning and activity between a design thinking-oriented challenge and a more traditional engineering design challenge based on the same ethical premise?

For a number of reasons unforeseen at the start of this pilot research project (see "Limitations and Future Work"), these research questions could not be fully answered. While I share some preliminary observations and findings below, I focus mainly on what the pilot work suggests about the research design and the intervention itself.

Methods

Participants and Setting

Five high school students participated in the pilot research during the summer between their freshman and sophomore year. All were 15 years old and enrolled in a diverse high school in Salt Lake City, Utah. Despite some of the students being in past classes together at their high school, they reported that they did not know each other very well. While the students worked in one collaborative group during the pilot study, two students were excluded from analysis due to missing information on a parental consent form and English-language challenges. The remaining students were Miguel, a young man who self-identified as Hispanic, Melia, a young woman who self-identified as Hawaiian, and Jillian, a young woman who self-identified as Asian.

Students were recruited by a teacher who shared a recruitment message with them, inviting them to a two-day workshop exploring STEM through designing ideas for self-driving cars. The workshop took place in a classroom facility at a large themed garden complex. A school bus was arranged to transport them from their high school in the mornings to the garden and return them to the school in the afternoon. The classroom was large, with a digital projector, and several round tables with chairs.

Procedures

In this section, I describe the structure of the two-day workshop activities and the types of data that were collected. Because of the small number of students who participated, all participated in the traditional engineering design challenge group for the purposes of the pilot. Data collected included pre- and post-workshop questionnaires, summative interviews, video of the full workshop, and photographs of the students' design artifacts and work products.

Pre-activity questionnaire

On the first morning of the workshop, students completed a paper and pencil questionnaire to collect some demographic information and assess their prior knowledge and attitudes related to autonomous vehicles and STEM domains more generally. In the demographic section, students had open-ended response blanks to write in their age, self-identified gender, and self-identified racial or ethnic background.

Knowledge and attitudes were assessed using a combination of five-point Likert scale items and open-ended responses. Regarding self-driving cars, example items included asking students how soon they believed self-driving cars would become widely available, how much they believed they understood already about self-driving cars, how they would describe how self-driving cars work to another person, potential benefits and drawbacks of the technology, and how much they would be interested in using one. They were also asked about the importance of ethical issues when it comes to self-driving vehicles, how similar they perceived the designers of self-driving cars to themselves, and how important it is for people like themselves to be involved in the design process.

Students were also asked about a range of subjects they might learn about in school: science, language arts/English, math, social studies, technology, and engineering. For each of these subjects, they were asked on a Likert scale how much they know about it, how interesting they found it, how useful it is to know about it, how important it is to learn about it, and how successful people similar to themselves are in using knowledge and skills related to it.

Day 1 activities

Activities for both days of the workshop included some direct instruction, discussion, and design work. At all times, at least one portable action camera was used to record video from the room. Usually, two cameras were recording with a third camera being recharged so that it could be swapped in when one of the other two cameras was depleted. By default, one camera was positioned on a table at the front of the room and another at the back of the room. The camera at the back of the room kept a wide angle to capture movement around the room, while the front camera was occasionally moved to provide a closer view of action in a particular area of the room at a given time.

On the morning of the first day, the students first completed research assent and the pre-activity questionnaire. Next, I facilitated a brief improvisational theater activity to help break the ice. Then the students viewed a TED talk video featuring Chris Urmson, the director of the Google autonomous vehicle project. The video's main argument was that fully autonomous vehicles will be safer in the long term than semi-autonomous vehicles that become incrementally more assistive over time, because the latter will eventually lead to human drivers relying too heavily on the autonomous capabilities of the vehicle and taking inappropriate risks. However, the video also gave an overview of how the Google autonomous vehicle sees the world through sensors and makes decisions about how to navigate.

In the next section, the students were introduced to a version of the engineering design process, which included the following steps: Identify needs and constraints, research the problem, develop possible solutions, select promising solutions, build a prototype, test and evaluate, and redesign as needed. To learn the steps, they engaged in a practice design challenge unrelated to autonomous vehicles. In the practice challenge, they were told that a major retail company would like to hire them to create a new product to sell as a gift for American teenagers. They then explored this challenge using the engineering design process steps.

Following lunch, the students were told they were now going to try out the same process again, but on the topic of self-driving cars. They were told that their client was a car manufacturer who wanted to design an "ethical self-driving car." Before they began the challenge, they were introduced to basic concepts of ethics. For instance, they were told, "Ethics is how we make decisions about what is right and wrong." As a group they brainstormed potential situations in which a self-driving car might be in an accident, despite its ability to avoid many potential crashes. Next, they were told that when a crash is about to happen and cannot be avoided, the car will have to "make a decision about how to behave."

To understand the potential consequences in a situation like this, the students were introduced to "the trolley problem," a classic scenario from moral philosophy. In one version of this scenario, a bystander sees an oncoming train that is about to strike five people tied to the tracks. However, the bystander sees that it is possible to flip the track switch so that instead the train goes down a track on which only one person is tied. The students discussed in pairs what they would do and why, then shared with the larger group. They were then introduced to a second version of the scenario, in which there is no track switch. Instead, the bystander is standing on an overpass with a very fat man, and the bystander can choose to push the man off the overpass and onto the tracks to prevent the train from striking the five people tied to the tracks. Again, the students discussed in pairs what they would do and why, then shared with the larger group.

Finally, the students were introduced to vocabulary about two major ethical theories in moral philosophy, "deontology" and "consequentialism." They were told that according to deontology "ethical action is determined by duty or rules" and according to consequentialism "ethical action is determined by the consequences." They then discussed as a group how these two theories related to their own intuitions about the two versions of the trolley problem. For instance, people who said they would not feel comfortable pushing someone off of an overpass because “it’s wrong to kill people” were using a rule to determine why that action seemed unethical to them.

To complete the remaining steps of the design challenge, the students first learned more about the problem of ethics and self-driving cars by conducting internet research. Second, they created possible problem statements (“The next generation of self-driving cars needs a way to ______ because ______.”) and selected one problem statement to move forward with. Third, they brainstormed possible ways to resolve the problem statement as a group, writing ideas for features that a self-driving car might incorporate on sticky notes and posting them on a wall.

Day 2 activities

The students began the second day by doing a quick warm-up activity that highlighted mistakes as opportunities to learn, then continued with the design challenge where they left off on day one. They began by selecting their favorite compatible ideas and deciding on a car concept they wanted to move forward with together. Using simple household materials like cardboard, pipe cleaners, foil baking dishes, paper, and tape, the students began to build a prototype of their “ethical” self-driving car as a group. They received feedback from the researcher, posing as an executive from the car manufacturer. After lunch the students were given an opportunity to decide on and execute revisions to their design based on the feedback they received. Before concluding the activity, the students had an opportunity to discuss their experiences with the engineering design process overall as a group.

Post-activity questionnaire

The post-activity questionnaire was completed at the end of the second day of the workshop, and was identical to the pre-activity questionnaire, except that it did not include the demographic questions.

Interviews

After completing the post-activity questionnaires, students were given access to explore the gardens. Students were called individually for semi-structured interviews during this time. Interviews included questions about how they would describe the meaning of “ethics,” and probes for students to give examples of “ethical” and “unethical” actions. Students were asked about their technology and engineering experiences in school and at home, whether they could see themselves pursuing a career related to those fields in the future, and why or why not. Students were also asked to discuss specific aspects of the design challenge experience in greater detail, including what it was like to collaborate with other students.

Data Analysis

For the purposes of this pilot study, the analysis of data was focused mainly on gathering insights toward improving the instructional design, research design, and data collection strategies. Analysis proceeded through repeated viewings of video data and listening sessions of interview audio, as well as transcription of selected segments of interest. Segments were selected on the basis of their relevance to research questions, as well as the indications they provided about potential improvement of the study itself. Artifacts of student work were also analyzed for indications of students' understandings of the content, as well as their attitudes and foci of concern. Pre- and post-activity assessments were treated as additional pieces of qualitative data to triangulate with interactional and interview data (Mathison, 1988).

Preliminary Findings

1. What do students engaged in an "ethical design" challenge learn about the STEM content related to autonomous vehicles and about ethics and ethical questions?

Students in this pilot showed evidence of learning about the technology used in autonomous vehicles, as well as some of the potential social consequences of this technology. All three students self-reported greater understanding about how self-driving vehicles work on the post assessment compared to the pre assessment. They also provided greater detail and accuracy in their open-ended explanations on the post assessment than on the pre assessment. For example, before the workshop, Melia wrote, "I'd probably say it's like auto-pilot for a car." After the workshop, she wrote, "Basically a self-driving vehicle is something that drives or operates itself by using programs and software to help navigate it around." The second response is slightly more comprehensive due to its inclusion of software as a factor.

Before the workshop, Miguel wrote, "They use a GPS to tell them where to go," and after the workshop he wrote:

> The car has a sensor at the top that scans its soroundings. The data it collects help it make a picture of whats around and it puts it in catagories like red boxes are for normal cars and small blue boxes are for byciclist. It also knows what color the start light is it also knows what to do because if its something it seen befor he'll respond the same and if its new it'll make a new memory for it.

Miguel's post response refers extensively to the role of sensors and other details from the video they watched on the first day. For example, the red and blue boxes refer to ways that the Google autonomous vehicle makes sense of forms in its environment and classifies them as certain kinds of entities, such as other cars, bicycles, or pedestrians.

Jillian's pre response said merely, "It drives itself." On the post assessment, she expanded on this significantly, writing, "The self-Driving car can drive itself, without the need of a human driver. It will prevent a lot of car accidents (drunk driving, texting while driving). It's from google."

Evidence from the pilot suggests that the students had more difficulty in understanding the meaning of "ethics" and identifying specific ethical issues related to this technology. In their interviews at the end of workshop, the students sometimes struggled to define ethics and give examples of ethical and unethical actions. Other times they gave inaccurate or incomplete definitions of these ideas. For example, Melia and the researcher had this exchange during her interview.

TV: What do you think ethics means?

Melia: Ethics? Well ethics I think kinda just sticks to one certain type of thing I guess. It's kind of a way to tell people how to like try and get people's trust I guess. And work towards mmn making people believe what you say in an ethical way I guess?

TV: So what would be an example of something that is ethical and then something that's not ethical?

Melia: So I guess an example of something ethical would be someone telling you how something is um... very good, with a very good type of word choice, with good facts to back it up, versus someone telling you of the same product but doing it in a totally different way of just trying to get you to buy it and not telling you what it generally does.

In this excerpt, Melia seems to relate ethics to the idea of transparency. She uses the example of someone selling a product and suggests that an ethical salesperson would explain what it does and give "facts to back it up," so that people can trust the claims being made.

Miguel and Jillian seemed less sure. Miguel asked in response to the interviewer question, "Is like ethical something logic?" Jillian admitted, "I don't know what it means. Coming here was the first time that I heard what it meant, because... So I thought it was like um what the good and the bad to it?" For Jillian, the concept of ethics related to positive and negative consequences of something. She later elaborated, saying, "The good is that it's gonna prevent like car accidents like drunk driving and then texting while driving."

The students' incomplete and sometimes inaccurate understandings seemed to be reflected in the focus they pursued in their design work. The students decided to pursue a design problem focused on safety and transparency. Jillian later related in her interview that the group had struggled in determining what problem to solve with their design, and that Melia had strongly pushed for this angle. This claim is plausible given that the problem statement they developed seems related to the definition of "ethics" Melia provided in her interview.

Figure 1. Miguel, Melia, and Jillian work on the car prototype.

The prototype the students built included features that also emphasized transparency and trust, along with safety. For instance, the car had seats that faced the center of the car, since there was no need for a driver seat facing forward (Figure 1). However, to make the behavior of the car more transparent to passengers, the students designed a video screen that would show a view out the front of the car for those facing backward.

2. Does engaging diverse students in an “ethical design” challenge help them see themselves as people who can participate successfully in STEM fields?

Data were inconclusive with regard to whether the design challenge improved students’ interest and identification with STEM fields. Pre and post questionnaires provided mixed evidence, and while the students’ final interviews included some evidence of interest in pursuing STEM-related activities and careers in the future, the students also expressed in several instances that these interests preceded their participation in the workshop, at least in some form. In addition, students’ incomplete and inaccurate understandings of ethics make it even more difficult to draw conclusions about the effects of an ethical frame on learning in design-based STEM learning environments.

3. How do learners collaborate and negotiate with one another regarding the design task and the ethical issues involved?

Due to environmental noise and the students’ low speaking voices during group discussions and collaborative activities, it was very difficult to distinguish what they were saying during significant sections of the workshop. In this social context the students were also sometimes very reticent to talk and reluctant to collaborate. These issues can be addressed through data collection strategies and the appropriate selection of participants and settings in future iterations of this research, which I describe in greater detail below.

4. What are the differences in student learning and activity between a design thinking-oriented challenge and a more traditional engineering design challenge based on the same ethical premise?

Because this pilot only included one of the two planned conditions, it is impossible to make claims related to this research question. While many students had expressed interest during the recruitment phase, only one student arrived for the bus on the first day of the first condition. As a result, one of the two-day workshop conditions was cancelled for the pilot phase, and additional recruitment effort was put into ensuring students would be able to participate in the remaining workshop two days later.

Limitations and Future Work

Participants and Setting

Recruitment was a major challenge encountered in this pilot study. It seems likely that part of the challenge related to the timing of the workshops during the summer break between school years and the location outside of the student's neighborhood. In addition, for a short intervention, the social challenges of engaging in something totally new with unfamiliar people may have proved too difficult, potentially hampering the students' comfort in collaboration.

In future work related to this project, I plan to explore the possibility of conducting the study during the normal school day with the cooperation of a collaborating teacher. In this kind of setting, students would already be familiar with each other and likely have some experience working collaboratively in groups.

Data Collection

Due to the poor quality of audio in the video recordings of student interaction, it was not possible to answer all of the research questions in this project. I have since been working with members of a video analysis interest group to explore additional strategies for video data collection, including camera and microphone hardware options and in-room arrangements that should make it easier in future iterations of this work to capture the nuances of student interactions in the various contexts of activity explored in this work: at table groups, brainstorming at a wall, and working on physical prototypes.

Support for Learning Ethics Content

Students in this pilot study struggled with the conceptual complexity of ethics and ethical problems. In future work, I will simplify this content by avoiding unnecessary jargon, and providing opportunities for students to explore these concepts more deeply. For instance, students' understandings may be better supported with additional or better examples of ethical questions or more curated learning media that effectively highlight the kinds of ethical tradeoffs that may be at stake with emerging autonomous vehicle technology.

Conclusion

While this pilot study was not able to provide answers to all of the project's questions, it did show promise for this line of research. Students showed evidence of important technology and engineering content learning related to autonomous vehicles, and they also made connections to some of the important social issues that may arise as this technology matures and becomes more widespread. Students will likely need additional support for exploring and understanding the ethical concepts introduced in this learning activity, which will allow for more complete research findings as the instructional and research design is improved in a future version of this study.

References

Bers, M. U. (2001). Identity construction environments: Developing personal and moral values through the design of a virtual city. *Journal of the Learning Sciences*, *10*(4), 365–415.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education*, *29*(1), 37–53.

Carroll, M. P. (2014). Shoot for the moon! The mentors and the middle schoolers explore the intersection of design thinking and STEM. *Journal of Pre-College Engineering Education Research*, *4*(1).

Civil, M. (2016). STEM learning research through a funds of knowledge lens. *Cultural Studies of Science Education*, *11*(1), 41–59.

Coyle, E. J., Jamieson, L. H., & Oakes, W. C. (2005). EPICS: Engineering projects in community service. *International Journal of Engineering Education*, *21*(1), 139–150.

The Editorial Board. (2014, October 4). Silicon Valley's Diversity Problem. *The New York Times*. New York, NY.

Esmonde, I., Blair, K. P., Goldman, S., Martin, L., Jimenez, O., & Pea, R. (2012). Math I Am: What we learn from stories that people tell about math in their lives. In B. Bevan, P. K. Bell, R. Stevens, & A. Razfar (Eds.), *LOST learning: Learning about out-of-school-time learning opportunities* (pp. 1–21). New York, NY: Springer.

Feenberg, A. (1999). *Questioning Technology*. New York, NY: Routledge.

Goldman, S., Vea, T., Bullock Zielezinski, M., Bachas-Daunert, S., & Kabayadondo, Z. (2015). Reconsidering engineering in middle school: Integrating design thinking and STEM content. In *American Educational Research Association Annual Meeting*. Chicago, IL.

Google. (2016). Diversity. Retrieved March 10, 2016, from http://www.google.com/diversity/index.html#chart

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2009). Problem-Based Learning Meets Case-Based Reasoning in the Middle School Science Classroom: Putting Learning by Design™ Into Practice. *Journal of the Learning Sciences*, *12*(4), 495–547.

Lin, P. (2013). The Ethics of Autonomous Cars. *The Atlantic*. Retrieved May 12, 2015, from http://www.theatlantic.com/technology/archive/2013/10/the-ethics-of-autonomous-cars/280360/

Mathison, S. (1988). Why Triangulate? *Educational Researcher*, *17*(2), 13–17.

Medin, D. L., & Bang, M. (2014). *Who's asking?: Native science, Western science, and science education*. Cambridge, MA: MIT Press.

Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). Racial and Ethnic Minority Students' Success in STEM Education. *ASHE Higher Education Report*, 36(6), I–140.

National Science Foundation & National Center for Science and Engineering Statistics. (2015). *Science and Engineering Degrees, by Race/Ethnicity of Recipients: 2002-12*. Detailed Statistical Tables NSF 15-321. Arlington, VA.

Payton, J., Barnes, T., Buch, K., Rorrer, A., & Zuo, H. (2015). The effects of integrating service learning into computer science: an inter-institutional longitudinal study. *Computer Science Education*, *25*(3), 311–324.

Pea, R., & Martin, L. (2010). Values that occasion and guide mathematics in the family. *National Society for the Study of Education Yearbook*, *109*(1).

Roth, W.-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York, NY: Routledge.

Sanderson, P., & Vollmar, K. (2000). A primer for applying service learning to computer science. *ACM SIGCSE Bulletin*, *32*(1), 222–226.

United States Census Bureau. (2015). United States QuickFacts. *U.S. Department of Commerce Website*. Retrieved March 29, 2016, from http://www.census.gov/quickfacts/table/RHI125214/00

Urmson, C. (2016). Report of traffic accident involving an autonomous vehicle. *California Department of Motor Vehicles Website*. Retrieved March 20, 2016, from https://www.dmv.ca.gov/portal/wcm/connect/3946fbb8-e04e-4d52-8f80-b33948df34b2/Google+Auto+LLC+02.14.16.pdf

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