# EVALUATION OF ENGINEERING ETHICS PROGRAMS IN HIGHER EDUCATION FOR BETTER EQUIPPING STUDENTS IN A DATA-DRIVEN WORLD

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The past decade has offered an explosion in the amount of available data. The applications of data are limitless and can help firms hire new employees, stores optimize their spending, local governments develop safer emergency evacuation plans, and even individuals track their health data. Taking advantage of available data, the technical report coupled with this STS research will monitor how safely and eco-friendly the Facilities Management vehicle fleet at the University of Virginia is driving with the goal of improving overall fleet performance in both of these categories. The study will monitor driver performance in a variety of metrics in order to evaluate the most effective training programs. The technical report was written together with Grace Parzych, Ryan Ahmadiyar, Jenny Chun, Caroline Fucella, and Benjamin Weisel and under the advising of Professor Brian Park.

Increasingly, the world is seeing the use of data on people to create programs, algorithms, and judgement calls on a regular basis (O'Neil, 2018). Because such practices are so recent and because engineering education has historically not stressed the value of ethics, there has been a disconnect between engineering design of such technologies and their consequences on users. For example, companies and governments use of algorithms has led to racist policies and practices. The rise in journalistic reporting on these issues has further emphasized the need for change (Joyce et al., 2018, p.2). As a result, this report is closely coupled with an STS analysis into engineering ethics education and specifically attempts to answer the research question of which engineering ethics programs should US public universities employ in order to best train the next generation of engineers.

The STS research question attempts to analyze an ongoing controversy and is relevant because of the lack of existing ethics education in engineering schools all across the US. Public universities in the US do not use a cohesive engineering ethics curriculum. The research for this report will look into specific examples of ethics curricula as well as what experts, such as ABET, discipline specific accreditors, like the American Society of Chemical Engineers (ASCE), and leading STS scholars argue is the best solution. To further reinforce expert opinion about the controversy, each suggested curriculum will be looked at through the STS lenses of the Social Construction of Technology model as well as a social construction framework. The Social Construction of Technology (SCOT) model was developed by Wiebe Bijker and Trevor Pinch as part of their social construction of facts and artifacts article published originally in 1984. The social construction framework is a subset of SCOT and was developed by Bernard Carlson as part of his own variation of the social construction model (Carlson, 2009).

## METHODOLOGIES FOR ETHICS PROGRAM EVALUATION

In order to best answer the research question, this report will be broken down into three distinct sections. First, there will be an analysis of the current engineering ethics education status. It is important to understand where public university engineering ethics programs are at the moment and what factors led to such a position. Existing comparative ethics programs will be delineated using the SCOT framework

Second, this report will examine new and emerging ethics education among engineering programs. Within this section this report will explore what experts, such as the ASCE or accreditors, propose are the right solutions to improve engineering ethics education. As before, there will be exploration of the standout suggestions through STS lenses in order to further understand their validity.

Finally, in an integrated format, this report will synthesize the different options in order to reach a more cohesive conclusion. It is important to note that the ultimate findings will not be based on the claims of this report, rather what accreditors and experts deem the best solution. However, this report will contribute an added layer of evaluation through STS analysis. While the focus of the report is on improving engineering ethics education at public universities in the US, much of the research and investigation will pull from examples abroad. In many instances, programs abroad are designed in ways that could translate well to the system in the US.

## UNDERSTANDING CURRENT ENGINEERING ETHICS EDUCATION

For the past half century technology has been developing at an incredibly fast pace. While this has brought tremendous advances and improvements to society, it has also left a lot of people worse off and in the dust. Worst of all, even engineers and the designers behind new technologies are not ready nor aware of the tools they are developing. This is in large part due to the lack of robust and pragmatic ethics education. In the coming years it is imperative that ethics education among public engineering schools in the US becomes a widespread and thorough part of the curriculum. Moreover, engineering school ethics curricula need to be robust and effective at helping shape engineers for problems of the future and what new technologies will bring.

### ORIGINS OF ETHICS IN ENGINEERING EDUCATION

Most of current engineering ethics education in the US began following dramatic new accreditation requirements by the Accreditation Board for Engineering and Technology (ABET). The changes made by ABET, highlighted in their Engineering Criteria (EC) 2000 report, were the most significant reason why engineering programs adopted their education to include more ethics (Barry & Ohland, 2009, p. 380). According to ABET (2006), EC 2000 was first adopted in

1996 (Engineering Change: A Study of the Impact of EC2000, executive summary). It was criterion 3f of the original EC 2000 report (ABET 1996) that called for engineers to have ‘an understanding of professional and ethical responsibility’ (as cited in Foley & Gibbs, 2019, p.2). From here on out, ethics was a requirement for engineering students to learn. However, the ambiguous language of the requirement left the actual employment by universities loose and variable. This can lead to a failure of understanding in students which then translates to misunderstandings of ethics in their future careers. Melanie Jeske (2020) emphasizes what the consequences look like if poor ethics focus continues amongst engineering education. Right now, ethics is viewed as a box to check off or a hindrance to the process of engineering. This is especially pertinent as the line between industry and university research disappears more and there becomes a greater pressure to output products. For example, these products might be state-of-the-art medical devices or drugs (p. 310).

## WHAT ENGINEERING ETHICS COURSES CURRENTLY LOOK LIKE

Some of the most common ways in which engineering ethics education manifests itself are outlined in a systematic literature review conducted by Shen and Li (2021). Their findings show that a majority of ethics education is done through standalone courses and embedded courses (p. 721). Standalone courses involve a professor with expertise in philosophy or ethics teaching a semester long curriculum usually as an elective. This takes ethics out of the center of engineering education. Embedded courses are cases in which ethics is taught throughout a variety of engineering courses through small modules (Shen & Li, 2021). The most common forms of instruction within these courses include case studies and ethics criteria (p. 721). In addition, some universities employ online modules as their form of ethics instruction.

## STS ANALYSIS ON CURRENT SYSTEMS

Given what the research indicates, the most common ethics instruction that exists today based on the criteria that ABET put into place is standalone courses filled with case studies. Keeping in mind the goal given out by ABET, this form of instruction can be treated as a technology for a Social Construction of Technology (SCOT) analysis as first created by Bijker and Pinch. The different social groups relevant to such a form of instruction are limited and include the instructors, students, case study creators, and accreditors. While there might be more abstraction to include more social groups, such as those affected by what the students learn and carry forward, the more direct involvement and influence comes from those four. Immediately, a limitation is present in the sense that the development of the technology is limited. Ethics is inherently mixed into the real world and the responsibilities that it brings can't be fully grasped if the limits of the technology are kept to a small group. Students and professors might interact well and shape the interpretation and meaning that the cases they learn bring. However, this can become an echo chamber or process that is very limited and not translatable to real scenarios. Likewise, the accreditors involved in furthering the education don't have lots of involvement with the actual education process. The requirements they put in place, while noble, do not call for furthering of the educational process towards better results. This is also expressed by Bairaktarova and Woodcock (2015) who highlight that engineering ethics education became more focused on including some form of ethics in their curriculum as opposed to the actual effects that the curriculum had on students (p. 19).

On a similar note, when looking as current popular engineering ethics education through the social construction system developed by Carlson (2009), there is little space for two-way interaction. Effectively no one can provide feedback except the accrediting bodies. In this way, a lot of the potential improvements and value is lost.

## INVESTIGATING WAYS TO IMPROVE ENGINEERING ETHICS EDUCATION

There are a lot of proposals to improve the current state of engineering ethics education. The standard to which these programs are working towards is outlined in the most updated version of ABET's engineering criteria. ABET (2021) states that students must have "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (Criteria for accrediting engineering programs, 2022-2023, General Criteria*)*. It is this requirement to which ethics engineering should strive toward. The latter half of the statement is an update that should particularly be paid attention to because it truly requires more thorough instruction of students.

## WHAT EXPERTS SUGGEST THAT ETHICS COURSES SHOULD LOOK LIKE

For purpose of this research question, we will consider experts in engineering ethics instruction to be STS scholars, members of professional engineering boards, such as the ASCE, and general philosophers and ethicists with background and experience in academia. One such proposed reformation is based on a case study, led by Sunderland et al. (2014). Their program offers some initial insight into the importance of feedback and multiple voices in the design of ethics education. Doing so will allow ethics to become more embedded into the core of engineering curricula and not just the periphery (p. 228). Sunderland et al. created a pilot program to back their claim. *Global Perspectives: Engineering Ethics Across International and*

*Academic Borders* was a pilot educational program administered on graduate students in order to facilitate discussion about ethics in engineering from multiple perspectives and fields. The program was given to students from the University of California, Berkeley and Delft University of Technology (p. 229). The authors of the program relied on teaching emotion-driven ethics as it improved student engagement and empathy toward the issues. Student engagement was considered a combination of how much time and effort students put into their own education as well as how much time and resources educational institutions put into their students. As a result, developing a proper engineering ethics curriculum relies on student input (Sunderland et al., 2014, p. 230). Their pilot course also demonstrated the importance of collaboration between engineers and those in other fields. Placing everyone on the same level and allowing for open discussion places engineers in a position to actively discuss where there are holes in ethics education (p. 236).

More suggestions are explained by Safatly et al. (2020) in their article for the ASCE. After looking at over 40 different syllabi and 60 different ethics centers, they argue that effective ethics education gives students the opportunities to be in realistic scenarios themselves where they are taught and forced to make ethical decisions. These situations could be brought about by simulator. Safatly et al. explain that when students learn in such circumstances the effectiveness of teaching improves statistically significantly (p. 4). They also claim that taking the student outside the classroom is really beneficial at making sure ethics are understood and internalized better. Specifically, their findings show that ethics centers are an effective location and method for better teaching students ethics with lasting results (Safatly et al., 2020, p. 6).

Foley and Gibbs (2019) present another strong proposal for what engineering ethics education should strive toward. Their main argument is built behind orienting engineering ethics toward also considering macro-ethics and large-scale problems. In doing so, engineers can be more equipped to work in the real world where large-scale problems are their responsibility (p. 6). Their paper suggests different reasons and places where engineering as currently constructed fails and brings about massive problems. One note that the paper highlights is how integrated and complex engineering systems really are. Most engineering feats are not limited to one domain or one entity and as a result it is hard to pinpoint responsibility. For example, the hurricane Katrina disaster cannot be blamed on any one unit but at the same time everyone is to blame for the lack of systemic coordination and ethical design (Foley & Gibbs, 2019, p. 7). The article then suggests educational and pedagogical solutions to improving ethics education in universities. Foley and Gibbs ultimate proposal is a deeply embedded ethics curriculum such as the STS department at the University of Virginia where students take ethics courses embedded in their engineering program throughout nearly all their years of study. Such a system gives students exposure to both the macro considerations needed for ethical understanding in the future as well as the more traditional micro ethics situations on individual morality and decision making (p. 16). Foley and Gibbs add that the STS program at UVA was also approved by ABET in 2016, which further reinforces the validity of such a system at ethics education (Foley & Gibbs, 2019).

## STS ANALYSIS ON EXPERT RECOMMENDED SYSTEMS

For purposes of STS analysis, the ideal format that engineering ethics education should take is a system of embedded ethics programs into the curricula in which students have the opportunity to be exposed to those in other fields as well as realistic ethics scenarios. Furthermore, such a system would be fueled by consistent student feedback and input. Looking at this proposal through a SCOT lens there are a variety of different social groups that contribute towards the technology. As with what is already in wide effect for ethics programs, students, instructors, case study creators, and accreditors are relevant social groups. However, now there are other groups such as students in other fields, out-of-school ethics centers, ethics simulation designers, and department heads and creators. The technology has the chance to be shaped by more different social groups. In particular, it can lean toward more effective ethical teachings because of the greater interactions between different groups and the technology. As Figure 1 on page 9 shows, engineering education as a technology is shaped by different competing groups such as corporations, professors, and degree accreditors.

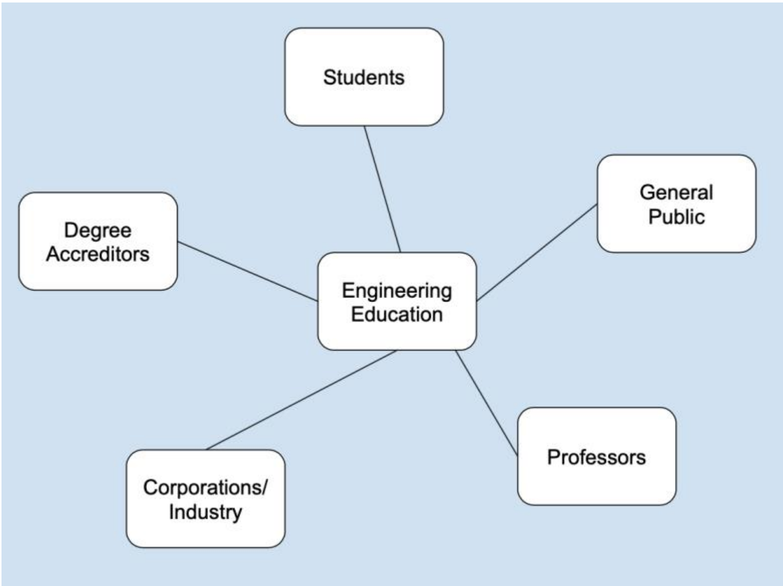


Figure 1 - Social groups and Engineering Education: SCOT model of relevant social groups that have an influence on engineering education. (Adapted by Hrnjez (2022) from Bijker, Pinch, 1984)

The above, expert-suggested, ethics education gives more influence to the social groups such as professors and students that promote more of an outcome in line with what accreditors are requiring. Corporations and industry have lots of their own influence and biases that might prevent ethical action on a large scale, such that might decrease the consideration of global, social, or environmental impact. Consequently, it is imperative for the other social groups to have more control in order to change the shaping of the technology. For example, in a system where student feedback is not only asked for but valued then the ethics education has even more room to improve and fine tune towards a sweet spot where its message and mission can get across. Ideally, education needs to be constantly changing and adapting towards the needs of the students. Student feedback is a clear way to promote this principle.

Likewise, figure 2 on page 10 demonstrates how the interaction between relevant social groups and the technology of engineering education is extremely important. Many ethics programs currently in place do not have a two-way feedback system with any social groups, especially professors and students. However, their interaction is just as important as the other social groups especially with the goal that ABET has laid out for engineering programs at public universities in the US.

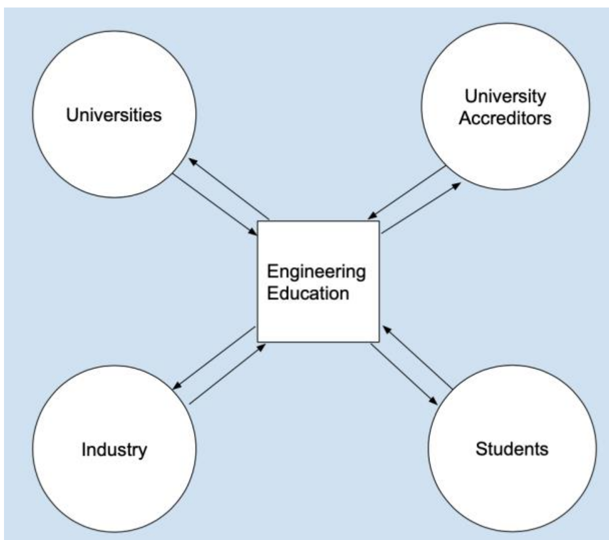


Figure 2 - Engineering education interactions: Social construction of engineering education with two-way interactions. (Adapted by Hrnjez (2022) from Carlson, 2009)

If industry or universities are the only interaction with the technology then it is very easy for the direction of engineering education to go towards their interests. However, for a changing world with more and more data, old systems with archaic principles cannot be the driving factor behind where the education goes.  Education needs to be dynamic in order to teach new groups of students, in order to understand what the generation is in need of. New generations need a lot more than what existed before and in a very different manifestation than before. The increase in data and its application is just one of many examples in which modern students might differ from those when the first ABET ethics requirement was published. With a clear interaction between curriculum and students and curriculum and professors the technology of education can properly update itself.

## MOVING ENGINEERING ETHICS EDUCATION FORWARD

With more and more data we will see more and more ethical issues arise. Engineers, as designers of the future, will need to be equipped more than anyone with the right ethical frameworks and morals. If engineers are trained properly in ethics, which ABET accreditation is increasingly stressing, then they will be ready to properly handle the micro and macro ethical challenges presented to them. Given expert opinion and STS framework analyses, structured by Bijker and Pinch’s Social Construction of Technology and Carlsons social construction adaptation, engineering ethics education should be built into engineering curricula as its own department with plenty of opportunity for student feedback, realistic engagement, and interaction with students of other disciplines.

Future considerations for this research question should analyze the limitations of such a suggestion and evaluate whether the costs from it outweigh what is gained. There is room for improvement in the suggestion and further expert opinion is needed in cohesion with ABET standards to understand whether such a system is scalable and applicable to all engineering programs. For example, purely engineering schools might operate differently than larger universities with engineering departments.

## REFERENCES


Accreditation Board for Engineering and Technology. (2021). *Criteria for accrediting engineering programs, 2022-2023.* https://www.abet.org/accreditation/accreditation criteria/criteria-for-accrediting-engineering-programs-2022-2023

Accreditation Board for Engineering and Technology. (2006). *Engineering change: a study of the impact of EC2000.* https://www.abet.org/wp content/uploads/2015/04/EngineeringChange-executive-summary.pdf

Bairaktarova, D., & Woodcock, A. (2015). Engineering ethics education: aligning practice and outcomes. *IEEE Communications Magazine*, *53*(11), 18–22. https://doi.org/10.1109/mcom.2015.7321965

Barry, B. E., & Ohland, M. W. (2009). Applied ethics in the engineering, health, business, and law professions: A comparison. *Journal of Engineering Education*, *98*(4), 377–388. https://doi.org/10.1002/j.2168-9830.2009.tb01034.x

Bijker, W.E., & Pinch, T.J. (1984). Social groups and Engineering Education [Figure 1]. The social construction of facts and artifacts. *Social Studies of Science*, 14, 399-441.

Bijker, W.E., & Pinch, T.J. (1984). The social construction of facts and artifacts. *Social Studies of Science*, 14, 399-441. https://doi.org/10.1177/030631284014003004

Børsen, T., Serreau, Y., Reifschneider, K., Baier, A., Pinkelman, R., Smetanina, T., & Zandvoort, H. (2020). Initiatives, experiences and best practices for teaching social and ecological responsibility in ethics education for science and engineering students. *European Journal of Engineering Education*, *46*(2), 186–209. https://doi.org/10.1080/03043797.2019.1701632

Bucciarelli, L. L., & Drew, D. E. (2015). Liberal studies in engineering – a design plan. *Engineering Studies*, *7*(2-3), 103–122. https://doi.org/10.1080/19378629.2015.1077253

Carlson, B. (2009). Engineering education interactions. [Figure 2]. *Class handout* (Unpublished). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Foley, R., & Gibbs, B. (2019). Connecting engineering processes and responsible innovation: A response to macro-ethical challenges. *Engineering Studies*, *11*(1), 1-25. https://doi.org/10.1080/19378629.2019.1576693

Hess, J. L., Kerr, A. J., Lin, A., & Fore, G. A. (2020). WIP: Synthesizing exemplary engineering ethics education efforts. *2020 IEEE Frontiers in Education Conference (FIE)*. https://doi.org/10.1109/fie44824.2020.9274159

Hrnjez, D. (2022). *Social groups and Engineering Education*. [1] *STS Research Paper:*

Evaluation of Engineering Ethics Programs in Higher Education for Better Equipping Students in a Data-Driven World (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA

Hrnjez, D. (2022). *Engineering education interactions*. [2] *STS Research Paper:* Evaluation of Engineering Ethics Programs in Higher Education for Better Equipping Students in a Data-Driven World (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA

Jeske, M. (2020). Lessons from Theranos: Changing narratives of individual ethics in science and engineering. *Engaging Science, Technology, and Society*, *6*, 306-311. https://doi.org/10.17351/ests2020.411

Joyce, K.A., Darfler, K., George, D., Ludwig, J., & Unsworth, K. (2018). Engaging STEM ethics education. *Engaging Science, Technology, and Society, 4*(1), 1-7. https://doi.org/10.17352/ests2018.221

Klein, J. D. (2015). Teaching and learning limits in engineering education. *Engineering Studies*, *7*(2-3), 135–137. https://doi.org/10.1080/19378629.2015.1062494

Martin, D. A., Conlon, E., & Bowe, B. (2021). Using case studies in engineering ethics education: the case for immersive scenarios through stakeholder engagement and real-life data. *Australasian Journal of Engineering Education*, *26*(1), 47–63. https://doi.org/10.1080/22054952.2021.1914297

Ocone, R. (2013). Engineering ethics and accreditation. *Education for Chemical Engineers*, *8*(3), e113–e118. https://doi.org/10.1016/j.ece.2013.07.002

O'Neil, C. (2018). *Weapons of math destruction: How big data increases inequality and threatens democracy*. Penguin Books.

Safatly, L., Itani, M., Srour, I., & El-Hajj, A. (2020). A comprehensive overview of approaches to teaching ethics in a university setting. *Journal of Civil Engineering Education*, *146*(2), 040200011-040200019. https://doi.org/10.1061/(asce)ei.2643-9115.0000009

Shen, J., & Li, H. (2021). The "real images" of engineering ethics education: an analysis based on systematic literature review (SLR). *2021 IEEE Global Engineering Education Conference (EDUCON)*. https://doi.org/10.1109/educon46332.2021.9454004

Sunderland, M. E., Taebi, B., Carson, C., & Kastenberg, W. (2014). Teaching global perspectives: Engineering ethics across international and academic borders. *Journal of Responsible Innovation, 1*(2), 228-239. https://doi.org/10.1080/23299460.2014.922337

Tomblin, D., & Mogul, N. (2020). STS Postures: Responsible innovation and research in undergraduate STEM education. *Journal of Responsible Innovation, 7*(sup1), 117-127. https://doi.org/10.1080/23299460.2020.1839230