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High School STEM Teacher Perspectives on the Importance and Obstacles to Integrating Engineering Ethical Issues in Their Courses

Jake Walker Lewis,

Graduate of the University of Colorado Boulder with a bachelor's degree in environmental engineering and a master's degree in civil engineering. Was involved with undergraduate research regarding ethics in engineering education, presented work in the form of a poster at the 2018 Zone IV ASEE Conference. Defended and published master's thesis examining if/how ethics are being introducted in K12 STEM education in November 2019. Co-authored paper entitled "Educating Civil Engineering Students about Ethics and Societal Impacts via Cocurricular Activities." This paper was recognized by the Journal of Professional Issues in Engineering Education and Practice as an Editor's Choice. Currently working with Dr. Angela Bielefeldt as a research assistant. Preparing to submit three papers regarding ethics in engineering education as co-author at the 2020 ASEE Annual Conference & Exposition.

Dr. Angela R. Bielefeldt, University of Colorado Boulder

Angela Bielefeldt is a professor at the University of Colorado Boulder in the Department of Civil, Environmental, and Architectural Engineering (CEAE) and Director for the Engineering Plus program. She has served as the Associate Chair for Undergraduate Education in the CEAE Department, as well as the ABET assessment coordinator. Professor Bielefeldt was also the faculty director of the Sustainable By Design Residential Academic Program, a living-learning community where students learned about and practice sustainability. Bielefeldt is also a licensed P.E. Professor Bielefeldt's research interests in engineering education include service-learning, sustainable engineering, social responsibility, ethics, and diversity.

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Abstract

Engineering topics are increasingly being integrated into K-12 STEM education. The Next Generation Science Standards (NGSS) integrate engineering topics into science education, including outcomes such as defining engineering problems, designing solutions, and the influence of engineering, technology, and science on society and the natural world. The NGSS make no explicit mention of ethics in the context of engineering, although the societal and environmental impacts regarding engineering are considered to be macroethical themes. Although Colorado adapted the NGSS in K-12 education statewide, the engineering standard was not adopted. It was of interest to determine whether Colorado high school teachers believe that it is important to integrate ethical and/or societal issues into STEM courses they teach, and any obstacles they perceived to this integration. This exploratory research interviewed 14 STEM teachers from 13 different high schools in Colorado, including 7 who primarily taught engineering. Interview transcripts were analyzed using emergent coding methods. Most teachers believed that ethics, environmental, and/or societal impacts (EESI) are important in high school STEM education. The extent of importance and why EESI was believed to be important varied among the teachers, with some teachers viewing environmental/societal impacts and ethics as congruent, and others viewing these as distinct and having different importance. Each teacher interviewee identified one or more obstacles to engineering ethics integration. The obstacles fell into seven categories. For all seven, one or more teachers described these as challenges that were able to be overcome. However, five of these obstacles were considered barriers that were not presently being overcome for one or more teachers (e.g. teaching standards, comfort level, negative perceptions by students and/or parents, students struggle to understand ethics). The research findings indicate that incoming engineering students may have different views about the importance or lack of importance of ethical issues in the engineering design process, and highlights opportunities to enhance the integration of EESI into high school STEM education.

Introduction

Engineering is increasingly being integrated into K-12 education [1,2]. In 2018, 57% of American students in eighth grade indicated that they had taken or were taking one or more classes related to engineering or technology, an increase from 52% in 2014 [3]. Engineering may be taught as a stand-alone topic or integrated with other STEM (science, technology, engineering, and mathematics) fields [1]. As a result, many students entering engineering majors in college are likely to have some knowledge and/or preconceptions about engineering. It is important that from the beginning, students understand the important role of ethics in engineering.

Engineering ethics includes both microethics and macroethics. Microethics encompasses individual responsibilities (such as avoiding bribery and issues such as cheating in an academic setting), while macroethics are the larger responsibilities of the engineering profession such as concern for environmental and societal impacts from the practice and application of engineering [4]. In this paper we will refer to the breadth of microethics and macroethics as EESI (ethics and environmental/societal impacts). Engineering codes of ethics endorsed by professional societies

embody the responsibility of engineers to consider broader societal and environmental issues in their work. For example, the recently updated code from the American Society of Civil Engineers (ASCE) explicitly identifies a hierarchy of responsibility to five distinct stakeholder groups, society being first (including protection of public health, safety, and welfare) and the natural and built environment second (including adhering to principles of sustainable development) [5].

One driver for the integration of engineering in K-12 settings is the Next Generation Science Standards (NGSS) [6]. The NGSS includes the four topics of life science, earth & space science, physical science, and engineering design. Cross-cutting practices integrate engineering-related concepts into the sciences such as defining problems, critical analysis, and iterative design, while the "influence of science, engineering, and technology on society and the natural world" is another theme. Although there is little to no explicit integration of ethics into the NGSS, two points are related at the high school level: (1) "society is influenced by science and engineering" and (2) "scientific knowledge indicates what can happen… not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge" [6, vol. 2, pg. 100]. The NGSS is a common driver for K-12 education in many states. "Twenty states and the District of Columbia (representing over 36% of U.S. students) have adopted the NGSS," while "24 states (representing 35% of U.S. students) have developed their own standards based on [the NGSS]" [7].

EESI integration in STEM education before eighth grade could be evaluated in part by the National Assessment of Educational Progress (NAEP) Technology & Engineering Literacy (TEL) exam [8]. One of the three areas assessed on the TEL is "technology and society" defined as "the effects that technology has on society and on the natural world and the ethical questions that arise from those effects." The average score on this topic among eighth graders who took the assessment in 2018 was 152 [3], which is just below the cut score of 158 associated with a proficient level of knowledge (e.g., "explain how technology and society influence each other by comparing the benefits and limitations of the technologies' impacts") [8]. The average technology & society scores were similar to scores on the TEL practices (e.g., developing solutions and achieving goals) and content areas (e.g., design & systems). The assessment results in 2018 affirmed that students who had taken one or more engineering or technology classes performed better on the TEL assessment overall (results specific to the technology and society sub-score were not provided). Unlike topics such as math and science, the TEL exam is not administered to 12th graders, so it is unclear to what extent TEL achievement might increase in high school.

In high school STEM courses, it is unclear to what extent there is a focus on EESI. Teachers have quite a bit of autonomy, regardless of standards (especially those teaching in private and charter schools where STEM curriculum can vary from the regulated curriculum of public schools). Research in higher education found that many professors talked about obstacles to integrating ethics into engineering education [9, 10], and it was of interest to see if similar or different obstacles would be described by high school STEM teachers.

As an exploratory study, the authors elected to examine engineering ethics integrations into high school STEM education within Colorado, by interviewing teachers at different kinds of schools.

This choice was made based on some pre-existing contacts and the ease of data collection. In Colorado, public institutions must meet the Colorado Academic Standards, established by the Colorado Department of Education [11]. Regarding the subject areas included in these standards, mathematics, science, and computer science are defined while engineering is omitted. Colorado therefore represents one of the states that developed their own standards based on the NGSS, with full adoption of the science and mathematics areas. There are differences in the extent these standards must be met between public, private, and charter high schools. In Colorado, non-public institutions are defined by the Colorado Department of Education as "a private business" where "neither the State Board of Education nor any local board of education has jurisdiction over the internal affairs of any non-state independent or parochial school in Colorado" [12]. Thus, non-public institutions have optional accreditation, no requirements on registration, optional licensing, and do not require teacher licensure when hiring instructors. They are still required to enroll students of comparable ages to public institutions and include curriculum addressing basic academics, including but not limited to science, mathematics, history, civics, literature, and the communication skills of reading, writing, and speaking [13]. In Colorado, charter schools are defined as "public schools that operate via a contract with an authorizer such as the local school district or, in some cases, the Colorado Charter School Institute" [14]. This allows charter institutions more relevant agency at the school level, operating in organizations mirroring public school districts but self-contained. Note that because charter and private institutions do not necessarily need to meet the same standards as public institutions, data on non-public institutions regarding graduation rates and student demographics are often unavailable.

Research Questions

The research reported in this paper examines two main questions:

RQ1. How do high school teachers engaged with engineering/STEM classes view the importance of environmental/societal impacts and/or ethics integration?

RQ2. What obstacles are perceived by high school STEM teachers to integrating environmental/societal impacts and/or ethics into their classes?

Methods

This preliminary research used Colorado as a case study. Colorado adapted the NGSS by electing not to adopt the engineering standard [11]. The data to answer these research questions was derived from interviews with 14 Colorado high school teachers instructing STEM-based courses. Details on the research methods are provided in [15]. All research was conducted in accordance with IRB Protocol #19-0263 which was approved by the Institutional Review Board for Human Subjects Research at the University of Colorado Boulder.

Data Collection

Interview invitation emails were sent to high school STEM teachers in May, August, and September 2019, with a subject heading of "high school engineering study", and invited participation in "research exploring the extent to which engineering integrated into K-12 settings includes elements of societal impacts or ethics." Teachers were sent an initial invitation and one or two reminders. Participants were provided $50 Amazon e-gift cards to compensate them for their time.

Semi-structured interviews were conducted with each teacher via phone or Skype, lasted 30-60 minutes, and were audio recorded. The interview protocol asked each teacher the same base questions but allowed for varying follow-up questions regarding their responses. Early questions in the interview prompted teachers to describe the courses they taught, how they integrated engineering topics into their teaching, and if/how they included societal, environmental, and ethical issues into their classes. Near the end of the interview, teachers were asked "Do you personally believe that K-12 [engineering/STEM] programs should integrate ethics and/or societal and environmental impacts?" (to answer RQ1). The wording of the question was modified during the interview depending on whether the teacher primarily taught engineering courses or not, to avoid confusion or misinterpretation of the question. As a follow-up question, teachers were asked "Are there any challenges or barriers to this integration?" (to answer RQ2). The teachers were also asked to self-select a pseudonym, and these are used in discussing the results.

Participants

The contact emails for high school STEM teachers in Colorado were compiled from online school directories, looking explicitly for individuals teaching engineering, computer science, or other STEM courses. The teachers identified through the online directories represented 67 public schools in 15 districts, 7 private schools, and 12 charter schools (with the private and charter schools in similar geographic areas as the public schools). The 15 public school districts were intentionally selected from among the 178 in Colorado to encompass urban, sub-urban, and rural areas of the state. Only a small percentage of the 641 high schools in Colorado (519 public, 42 charter, and 90 private) were represented by the sample. Research participation invitations were sent to 46 engineering teachers and 48 non-engineering teachers, leading to interviewing 7 engineering teachers and 7 non-engineering teachers.

The demographic characteristics of the 14 STEM teachers interviewed are summarized in Table 1. These teachers represent 13 different schools (8 public, 3 public charter, 1 private religious, and 1 private nonsectarian). These schools spanned eight different districts/geographic areas in Colorado. As an indicator of the average socioeconomic status of the students attending the schools, the percentage of students eligible to receive free or reduced cost lunches ranged from 4% (Joelle's school) to 86% (Palden's school). The overall 4-year graduation rates from the high schools ranged from 82% (Allison's school) to 98.6% (Joelle's school). Seven of these teachers primarily taught engineering courses, five science (biology, life science and physics), one computer science, and one mathematics. The extent of teaching experience ranged from 3 to 25 years. Five of the teachers had bachelor's degrees in engineering and five had prior work experience as engineers/computer programmers. Eight identified as male and six female.

Data Analysis

Transcripts were made from the audio recordings of the interviews, assisted by the online software Trint. For RQ1, both authors explored the teacher statements related to the importance of ethics and environmental/societal impacts. The extent that the teachers discussed the importance of these topics and why was evaluated through a negotiated process. The analysis was complicated by the fact that the teachers differed in how they defined ethics; for example, some appeared to limit their definition to microethics while others focused more on macroethics (for more information see [15, 16]). For RQ2, the types of obstacles described by the teachers

were analyzed using emergent, thematic coding [17]. The first author led this effort, then the two authors negotiated the initially defined codes. Both authors applied the codes to all of the transcripts, and negotiated any discrepancies. After identifying difference types of obstacles, the authors realized that the language around those obstacles varied, whereby some teachers seemed to consider them barriers (too difficult to overcome) or simply challenges (which the teacher characterized as posing a difficulty that they were able to surmount). The characterization of each teacher as perceiving the obstacles as barriers versus challenges was again negotiated by the two authors through discussion.

Table 1. Characteristics of high school teachers

Pseudonym	Subject primarily taught	Years teaching	School type	Degrees	Years work as engr/CS
Allison	Science	20	Public [F]	BS, MS Sport Sci	0
David	Engineering	15	Public [f]	BS Physics Edu, MS Technol Edu	0
Jeff	Engineering	6	Charter [f]	BS Civil Engineering	10
Jimmy	Engineering	23	Private [u]	BS Engrg, MA Science Education	5
Joelle	Science	20	Public	BS Biology, M.Ed. Leadership	0
Larry	Math	25	Public	BS Math Education	0
Lori	Science	3	Priv Relig [u]	BS, PhD Chemical Engineering	5
Michael	Computer Science	15	Public [f]	MS Computer Science	18
Olivia	Engineering	15	Public [f]	BS Biomed Eng, MS Biology	0
Palden	Science	10	Charter [F]	BS Physics, MS Atmospheric Sci	0
Paul	Engineering	15	Public	BS Civil Eng, ME Energy Eng, MEd Math Ed	10
Renae	Science	5	Priv Relig [u]	(unknown)	0
Ron	Engineering	8	Charter [F]	BA Physics, MS Math Edu	0
Simon	Engineering	6	Public	PhD Physics	0

Percentage of students eligible for free/reduced lunch: [F] >50%, [f] 25-50%, [u] unknown

Results and Discussion

RQ1. Importance

The teacher interviewees had varied perspectives regarding the importance of environmental/ societal impacts and/or ethics (EESI) integration in high school STEM courses. This included both the level of importance and why these topics should be included in K-12 education. Below are some examples of this breadth, including quotes in the words of the teacher interviewees.

Joelle, a biology teacher at a public high school, felt that EESI was very important.

> It's important, super important, because these are issues that people are going to be voting about, making decisions as members of society. So, I think it's super important, but I also think it's important that the teacher teaches. It's important we teach the science and allow students explore arguments on both sides, but that we allow students to develop their own opinion and we give them that freedom to do that. And in encouraging them to have conversations with their parents. In the work I assign, it allows their parents to have a voice in the process as well. And because I give the parents a voice I don't have issues with parents being upset about topics that I am teaching because they are given the opportunity to talk about their family values and their personal values around that with their child.

Joelle described why the inclusion of these topics is important and explains that it must be done in a conscious manner. Her response alludes to a potential obstacle (parental resistance) and how she overcomes this challenge. Her response is an example of a teacher viewing an obstacle as being able to be overcome or otherwise addressed, leading us in this research to classify it as a challenge rather than a barrier.

Allison, an environmental science teacher, provided a different perspective on why EESI is important, but contrasts the teaching that she believes occurs in the engineering versus science courses at her public high school.

> It all depends on the program I guess. I would say our engineering program… I don't think they will be getting into many ethical discussions…. But in a science course, like our biology classes with genetics and stem-cell research, they talk about the ethics. In my environmental science class… I think it's appropriate. You should always be talking to kids about ethics because it's like Spider Man. 'With great power comes great responsibility.' And this technology can be very powerful, it's important to make sure you are using it appropriately. …. So, we need kids that can think in terms of not what can you do but what should you do.

David, an engineering teacher, echoed this "should" perspective, describing at length why EESI was very important.

> …so often in engineering the question is asked 'can we do this?' And it seems often times that is the only question. And I think the question of 'should we do this?' should be tied into that as well. And so, the discussions [in class] on should we do something versus can we do something tend to be more rich.

Near the end of the interview, David described the importance that EESI integration helps make things interesting for students and therefore motivates their learning:

> … given what I teach has a huge emphasis on social impacts and ethical impacts and environmental impacts, I can see the value in that students really get into it. They personalize it a lot more. They care about it a lot more when there's ethical considerations incorporated into it… [Students] would have a lot more buy-in in the content if they're thinking about "What are the impacts of that?" … And I think it would help improve student engagement with just a little bit of conversation around that…

A somewhat different perspective on ethics implementation came from Paul, an engineering teacher.

> Interviewer: Well, do you personally believe that K-12 engineering programs should integrate ethics?
>
> Teacher: Yeah. When you are just doing your homework or class assignments, if you have a kid who is going to copy, there is an ethical dilemma between the student and academic dishonesty. And the same is true in engineering. If you fudge a number and it comes back to that design that you forged a number or lowered a factor of safety in the calculation just so you don't have to go through the reiteration again, that's an ethical issue. Those are little things that actually could matter and you [the teacher] are responsible just getting [the students] to think that their purpose is providing something for the public in a safe and effective way. Essentially what engineering is.

Paul gives examples of microethics and emphasizes safe and effective engineers.

Finally, Ron was an engineering teacher who distinctly separated environmental/societal impacts from ethics:

> Societal and environmental impacts absolutely [should be implemented]. As far as ethics goes, I think it's worth considering. I think it is definitely important for K-12 engineering programs to help students realize that every choice they make has repercussions. That's a good lesson for our kids to learn in every part of their life, but especially engineers because engineers have power that is magnified throughout their projects. An engineer of something small and inconspicuous could eventually be used to do something catastrophic or damaging to a certain subset of people. And that responsibility falls on the engineer to be wise about the choices that they make on the drawing board, because eventually these choices will be translated into concrete and steel and machinery. So, I think having a conversation about ethics would be worthwhile to have for sure.

To synthesize the 14 interviews conducted, most teachers considered environmental and/or societal impacts important to include in engineering (or STEM) education. This is aligned with the fact that 78% of interviewed teachers incorporated environmental/societal impacts and/or ethics in their own teaching. Even among three engineering teachers who stated they did not explicitly teach EESI, most still indicated that it was important. For example, when asked "*Either in your classes or just in general, do you believe it's important to include these [EESI] topics in K-12 education?*", Simon responded "I think it is, although I think it depends on the class. I think it's more suited to some classes than others." Three teachers considered STEM's environmental/societal impacts to be somewhat important and ethics somewhat less important (Jeff, Jimmy, Simon); all three taught engineering courses. Six STEM teachers were strong proponents for the importance of both societal/environmental impacts and ethics, viewing these as largely synonymous concepts (Allison, David, Larry, Lori, Joelle, Michael). The remaining five STEM teachers generally felt EESI was important, but their responses were somewhat less effusive. The relative importance that the teachers placed on ethics high school STEM education is approximated in Figure 1, as interpreted by consensus by the authors based on the interviews.

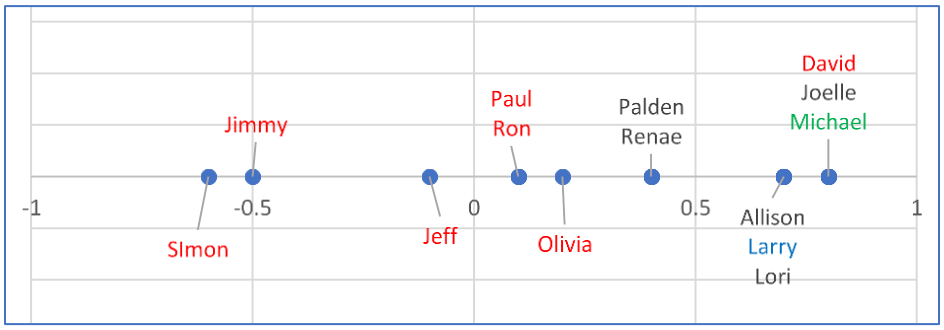

Figure 1. Relative importance of ethics in high school STEM education where moving to the right represents higher importance. Text color represents primary subject taught: red = engineering, black = science, green = computer science, blue = mathematics.

The reasons high school STEM teachers gave for the importance of EESI education included: students should understand the purpose and intent of technology, responsible STEM development and/or use includes EESI considerations, citizens should be educated on EESI issues related to STEM, and EESI/real world issues motivate student interest and learning.

RQ2. Obstacles

Research question 2 explored teacher's perspectives regarding obstacles to integrating EESI. Table 2 summarizes the obstacles identified in the interviews. Each teacher identified at least one obstacle to EESI integration. These obstacles were categorized as being either ***challenges*** able to be overcome or otherwise addressed or ***barriers*** that as-of-now cannot be overcome. In five cases, the same type of obstacle posed a challenge for some teachers and a barrier for others, depending on local conditions and individual characteristics. Most of these obstacles to EESI education have been previously identified among college professors [9, 10]. Each obstacle is elaborated on further below.

Table 2: Challenges and barriers to EESI integration identified by teachers

Obstacle	Definition	Challenge	Barrier
Curriculum[1]	Space in teacher's course curriculum to incorporate EESI.	David, **Lori**, *Palden*	**Jimmy**, Allison
Teaching standards	Established standards that the teacher must meet impacts ESSI implementation.	**Lori**, Paul, **Renae**	**Jimmy**, Allison
Perception[1]	EESI is negatively perceived by students, parents, etc.	David, Olivia, Larry	*Ron*, Michael
Difficulty[1]	Students struggle to understand implemented EESI.	Joelle, Olivia, **Renae**	Michael, Simon
Comfort level [1,2]	Implementing EESI is uncomfortable to teachers.	Olivia	*Ron,* Simon
Lack of content	Lack of EESI material or framework for teachers to utilize.	*Jeff*, **Renae**	
Time	Preparation time for EESI implementation in courses.	Olivia	

Obstacles in higher education : [1] [9], [2] [10]; Names in red text = engineering, black = science, green = computer science, blue = mathematics; normal text = public school, bold text = private school, italicized text = charter school.

Curriculum: Some teachers perceived that the amount of content in their curriculum, self-imposed or related to established school/district expectations, allowed for little availability to implement EESI. A quote from David exemplifies this challenge to EESI implementation:

> I think that the biggest constraint and challenge is time [meant as curriculum time], you are focusing on your content. You are thinking 'I want to make sure that students learn all of this information', and so it's wrestling with do I have enough time to go into the 'why'. I can say this as a teacher, I'm assuming someone has already addressed the 'why' ….

This details how this obstacle is apparent at multiple levels of engineering education. Regarding this example, David explains how he addresses this obstacle by balancing subject material and ethics implementation appropriate for his courses, hence why it is considered a challenge.

Teaching standards: Established teaching standards were viewed as an obstacle to EESI implementation by some teachers, either through the lack of structure regarding these topics or by limiting the level of implementation. As an environmental science teacher, Allison described teaching standards as a barrier:

> Well the current policy of standardized testing is a major roadblock. Because there's nothing in our standardized tests that addresses ethics, whether someone has a general understanding of what it means to have an ethical dilemma. There is no crossover, even in our civics classes. I just don't think that the curriculum is allowing to let us raise and teach a generation of critical thinkers who can basically agree to disagree. And that is because of the constraints

> of 'I need to make sure they do well on the SAT.' There is nothing on the PSAT or SAT about being a civically-minded person.

This quote from Allison details that the standards she faces as a teacher impacts what she can and can't include in her courses.

Comfort Level: The implementation of EESI is viewed as being uncomfortable to some teachers, with reasons including but not limited to a lack of understanding and practice in implementing these topics or personal beliefs regarding their implementation. Simon, an engineering teacher, spoke about this:

> I think there is an issue with buy-in. I think you would have to convince teachers who are physicists, who love the physics or engineering. I think it might be somewhat difficult to convince them that it is important to address ethics which may be a topic they are not familiar with, and don't feel qualified to include.

Individuals without engineering training are perhaps more hesitant around their knowledge of engineering ethics. For example, Ron noted, "other teachers I believe have engineering backgrounds. So, I don't know if I have any right to say what engineering is or is not or what should be included in an engineering class versus what is not." The quote above is an example of a barrier as the teachers do not offer a solution or way to overcome this obstacle.

Perception: Teachers' implementation of EESI was in some cases hindered by their concern about possible negative perceptions from the students and/or their parents, particularly in relation to political and/or religious cultures. Engineering teacher David identified this as a challenge: "One very small, very small barrier is that with some ethical questions, if you get into things that are very controversial in our current culture, it would be wise to inform parents of this, inform administration of this. I have never run into any issues there."

In another example, engineering teacher Ron described imagined difficulties around perception:

> Yes, absolutely [there are obstacles]. Any time there is a controversial topic. It seems ridiculous that environmental impacts are a controversial topic, but it is. In my particular school, and in my network, we are very forward looking and so we are able to have thoughtful, productive discussions where we can see both sides of an issue. But I feel that in other districts, including even the one that I was in previously, because of political connotations as well as people come from different political stances and that impacts whether or not they want to engage in particular conversations, they think ethics and societal environmental impacts and engineering might potentially be one of those. I can just imagine a parent coming in and saying, "Why are you telling my son that…?" Yeah, I can just imagine that scenario playing out anytime a topic is controversial.

Something to note regarding this example of perception is that it is unclear whether the perception of potential pushback is stronger than the actual risk. Ron does not go into depth on the possible consequences of addressing these "controversial" topics, however he places notable weight on the backlash he could face as an instructor.

Larry was also concerned with parent responses; he was teaching math at a public school and had 25 years of teaching experience:

> I think quite honestly it's the parents who aren't there to hear the nuances of how it's approached in class. …And, you know, that that parent going to superintendent or school

> board or a principal and saying you know misunderstanding what the teachers' [intended]….. But you know, that's for me the thing that keeps it from being fully authentic and really digging into these controversial ideas and challenging our paradigms in a classroom setting.... I wish I had a nice answer to [addressing this obstacle] … I guess my best bet and advice for [overcoming] that would be keeping people informed ahead of time and not having them be shocked.

Initially it is being set up that Larry views perception as a barrier. However, after being prompted for any advice regarding this obstacle, he elaborates how this may be addressed with increased communication. This draws similarities with David's approach at overcoming perception, indicating a commonality in how this obstacle may be addressed.

Difficulty: Teaching EESI to students is challenging, with regards to the student's understanding of the material. Michael, who taught computer science at a public school and had 15 years of teaching experience across multiple schools, perceived this as a barrier:

> My experiences I've had as a teacher, which blows me away, is that the political leadership in America really either consciously or subconsciously affects the way our students approach their vision of the world. I'm finding that our students are not understanding a good sense of what is right and wrong because they are getting inundated with things that occur that really blur the line. And I find it concerning because I'm having to overcome that there is plenty of examples in our society of people questioning the idea of science being true or not. Yet you have students who get this idea of 'what's the problem with not telling the truth?' It's hard for me as a teacher to know what to do. I think one person can create some momentum, then others get on and those other people spread or reinforce that idea. So, I think my biggest thing is that our students are having a hard time understanding what an action means to be ethical.

What is notable here is that Michael forms the link between difficulty and political leadership, and how actions taken by those in a leadership position has far reaching consequences to his students.

Another example of difficulty in teaching ethics was describe by Olivia:

> To have a conversation with a bunch of high school kids, we're talking about, [a teacher] can't show up on the first week and be like "Hey, we're going to talk about this today. Get in a circle." You need those kids to trust each other. You need to have been doing all kinds of things in the two months prior to that big-charged conversation before you're able to really have people sharing their beliefs on it and feel comfortable doing so.

This quote describes another difficulty involved with teaching students about ethics, in that they must be familiar and comfortable around each other. Separate from teachers being uncomfortable regarding ethics, students must be able to trust each other to where they can openly address ethical issues in a group environment. This obstacle is a challenge as Olivia describes how this can be addressed by promoting student interaction in advance of an ethical discussion.

Lack of Content: Implementing EESI may be obstructed due to a lack of material a teacher can easily utilize. An example of this obstacle was described by Jeff, who is an engineering teacher:

> I think that maybe the barrier would be having, at least for me, good material to use… I just make my own lesson plans... And I think that if I had access maybe to more material that

> taught ethics and taught it well and taught it in an interesting and relevant way, some of the examples that we talked about probably could include more [ethics]….

Renae, a science teacher at a private, religiously affiliated, high school also discussed a lack of content as a challenge:

> I think one of the biggest challenges is that [ethics implementation] hasn't perhaps been done very effectively in the past. And I think as teachers, I can speak for myself and some of my close colleagues, we tend to reflexively teach the way that we were taught. And so, I think it can be challenging to try new things when it's never been modeled for you, or if there isn't like a gold standard to hit. And I think there's attempts nationwide if we look at what NGSS curriculum looks like, there is an attempt to bring that in.

Renae's concerns also link to the obstacle of time (below), as teachers would require some amount of time to learn new material.

There may be content available but that teachers are simply unaware of it. For example, in the TeachEngineering digital library (https://www.teachengineering.org/) a search with the term "ethics" and limited to grades 9 to 12 found 104 results. There was one lesson with ethics in the title ('Engineering Ethics: Evaluating Popular Inventions'; 3 hour partial design activity) it is brand new as of 2021 [18]. The other lessons varied widely in the extent of ethics content. However, it is encouraging that so many of the lessons at least touch on ethical issues.

Time: This obstacle represents the time it takes a teacher to prepare for classes or subjects, including but not limited to, the time it takes to learn about EESI and how to best implement related topics into a teacher's pedagogy. This quote comes from Olivia, a former engineering teacher who also taught science courses:

> I think the biggest complaint with teachers is that there's not enough time. 'I don't have time to read those three articles.' Well, first I have to find those three articles, maybe I am unsure about whether those articles exist let alone find them. I think that is one of the biggest factors. … I think there are more and more resources available but sometimes it becomes really daunting and overwhelming to the teacher because there is just so much there.

To conclude, each teacher interviewee was able to identify at least one obstacle to integrating ethical topics, with one identifying as many as four (i.e., Olivia). A larger sample size of interviewed teachers may have identified additional obstacles. From this small sample size, the teachers at private high schools viewed obstacles as more challenges than barriers. Additionally, four of the five science teachers viewed obstacles to ethics implementation as challenges rather than barriers.

Note that many of the findings related to obstacles mirror those in previous research in higher education. This issue of perception is somewhat akin to the challenge of student resistance that was identified in a study with engineering faculty at universities [9]. For example, Riley [19] noted that a project related to climate and ethics integrated into her thermodynamics course "met with a great deal of resistance from students in 2010." The issue that teaching ethical reasoning to students is difficult was previously found [9]. Discomfort teaching EESI among faculty stems from a variety of sources, including feeling unqualified to teach the material [9,10]. This lack of personal knowledge then leads to a desire for pre-existing materials that can be utilized, although

this was not directly articulated by faculty. The issue of lack of time is not specific to EESI but rather a common obstacle to changes in teaching [20].

Limitations

Limitations to this study include the small sample size among high school teachers and interviewing only those teachers in Colorado. This may have led to inaccuracies as a larger sample size would have better indicated trends in ethics importance and identified obstacles, while interviewing teachers operating in different states may have yielded perspectives based on possible state-specific teaching standards. Specifically, one would assume that states that have fully adopted the NGSS would have greater integration of engineering. Further, the study was conducted in 2019 and progress may have been made on EESI integration since that time, particularly given that teachers are becoming more familiar with the NGSS.

Conclusions

Each of the 14 Colorado high school STEM teachers interviewed believed that it was at least somewhat important to integrate societal/environmental impacts and/or ethics in STEM courses. However, the level of importance and relative emphasis on impacts versus ethics varied, as well as the reasons why the teachers believed EESI education was important. Each of the teachers also identified one or more obstacles to EESI integration, with these obstacles falling into seven general categories. Among these seven identified obstacles, all were considered by at least one teacher to be a challenge while five were considered by at least one teacher to be a barrier. Many of these obstacles were similar to those previously identified for EESI integration into engineering by college faculty. Although the results should not be overly generalized due to the small number of teachers interviewed, the results indicate that many entering college students may already be somewhat familiar with the importance of EESI in engineering. In addition, the findings dovetail with recent attention on the preparation of K-12 teachers to educate students on engineering [21], indicating that teachers should be aware of the important role of ethics in engineering.

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