A Short Course in Engineering Ethics: Opportunities and Challenges for Pedagogy and Assessment

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Ethics and engineering: problem of practice

This evidence-based practice paper presents findings from a one-semester pilot of a short course in ethics for students in engineering and science majors at Colorado School of Mines. At its core, the Nature and Human Values course centers on ethical issues and cases in order to foster communication, writing, and research skills for incoming freshmen. It has undergone extensive revision over 25 years of existence and faculty have participated in national initiatives to improve ethics education in engineering in recent years. The National Academy of Engineering's Infusing Ethics into the Development of Engineers workshop brought together professors and curriculum designers from around the country to share strategies and brainstorm about ways to design and teach ethics curriculum for engineers. I participated with colleagues from Colorado School of Mines and published our course development outline in the proceedings of the workshop. We also answered the call from ASEE's Advances in Engineering Publication to discuss the intersection of Nature and Human Values course development with our honors first-year experience. Both the traditional and honors courses cover extensive curriculum and are centered on teaching ethical reasoning alongside communication skills.

Universities are facing changing enrollment trends and engineering curricula is full of required content, making curricular reform fraught with challenges because every credit hour is valuable. As my colleagues and I grapple with these trends, we face a curriculum and enrollment challenge for students who have taken writing courses at other institutions. Some transfer students have also taken ethics courses, but it is hard to match the suite of engineering and environmental ethics concepts that Nature and Human Values covers, such as water in the West, environmental justice, and the socio-political impacts of digital technology or human genetic engineering. This study compares the standard 4 credit hour required course to a "short form" 2 credit hour version that was piloted in the Fall 0f 2021 with incoming students who had either taken composition 1 and 2 at another college or who had taken AP language and gotten a 5 on the exam. We want to understand the efficacy of this class in teaching the ethics content of the course as well as the outcomes of developing research skills, engaging in the writing process completion, and constructing supported arguments. To this end, I posed the following research questions:

- o Do students in the short form course achieve similar outcomes on ethics, argument and research to students in the regular course?

- o What pedagogical choices can instructors make to support student learning about ethics, argument, and research?

Literature review

Engineering ethics education research gives some context to the goals of the present study. ABET's ethics requirement, instituted in 2000, gave institutions the push to incorporate ethics for accreditation and this curriculum reform has come in many different formats in the ensuing

years. Many of the early iterations of ethics in engineering curricula were modeled on Davis' approach to use codes of ethics as foundations for studying cases [1] In 2000, Herkert highlighted the suite of case study materials that had been developed and the types of ethics initiatives being implemented in the United States, as well as some of the challenges in implementing these curricula, most notably, engineering faculty themselves [2]. Pritchard addressed the frequent negative focus of engineering ethics education on disasters and problems and encouraged a more positive focus on moral character and imagination [3]. The National Academy of Engineering's workshop in 2012 addressed the purpose of engineering ethics education, worked towards standards for assessment of pedagogy and curriculum, and navigated concerns about the impact of culture of institutions on these efforts [4]. In addition to individual efforts on teaching and designing courses, researchers also write about Ethics Across the Curriculum efforts and both the promise and challenge in these efforts [5].

The NAE's report on exemplary activities and programs in engineering ethics offers examples of how institutions are incorporating ethics in their engineering curricula [6]. They selected 25 educational activities that can inspire similar work at other institutions in a variety of forms. Some institutions insert ethics in small doses in the form of a module, assignment, or activity in courses in the disciplines or in required core courses. Other institutions offer entire undergraduate or graduate courses, required or elective, that can be housed in different disciplines. These curricula can include theory-based ethics, applied ethics and case studies, individual moral development, macro- and/or microethics, and experiential or active learning. Engineering educators can access the descriptions and resources for the exemplary assignments, courses and programs in [6]. From a senior thesis assignment at University of Virginia to a phenomenological listening tool at Virginia Tech, there are examples of inserting ethics into already existing courses. A Kansas State graduate course and a Michigan Technological University undergraduate course both require the experience of interviewing a practicing engineer. Full-length courses at MIT and Colorado School of Mines infuse ethics via a required course in an engineering class and in the humanities curriculum, respectively [6].

Researchers also advocate for particular pedagogies when it comes to teaching engineering ethics. Sarah Pfatticher suggests that we consider "the right balance of structure and flexibility in our curricula to foster the habits of mind appropriate to ethical practice of engineering education in a globalized world" [7, p. 256]. To this end, she argues that scaffolding the practices and thought processes of ethical decision-making should be part of our curriculum conversations. Other researchers support hands-on projects and teamwork for engaging future engineers in practicing and applying ethics. For example, William Frey writes about teaching moral imagination through service learning, "dramatic rehearsals," and alternative job fairs. [8, p. 243]. Zhu and Jesiek argue that engineering ethics needs to focus more on the pragmatic than the idealistic, especially because engineering is such a global enterprise. They argue that the main trends in engineering ethics education "decontextualizes ethics practice from the situated contexts in which ethical theories are to be 'applied,' the sociotechnical realities of real-world work environments, and the broader social and political contexts of engineering practice" [9, p. 667]. They emphasize the relational and communicative components of dynamic decision-making involving stakeholders that students need to understand to be successful in their careers [9]. In a similar vein, Hitt, et al. argue for multiple perspectives across disciplines in designing

and delivering ethics education: "both faculty and student collaboration across backgrounds and disciplines is crucial for success in integrating ethics in engineering curriculum" [10, p. 5].

Despite these developments in ethics education for engineers, faculty continue to experience significant challenges that are examined by researchers. As a follow up to the Infusing Ethics exemplars publication, the National Academy of Engineering offered a workshop on Overcoming Challenges in Infusing Ethics into the Development of Engineers in early 2017. Participants discussed challenges such as the perceived and actual divisions between the technical and the non-technical disciplines and how to influence the engineering mindset and culture that can seem fixed [11]. As a part of this workshop Erin Cech presented her findings on the disconnect between graduating senior engineering students and concern for public welfare, labeling it a "culture of disengagement." She argues that programs should work to "dismantle the ideological pillars of disengagement in their local climates" in order to truly engage students [12, p. 43]. Ethics education continues to face challenges receiving institutional support, building faculty buy-in, finding space in the curriculum, and establishing relevance to the discipline and to students. There is a continued call to revise language and communication about ethics education [11], especially as we navigate social justice challenges and work toward more diversity and inclusion in STEM fields. In a national survey of engineering and computing faculty, Bielefeldt et al. found that "a majority of all faculty respondents indicated that they believed that the ethics and/or broader-impacts education of undergraduate and graduate engineering and computing students in their program was insufficient" [13]. Finally, how to assess students' ethical growth or competence, whether for accreditation or institutional purposes, is an ongoing challenge. Both qualitative and quantitative assessment methods can be valuable in describing what students learn [14].

Another area of research that provides insight on this study is the conjunction of engineering education with the humanities and social sciences, and, in particular, writing instruction for engineers. Employers consistently report that communication skills are among the most valuable assets for new employees coming out of college engineering programs. Just as with ethics instruction, various institutions handle teaching writing and communication in different ways, from requiring stand-alone courses to integrating writing across the curriculum. Even though ABET requires proficiency in communication skills as an outcome, Reave found that institutions' methods of including writing in engineering curricula is scattered and exposure to writing practice is minimal [15]. Buswell et al. summarize important findings about engineering curricula and writing instruction [16]. Matusovich et al. found that half of engineering instructors believed that communication skills were taught by someone else [17]. Integrating writing in several engineering courses and giving students exposure to writing tasks throughout their time in college is ideal, but this can be difficult to achieve [16]. Leydens advocates for teaching sociotechnical communication in opposition to the notion that engineering writing is neutral or objective [18]. House, et al. showed evidence that assigning writing portfolios, integrating writing into several courses, and using rubrics and peer review are effective methods for teaching writing in engineering [19].

The curriculum for writing instruction can also range from technical, discipline-based writing to analysis and approaches drawn from humanities and social sciences. Ultimately, when it comes to teaching ethics, incorporating written work prioritizes critical thinking about ethics content

and encourages students to incorporate new ideas into their own thinking and articulation of an argument. As argued in [10], interdisciplinarity, collaboration, and communication tasks also integrate STEM curricula with the humanities, arts, and social sciences. The present study is situated in this space of engineering ethics education from within the humanities, and the efforts of previous engineering education researchers informs both the class and its evaluation.

Description of course

The focus of this study, Nature and Human Values, is a required 4 credit-hour course that serves two intersecting curricular purposes: ethics education and writing instruction. It has been continuously evaluated and improved by the team of faculty, both full time and adjunct, throughout its 25-year history at Colorado School of Mines. Faculty meet at the beginning and end of each semester, and often more informally in between, to share pedagogical approaches, brainstorm solutions to challenges, and evolve the objectives and elements of the class. The driving goal of the course has always been to help future scientists and engineers situate their profession within broader social contexts and to develop supported arguments through writing tasks. In its current iteration, students meet in small seminar sections for three hours a week and the fourth hour is devoted to the lecture activity series. In the past, the lecture was a live classroom component students attended in groups of 150. During Covid shutdowns, the lecture series was converted to a series of online interactive experiences we called lecture activities. Most of them have short video lecture segments from a faculty member, but also contain links to other readings, images, videos, and interactive ethics experiences. These lecture activities serve as the common content across all seminar sections, along with a required reading series of five essays on professional and environmental ethics.

Writing instruction for Nature and Human Values is scaffolded throughout the semester and is also a common component among sections. The semester begins with a short paper on summarizing and responding to another writer's argument to work on reading and composition. Next, students begin to research ethical issues and synthesize multiple perspectives in a second writing assignment. The third paper requires independent research and an exploration of different ethical perspectives on a specific case or a more general issue. Students showcase their ability to acknowledge various ethical perspectives by applying course terms and concepts to their chosen topic. Finally, all students submit a portfolio that reflects on their progress as ethical thinkers and as writers and researchers. It includes a choice component to encourage creative expression of ideas and impacts from the course, and it requires attendance at one campus event or lecture that connects to the content of the course.

For the Fall of 2021, we piloted a truncated version of the course to be offered as a 2-credit hour Nature and Human Values class for students who had scored a 5 on the AP Language exam or had 6 hours of composition credits transferred from another institution. The design of the course was one hour in seminar and one hour completing the lecture activity series described. The writing assignments and portfolio were also assigned in the short course, as above, but there was far less instructional time in the course. Most of the one-hour seminars each week were devoted to discussing the rich content for the week, so writing and research instruction was minimal. Both courses share the same 6 outcomes:

1) Understand major ethical theories and concepts and apply them to current and past debates about technology, resource use, and environmental issues
2) Read and think critically about course reading assignments and lecture topics; discover personal biases and values, diverse perspectives, and rhetorical strategies
3) Construct written and oral arguments about course topics that are supported by relevant experts and evidence
4) Find and employ relevant research to writing assignments; consistently cite use of sources in-text and in bibliographies
5) Develop written work through a process of drafting and revision to produce clear summaries, comparisons, and analyses of texts
6) Appreciate the context of the engineering profession and the impact of work on social, environmental, and ethical systems.

This study focuses specifically on 1, 3, and 4 as the outcomes most directly tied to ethics content, argument construction, and research skills.

Methods

This evidence-based practice paper presents results from a case study comparing student work from one traditional Nature and Human Values course with student work from the pilot sections of the short course offered by the same instructor. Case and Light argue that case study is appropriate "to address research questions concerned with the specific application of initiatives or innovations to improve or enhance learning and teaching" [20, p. 191]. It is also an action research study in that it involves collaboration with colleagues and will result in action steps taken to improve the design of the course and how it is offered.

I selected twelve students from each version of the class, based on the ranking of their grade on the final paper. I wanted to assure that the selection of the students in the sample represented the overall spread of the grades assigned and was not skewed to a particular skill level if students were randomly chosen. I also selected for a representative balance of male and female students and noted their previous coursework prior to taking Nature and Human Values. Of the 24 students, 7 of them had taken community college courses in composition, 7 of them had taken the AP exam and received a 5, and the other 10 had transferred directly from high school with no previous college composition experience. For each of the students selected, I assigned a random number and anonymized their writing samples from the beginning and ending of the semester. I assessed the whole group of students at once to assure that my application of the rubric to the work was fair and consistent across the different preparation levels and grades on the final paper. While this sample size is relatively small, the selection of students allowed me to analyze the work of a variety of student characteristics in terms of course preparation and final grades who all received the same instruction and assignment prompts.

Both the short and regular courses were taught by the same instructor and included the same assignment prompts and grading criteria. The course structure differed in that, for the short course, we had only one hour a week to discuss the lecture activity, reading assignments, and cover any announcements or instruction on writing and research. The regular course met for three hours a week and had time to carry over discussions into another class period, approach

one subject from several angles, and work on drafting and revising with more in-depth focus on writing instruction.

I included two samples of writing in this study to get a sense of how students were able to apply ethics through writing over the duration of the class. The first major writing assignment asks students to objectively summarize another's argument and then write an argument in response to the author, using course readings and original examples for support.   I evaluated the argument section of the paper on three criteria: applied ethics, supported argument, and use of research. At the end of the semester, students choose an environmental ethics debate and research the stakeholders and ethics involved in the conflict. I evaluated a section of this final paper that discussed the environmental context and ethical issues of the chosen environmental ethics case. To be sure, this method of analysis does not cover all of the course objectives in their entirety, nor does it cover the scope of ethics content in the course. We study professional ethics at length, but those topics were only tangentially included for some student papers because the prompt focused on an environmental case study. The research skills were assessed in a general way to determine competency with in-text citations, but not on the quality of materials found. In addition, I did not use the study to do any comparison on grammar, usage, punctuation, or other writing concerns. I reviewed the work only for coherent argument in alignment with the outcome and ignored minor writing errors.

Using the course objectives as a guide, I created the rubric in Figure 1 to assess evidence of competency of the ethics, research, and writing goals of the course. Each of the 24 students was assessed with the rubric in Figure 1 for the first writing assignment of the semester to establish their incoming level of proficiency.

Outcomes-based criteria	Advanced	Beginner	Developing	Underprepared
Identify ethical and social issues key to the future of STEM fields in professional context.	clearly presents ethical and social issues that intersect with STEM professions	presents some ethical or social issues in STEM professions	attempts to explain ethical or social issues in STEM professions, but may be vague	avoids or ignores ethical and social issues in STEM professions
Construct written arguments about course topics supported by relevant experts and evidence	well-articulated argument with advanced use of a variety of textual support and original examples	a clear argument with sufficient support from several texts or examples	attempts at an argument and includes some support, but it lacks depth or support	argument is hard to discern and/or does not include supportive evidence
Show research skills of quoting, paraphrasing, summarizing and citing relevant sources in a consistent format.	cites a diverse array of course materials and relevant sources; balances quotation and paraphrase with precise formatting	accurately quotes and paraphrases from a variety of sources with clear, well-formatted citations	the quality of the research is monotonous or lacks depth, use of sources may be inaccurate or sloppy and there are formatting errors	very basic, descriptive research and/or lack of proper citations, unclear use of outside sources

Figure 1. Assessment rubric for first writing sample

For the assessment of the final paper, the same three criteria were used in the rubric to assess the students' application of ethics, construction of a supported argument, and expression of research skills at the end of the semester. I also added an additional criterion, based on the growth we expect to see throughout the course in students' ability to engage in perspective-taking and empathy for values and expressions outside their own experience. Figure 2 shows the rubric's additional criterion for assessing perspective-taking on the final paper. Note that there is no perspective-taking criterion in the rubric for the first writing sample because students were not asked to write about others' perspectives on the first assignment. The first paper is a summary of an argument and a response to that argument, whereas the final paper asks students to research and present multiple ethical perspectives.

Engage in perspective-talking and fairly represent stakeholder values	navigates perspectives of others and identifies values represented in research	articulates some perspectives and values of stakeholders	shares stakeholder facts, but struggles to discuss values or alternative perspecitves	shows little perspective-taking and stays in argument mode instead

Figure 2. Assessment rubric additional criterion for final writing sample

The other source of data for this comparison study is a questionnaire given to the short course students at the end of the semester. Students completed this questionnaire in all 4 sections of this pilot course, two taught by the researcher and the other two taught by fellow faculty. Student input from the pilot sections of the course was insightful to the student experience in the class and helps to answers the research question about what pedagogical changes are needed to improve learning in this course. Students answered questions about how their ethics, argument, and research skills were impacted through the course and gave suggestions on what instruction or support they found missing in each of these categories. Students in the regular course were not offered this survey, as it was related to the assessment of the pilot, so the analysis centers on 56 respondents from the short course.

Findings on Research Question 1

To answer research question 1 on the comparison of outcomes between the short course and the regular course, I compared the rubric results on both the early and late semester assignments. Table 1 shows the results from the early writing sample and Table 2 shows the results from the end of semester writing sample. I will discuss each in turn, then reflect on the potential lessons from these results. Note that in these results, I combined the Developing and Unprepared categories into one column labeled Developing. I found either zero or one student scoring unprepared in any given category, so for simplicity, I am considering them part of the developing skills cohort.

Table 1. Comparison of outcomes on early writing

Early writing	Short Course			Regular Course		
	Advanced	Beginning	Developing	Advanced	Beginning	Developing
Ethics outcome	4	4	4	5	4	3
Argument outcome	3	5	4	4	4	4
Research outcome	4	4	4	4	5	3

In reviewing Table 1 results, it is worth noting that the students in both sections entered the course with skills across the three outcomes. Several outcomes showed 4 students scoring in each of the three categories, and the other outcomes were well distributed too, only varying by one student. It is not surprising to find an even distribution across the ratings since I selected student writing samples based on final paper grades. However, it is important to note that the students in both sections are coming in with similar skill level distribution, according to the assessment with this rubric. The regular course was comprised of mostly traditional freshmen and sophomores with one junior taking the course later in the curriculum. The short course had half freshmen and half sophomores and their backgrounds were split between students with a 5 on the AP Language exam and students with composition transfer credit from a community college. Within both the short and regular course, student preparation for the class spanned the spectrum from advanced to developing in all three assessment areas.

Table 2. Comparison of outcomes on end of semester writing

End of semester writing	Short Course			Regular Course		
	Advanced	Beginning	Developing	Advanced	Beginning	Developing
Ethics outcome	5	3	4	2	6	4
Argument outcome	4	4	4	2	5	5
Research outcome	4	4	4	2	2	8
Perspective-taking outcome	6	2	4	3	6	3

Table 2 shows some more varied results, but it is interesting to note the even spread across all skill levels in the short course for argument and research. For the ethics outcome, both courses had 8 students performing proficiently (beginning or advanced) and 4 students who did not meet the standard. For the argument outcome, results were similar, with most students scoring advanced or beginning, but still about a third whose argument skills were not at expected levels. The research outcome was the most surprising because so many students were still developing this skill at the end of the semester. Even with the short course results that are balanced among the rankings, there was no change in these scores between the first and last writing sample. Even more disappointing was the result for the regular course because 5 students moved from proficient scores at the beginning of the course to developing at the end of the semester. The first writing sample asked students to cite from one or two sources, whereas the final writing sample was a research paper with many sources. It seems that students who had had little research experience prior to the course struggled with the multi-source research project.

In comparing the two courses, the short course had more students scoring advanced and the regular course had more students scoring with beginner level skills at the end of the semester. This pattern held true for the ethics, argument, and perspective-taking outcomes. For the research outcome, the regular course results showed that only one-third of the students were proficient in the skill, while two-thirds of the students were in the developing or unprepared range. Overall, the short course resulted in more students with advanced skills than the regular course. It is possible that these results are connected to the preparation that the AP course provided to the students who had taken that course. The students in the regular course were more likely to still be developing skills at the end of the semester. This result might be explained by the wide variety in experiences of writing instruction in high school or any previous college courses.

Comparison of incoming preparation

Since one of our aims in assessing the course is to understand student preparation to succeed in the short course, the following section will compare the outcomes for three categories of students: those with community college composition credits (CC), those with a 5 on the AP exam (AP), and traditional undergraduates (TU). Note that there were no traditional undergraduates in the short course, but that the regular course had one AP and one CC student in the sample. There were 7 AP students, 7 CC students and 10 TU students in the sample for this study. The following figures compare these three types of students on ethics, argument, and research outcomes for the first writing assignment.
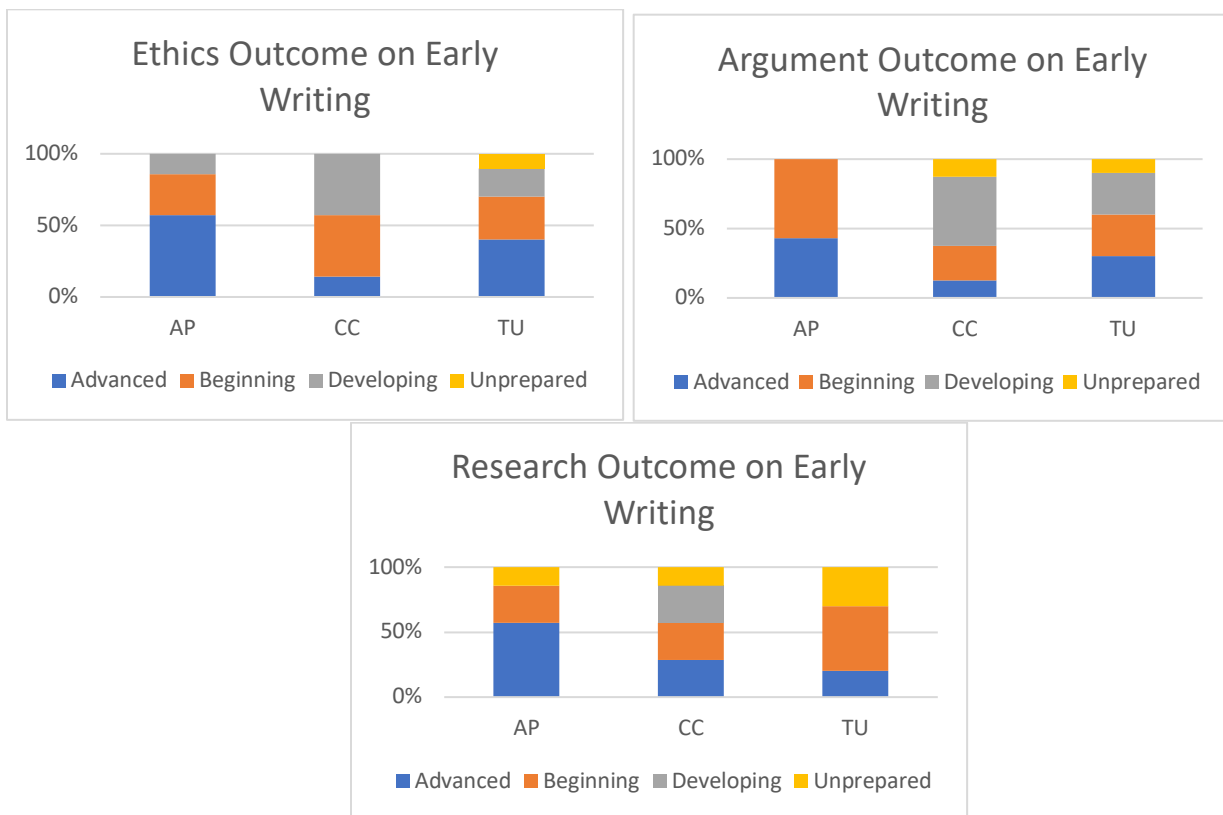
In comparing the AP, CC, and TU students on applying ethics in their early writing, AP students were more prepared for writing about texts than CC students. The TU group had more students who were developing or underprepared than the other two groups. For the argument outcome, AP students all scored as proficient, whereas the CC and TU groups had many students scoring in the developing or underprepared level. These results seem to indicate that the intensive writing for exam performance in AP Language prepares students well for analyzing texts and then constructing a supported argument. The research outcome shows that AP students scored advanced most often, but that there was one student who was not able to accurately cite sources in the early writing assignment. Across the board, there were more students who were not at the expected level of research skills required in the early writing assignment—namely, paraphrasing and quoting from one or two provided sources and citing them in-text.

Considering these incoming skills rankings from the rubric, it was next important to compare these results to the scores from the final writing assignment. The following figures illustrate the student performance on all four rubric categories at the end of the semester: ethics, argument, research, and perspective-taking.
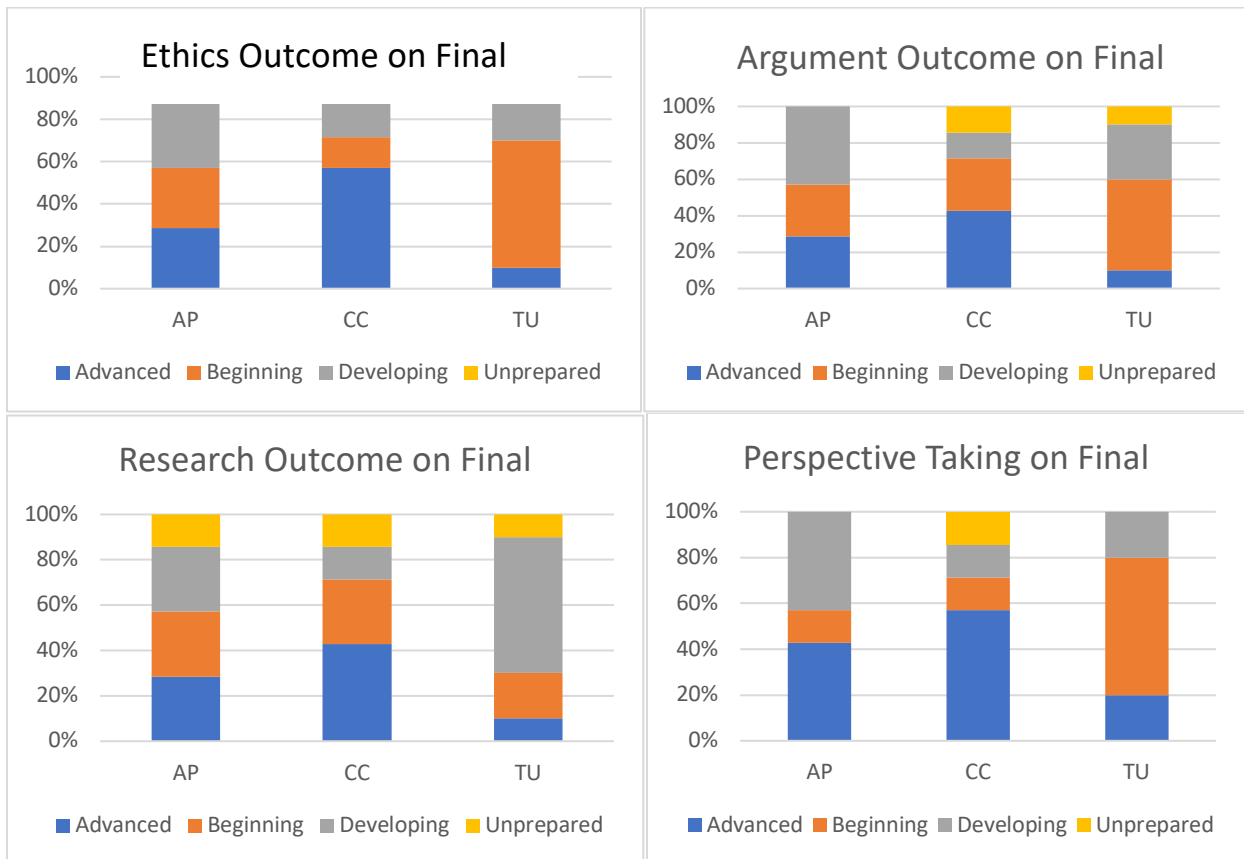
Reviewing all four outcomes across the different student groups, three general observations are noteworthy. First, there are more gray and yellow sections in these graphs than in the previous scores from the early writing assignment, indicating students are not performing as expected on these outcomes. Obviously, the hope of the instructor is that all students end up proficient in all the outcomes of the course, or that, at the least, students are improving over the semester. Part

of this result is likely due to my own bias as the instructor-researcher, expecting more depth of skill at the end of the semester then at the beginning. It is likely that my application of the rubric to these two writing samples was not fine-tuned enough to pick up on the growth between the papers. It is also likely that part of the result of poorer performance than expected is related to the timing of the assignment and the particular moment in time in which the data were collected. Students completed these papers at the end of 2021, after a long semester of managing demands during the pandemic, as concerns and protocols for Covid-19 continued to shift and stressors continued to mount. In addition to the impacts of 22 months of adjusting to the pandemic, the end of the semester for STEM students is usually a time when they are balancing many demands and making certain choices about what to prioritize. It is possible that students who showed less proficiency with these skills at the end of the semester were choosing to put less time into this assignment in order to focus on more concerning grades and exams in other classes, especially in math and science courses in their chosen majors.

Another potential reason for decreased performance outcomes on the final paper is the concept of cognitive load theory [21]. It is possible that students are overloaded with new content in this class, and in addition to their other STEM coursework, simply cannot bring all the acquired knowledge to bear on their final writing project for this course. Finally, it should be noted that students may have gained proficiency in skills that simply were not reflected in the writing sample analyzed from the end of the semester. It is impossible for one writing assignment to gauge everything a student knows, even when it is a comprehensive assignment for a course. These suggestions of why the performance on the final rubric showed fewer students in the proficient range could be incomplete, but they are rooted in my lived experience as the instructor of the course and observations of students at the institution for 17 years. Certainly, these concerns will impact future discussions on pedagogy and curriculum with fellow faculty and inform decisions about how to improve both the short course and the regular course.

Also of note in the data is the slightly superior performance of the CC students. Across all outcomes, CC students scored at the advanced level more often than AP or TU students. Considering the lower starting points for these outcomes in the early writing sample, this finding shows more significant growth in this group. Although CC students scored higher than AP students, the AP group also outperformed the TU group in all four categories. These results seem to corroborate the findings comparing the two sections in indicating that the outcomes for the short course students were slightly better than the regular course. At least for the outcomes studied, the results for the regular and short course are congruent and support the adoption of the short course for students with previous writing experience.

A final observation from the end of semester writing sample data is a concern about how we are teaching research skills in the course. In the TU group, all from the regular course, 70% of students finished the course with developing or underprepared research skills. This means that even with the extra time and feedback built into the 4 credit-hour version of the course, students still need more support in developing and practicing this skill. Even in the AP group, who seemed well-prepared at the beginning of the semester, the demands of a complex research project and writing assignment showed some areas of deficiency.

Findings on Research Question 2

The second research question for this study inquired about pedagogical choices instructors can make in this class and others to effectively teach ethics, argument, and research to a diverse group of STEM students. This section of analysis will draw primarily from the student questionnaire given to the short course students but will also reference the findings from question 1. While these responses come from only students in the short course, it is reasonable that their needs for additional instruction would match those of their peers in the regular course. I discuss student responses on how their skills in ethics, writing, and research were impacted by the class, as well as their suggestions about what additional instruction they need in these areas.

When asked how the course content on ethics issues impacted them, 34 of 56 students responded with a general appreciation for the chance to explore their own morals and the variety of ethical approaches to problems they hadn't considered before. The next most common comment was about the value of engineering and professional ethics; 18 students specifically mentioned engineering ethics, whereas only one mentioned environmental ethics, the other major focus of the course. Eight students highlighted the whole series of lecture activities and required readings as being impactful, and a few students mentioned particular topics, such as the Nazi engineers, nuclear power, and cutting-edge technologies. Overall, students were interested and engaged in the content, although certain topics appealed more to some students than others, as expected. In response to what additional instruction in ethics is needed in the course, a few students asked for more time on each topic—a chance to delve deeper and get more perspective on a particular subject, rather than talking for one class about each of the lecture activities and readings and then moving on to another topic the following week. A few students also asked for more philosophy or ethical theory to underpin the discussion of specific case studies. Two students asked for more focus on solutions to problems, rather than the problems themselves. Even though the number is small, this feedback about the negative message of the class is not new to us. It is true that discussing global and national environmental challenges and ethical conflicts about social justice issues and the future of technology can be draining and difficult, so we can keep this in mind as we frame discussions and assignments.

Student responses about writing instruction were more varied than the ethics question. When asked about how the class impacted their writing skills, the most common response was that their skills were the same. Of the 19 students who said this, at least 10 of them also said that they were very confident in their writing skills to begin with. 13 students said the class helped them improve their writing skills a little bit and 10 students indicated that their skills were a lot better. Another 10 mentioned that the class helped them stay in practice with writing so that their skills didn't atrophy. In terms of what additional instruction students need in writing, 15 students made comments about needing more instruction on the form, structure, and organization of their writing and the particular expectations of the instructor for writing assignments. This is an interesting finding because our assignments tend to be rather detailed and are associated with a rubric for each paper. My interpretation of this call for more support in this area is related to the lack of class time that is devoted to writing instruction in the short course. This is something that we can rethink, perhaps with videos or other instructional materials that can be accessed outside of class. 12 students asked for more support with citation and research formatting. Six asked for

more timely feedback or more feedback in general, and three specifically asked for more instruction on writing arguments. These are all areas to consider for improving the pedagogy and curriculum of the course.

Finally, on the question of how students' research skills were impacted, the majority of students reported that their skills remain the same or were slightly improved. Of the students who mentioned particular growth, 10 students were impacted by learning about the databases in the university library system and navigating the resources available to them. Seven students mentioned that they had learned a lot about discerning which sources would be most useful in the research process. When it comes to what they need for additional instruction, many students want to know more about citation, specifically new formats like IEEE that they might be asked to use in this course. Other students wanted more help in finding good sources, and they were seeking tips and tricks or feedback on the research they do. This call is a challenge for instructors because it is impossible to look at or read every source that every student is finding, but I think we could do a better job in putting students in peer groups that can support them in accessing and assessing sources and citing them within their own writing. This move would allow instructors to spend shorter amounts of time with the whole group, debriefing the peer research sessions.

Conclusions on pedagogy and assessment

The findings from this study can inform choices about pedagogy and curriculum design for engineering ethics. Even when students do not finish the course with all the ethics, writing, and research skills we intended, the exposure to ethical issues in their future professions has value and is difficult to measure. To address the finding that many students were not proficient by the end of the course, implementing the suggestions from the student questionnaire is likely a good start. Students were advocating for the continued offering of compelling cases and discussions, but especially for the short course, they suggested modifying the content to go deeper on fewer topics. This could also open up more space for research and writing instruction in the curriculum, which students were also asking for in the questionnaire. Presenting fewer topics with more depth could also help with cognitive overload and some of the end of semester pressures students experience. Clearer instructions on the writing process and more detail on formatting and organization are needed by some students, while others feel confident writing in many styles. Offering time for clarification of assignment expectations and additional support to less prepared students would individualize instruction.

In particular, finding and evaluating sources and then citing them accurately in IEEE is a daunting task for students with little research experience. It is another component of the writing process, and at least some students need explicit feedback on their progress towards proficiency. In a writing-intensive class, the instructor's available time to give individual feedback can be scarce, but using peer feedback groups, collaborating with librarians for research instruction, and having students prepare questions for 5-10 minute conferences can all provide more support to student writers. The findings on the research outcome indicate a strong need for more robust instruction on research skills, including better feedback and better understanding of student skill levels. Developing a method for assessing research proficiency early in the semester could guide pedagogy and curriculum choices to improve those outcomes.

Overall, this study shed light on the achievement of curricular outcomes for the regular course and the piloted short course and shows that students do not all progress to proficiency levels in argumentation, ethics content, research skill, and perspective-taking. Students report being engaged in the ethics content of the course and enjoy discussing and hearing various perspectives in class, but they may need more time to process these perspectives in order to represent them clearly in writing. It is difficult to assess ethical knowledge and the application of these ideas, and while written work may be an appropriate vehicle for assessment, other forms of assessment may be needed to supplement written work. The study emphasizes that students need more instruction on research skills in particular, and these skills likely cannot be attained in a single semester, especially because of the variety of preparation students receive before enrolling in college or in a particular course. Instructors of first-year engineering students may be making assumptions about the level of proficiency students have for written argumentation and research skills, so differentiating curriculum and pedagogy to reach students at various levels can be a way to mitigate these different needs. Our faculty can apply these results to our immediate decisions on curricular reform, but it is also my hope that other instructors and programs can benefit from these results in their work on curriculum and pedagogy reform. More research is needed on broader samples of students in engineering education to learn more about their proficiency and growth in argumentation, research, and ethics in first-year curriculum.

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