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Board 285: First-Year Electrical and Computer Engineering Undergraduate Performance at Identifying Ethical Concerns in IEEE Case Studies

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First-Year Electrical and Computer Engineering Undergraduate Performance at Identifying Ethical Concerns in IEEE Case Studies

Introduction

Concern for how to best teach ethical reasoning in engineering education persists, with research supporting that active learning strategies are useful instruction methods for teaching ethical reasoning in STEM fields. Active learning approaches, such as case studies or problem-based learning (PBL), are shown to increase student exam scores and decrease student failure rates when compared to instruction using lecture methods alone [1, 2]. However, there is not sufficient information to show that active PBL is effective for teaching ethical reasoning and decision-making in college-level engineering courses.

To evaluate PBL as an effective approach for teaching ethical reasoning, our team is examining differences in first-year electrical and computer engineering undergraduates after participating in an introductory course delivered in a traditional lecture format compared to PBL style [3]. As part of both courses, students complete three modules that require them to identify one or more ethical dilemmas present in a given fictional scenario. While evaluating student work for these modules in Year 1, the study team noted a large proportion of students had challenges correctly identifying the ethical dilemma(s) (and most appropriate IEEE codes of conduct) for the scenario given. This finding is concerning because awareness is necessary for ethical behavior. They also need awareness to be involved in ethical decision-making. In addition, students who fail to identify that an ethical dilemma is even present are not equipped to then resolve or mitigate the situation at hand. Finally, awareness is essential for risk mitigation. This is an area of concern that warrants improvement in this skill for these students.

In Year 2 of the study, the research team provided additional exercises (fictitious case studies) to 6 of the assignments in both PBL and lecture courses. For each case study, students were tasked to identify the IEEE ethics code most relevant to the case. This task provided all students the opportunity to practice identifying ethical dilemmas before the end-of-module problems.

This report provides an overview of the newly integrated case studies, an analysis of student performance at identifying the most appropriate IEEE ethics code for each case, and comparisons of students' identification of the ethical dilemmas in the end-of-module problems between groups who did, and did not, complete the additional case-studies. Additionally, we detail insights regarding which ethical dilemmas first-year electrical & computer engineering (ECE) students are most successful at identifying and where they have the most misconceptions. This information will be used to inform which topics require further focused content to improve student mastery, both in this course and for other engineering educators integrating ethical reasoning content into their freshman engineering courses.

Summary of ECE 121 (Introduction to Electrical and Computer Engineering)

At the University of Alabama (UA), one-credit courses in the College of Engineering introduce first-year students to their specific disciplines (e.g., mechanical, aerospace, chemical, electrical/computer, computer science). These courses focus on basic discipline-specific concepts, along with assignments that raise student awareness of other key skills important for ABET course requirements including design, ethics, computer simulations, and life-long learning. Each department has developed its own version of this course, numbered 121, to expose students earlier to their major discipline. This study is focused on ECE 121, the introductory course offered by the Department of Electrical and Computer Engineering.

Our redesign of ECE 121 [2] has centered ethics as a core feature of the engineering profession. The course introduces the codes of ethics from engineering societies (e.g., Institute for Electrical and Electronics Engineers (IEEE) [5], National Society of Professional Engineers (NSPE) [6]) as guides to inform the "why" behind the engineering design process rather than starting with the "how." The course is delivered as three modules with each module focused on a different set of technical topics that ethics are applied to: 1) circuits & safety, 2) materials for electronics, and 3) digital data & sensors. These specific topics were selected to continue the alignment with the power, electronic materials, and embedded systems research thrusts of the department faculty. Each module has 5 (50 minute) lecture periods. The first 4 are focused on technical and ethical elements in these domains and the final lecture is used to facilitate small group work to solve an end-of-module problem/case study. After each lecture, students complete a graded assignment (due before the next lecture) based on the covered material. These assignments were structured to provide integrated practice of both technical and ethical reasoning skills required to complete the end-of-module problem/case study.

The Year 1 student submissions of each end-of-module problem were evaluated using the Pittsburgh-Mines (PM) Engineering Ethics rubric [7]. This rubric assesses 5 attributes: recognition of the dilemma; information; analysis complexity and depth; perspectives; and resolution. This rubric was specifically developed to create a framework for educators to assess students' level of ethical achievement and understanding. Using this rubric, the project team noted lower-than-expected performance for recognition of the dilemma in the evaluation of approximately 114 student submissions. The average scores for these submissions were in the range of 2-3 (on a scale from 1 to 5). These scores correspond to evaluations of students as being able to identify problems (but only inferring it is an ethical dilemma) or recognizing obvious dilemmas (but failing to recognize less obvious dilemmas).

Based on these results, we revised the Year 2 course assignments to improve students' abilities to recognize ethical dilemmas. Specifically, we added questions that required students to identify the part of the IEEE Code of Ethics that was most relevant for a given case study.

IEEE Case Studies

A total of six case studies (developed and published by R.C. Woods, D.A. Conner, G.-A. Capolino, and G. Adamson, and the IEEE/EMCC Member Support Subcommittee, referred to as the authors throughout this document) were included in six ECE 121 course assignments in the Fall 2022 and Spring 2023 iterations of ECE 121. Two were added for module 1, two for module 2, and 1 for module 3.

These case studies are fictitious examples to illustrate ethical issues that can arise in the engineering profession [5]. Each case outlines the context, event, potential complicating factors, and authors commentary on the appropriate IEEE code of ethic relevant for the case. The exact case studies (from the 16 available) that were included are given in Table 1. Each was selected based on their alignment with major themes in the course.

Table 1. Case studies added to ECE 121 assignments for student practice to identify most appropriate Code of Ethic relevant to different situations.

ID	Case	Code
1	**[Context:]** Part of Christopher's job is final inspection, immediately prior to shipping, of all the Tergic Blips made by Exalted Electrical Engineering Pvt. Ltd. Christopher has been given wide latitude regarding what should be inspected as this is a "back stop", to catch any obvious manufacturing defects that should have been caught earlier in the inspection process, to make absolutely sure that customers find no cause for complaint with Exalted Electrical Engineering's products. **[Event:]** One day Christopher finds that the electrical insulation on all the Tergic Blips he tests that day is faulty and might be dangerous under some conditions. He makes some enquiries of the production staff and finds that Shoddy Materials Inc. was contracted to supply the insulation the previous month, and that all their parts have performed badly under this test. As a result, all the Tergic Blips previously sent out with insulation from Shoddy Materials may be potentially faulty. He reports the facts to his supervisor Dusty, the Senior Production Manager of Exalted Electrical Engineering, who tells him that Shoddy Materials was contracted because their insulation was much cheaper than that from their previous supplier, and it was cheaper because it was known to be not as good as what was used previously, but it is good enough for Tergic Blips. **[Complicating factors:]** The manufacturing specification followed by the Production Department at Exalted Engineering has just been adjusted and approved accordingly by Dusty to allow the use of insulation supplied by Shoddy Materials. Dusty advises Christopher to accept that the reduced performance of the current Tergic Blips is actually adequate and safe under all likely conditions, as otherwise Christopher's employment might be terminated. Christopher concedes that the performance meets the revised specification, but still feels that it is potentially dangerous. **Which of the IEEE code of ethics (if any) should drive the actions of Christopher and Dusty for this situation?**	#1
2	**[Context:]** Robert is a licensed Professional Engineer in the State of Arcadia. In that State, only licensed Professional Engineers are allowed to sign off (i.e., to certify conformation with all the applicable installation codes and regulations) the plans, designs, and specifications for the permanent electrical installations (including distribution panels, wiring, sockets, safety protection devices) planned in newly constructed or renovated buildings. In that State, this step is required before the local government authority will consider approval of the proposed construction or renovation. Robert's professional education and work experience is in electrical engineering with an emphasis in the field of power systems. His long-standing friend Elizabeth wants to start a business that will launder hotel items such as towels and bed linens. Elizabeth is not a licensed Professional Engineer but designs the electrical layout for the washers and dryers in her future business premises. **[Event:]** Elizabeth asks Robert to sign off and seal her design drawings so that they can be submitted to the local building authority for construction approval. **Which of the IEEE code of ethics (if any) should be the most important for Robert to consider during this situation?**	#1
3	**[Context:]** Harriet, a design engineer, attends an IEEE workshop that includes a plant tour of Tremendous Gear, Inc., a company noted for its innovative equipment design. **[Event:]** While on this tour, she happens to pass an unoccupied desk and sees a detailed schematic drawing of a new product that Tremendous Gear is about to manufacture and market.	#5

	She is impressed with the innovative nature of the design. Upon returning to her own company, she thinks about duplicating the design and presenting the idea to her manager as a product that her company could manufacture and market. **Which of the IEEE code of ethics (if any) should be the most important for Harriet to consider during this situation?**	
4	**[Context:]** Electrical Design Engineer John is tasked with designing a 110kV to 765kV step-up transformer for a unique US customer application. His new boss, Juan, recently transferred to the USA from the corporation's plant in Madrid, Spain. John is careful to make detailed inquiries to his customer regarding the environment in which this special transformer will operate and is also careful to ask about the type of transportation to be used so that his design will not be damaged in transit. He is told that the transportation will be accomplished via a specially-designed truck over the U.S. interstate highway system. **[Event:]** Two weeks after John met with the customer, the customer contacts Juan with the news that the transformer will, instead, be transported via a rail carrier. Unfortunately, Juan does not communicate that information to John. **[Complicating factors:]** After the design is completed and the transformer is transported to its destination site by rail, the site inspection of the transformer finds that the transformer has serious internal damage which requires its return to the manufacturing site, disassembly, repair, reassembly, and transportation back to the destination. The customer refuses to pay any part of the additional incurred cost, and Juan blames John for a poor design. **Which of the IEEE code of ethics (if any) is most relevant to this situation?**	None
5	**[Context:]** In 2018, Pierre Standalone (an IEEE Senior Member), Associate Professor of Electrical Engineering at the University of Western East Dakota, decides to offer a two-course special topics sequence for senior-year students that requires the design of an in-flight recharging system for a drone. Four students, Peter, Pyotr, Pietro, and Petya enroll in the sequence. During the design phase, Pyotr and Petya come across a technical report from Drohnen-Aufladen GmbH (a German company) that provides detailed information on an inflight recharging system for a drone. **[Event:]** Without disclosing their source, Pyotr and Petya present their design team with a "rough draft" of a design solution for their assigned project. Over the course of their senior year, the team uses that information to develop a working prototype. At the end of the year, Professor Standalone is so impressed that he suggests that all the students publish a scientific paper on their work. **[Complicating factors:]** A manuscript is written, submitted to the IEEE Journal of Drone Recharging, accepted for publication, and published. At no time does the team acknowledge the original source of their design solution. **Which of the IEEE code of ethics (if any) is most relevant for this situation?**	#5
6	**[Context:]** Lisa is a consulting electrical engineer who is competent to prepare specifications for Wifi and Bluetooth wireless systems for media access control and physical layer. Lisa also owns a small company (We WiFi U, Inc.) that manufactures and installs systems compliant with IEEE 802.11 (the Wifi and Bluetooth standards). **[Event:]** The Omni-Supply Corporation hires Lisa as an independent consultant to prepare specifications for a system that will be installed in their new 100,000 square-foot distribution center. Once the design specifications are completed and provided to the Omni-Supply Corporation, Omni-Supply requests bids for installation of the wireless system. And…the winning low bidder is We WiFi U, Inc. After the new Omni-Supply distribution center is operational, a newspaper article mentions that Lisa owns We WiFi U. The Omni-Supply Corporation becomes concerned.	#3

	Which of the IEEE code of ethics (if any) is likely to have driven Omni-Supply Corporation's concern?	

For each case study, students were asked to identify the most relevant IEEE code of ethic for this situation (or report if none applied) as a multiple-choice question. For reference, the IEEE code of ethics [5] that students were able to select from are summarized in Table 2.

Table 2. Summary of IEEE Codes of Ethics

ID	IEEE Code of Ethic
1	To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment
2	To improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems
3	To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist
4	To avoid unlawful conduct in professional activities, and to reject bribery in all its forms
5	To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others
6	To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations
7	To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression
8	To not engage in harassment of any kind, including sexual harassment or bullying behavior
9	To avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses
10	To support colleagues and co-workers in following this code of ethics, to strive to ensure the code is upheld, and to not retaliate against individuals reporting a violation

Each assignment was delivered using the Blackboard learning management software (LMS). Students were given 3-10 assignment attempts before the final deadline. There was no penalty to students for using multiple attempts, with the aim of encouraging engagement with the material and improving mastery of the concepts. Each submission was auto-graded by the LMS with the overall assignment score and incorrect questions reported to the students. However, this reporting did not provide the correct answer for incorrect questions in an individual submission to encourage students to keep engaging. The number of attempts per assignment varied, with higher attempts reported for assignments with challenging technical calculations and components.

After the assignment deadline, the commentary provided by the case study authors detailing the ethical problem and code of ethic most relevant for each case study was made available directly in the LMS as feedback to students. This was provided to help them increase their understanding of the most relevant code of ethic for each case.

Student Results

The student submissions from the three course iterations (two in Fall 2022 and one in Spring 2023) were exported from the LMS and merged into a single dataset for analysis. For this initial analysis, the students in the PBL and lecture-style courses were not differentiated. The merged dataset for each IEEE case was cleaned to remove duplicate entries from student submissions that contained the same answer for the IEEE case but a different answer for another question on that assignment. This cleaning was done to prevent over-representation of selected IEEE code of ethics from multiple submissions not related to the IEEE case studies.

The distribution of student selections of the IEEE code of ethic most relevant to each case (or identifying none as being appropriate) as a percentage of the total submissions were calculated using the merged/cleaned dataset. These values are provided in Table 3. Note that the **bolded** IEEE code of ethic for each case denotes the author answer. Additionally, the total number of students who submit responses and the total unique responses are also provided.

Table 3. Student selections of IEEE code of ethic for 6 case-studies in ECE 121

Case	Students (Responses)	Percentage of Student Answers for each IEEE Code of Ethic for each case										
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	None
1	113 (127)	**77.2**	0	3.9	1.6	6.3	2.4	0	0.8	0	7.9	0
2	114 (156)	**51**	0	7.2	9.2	7.8	19	0.7	0	0	5.2	0
3	115 (211)	12	1.7	12	20.2	**36.5**	2.6	0.9	0	3	1.7	0
4	112 (242)	9.1	3.7	10.3	2.5	16.9	8.7	2.9	1.2	11.2	6.2	**27.3**
5	109 (107)	1.9	0	2.8	3.7	**89.7**	0.9	0	0	0	0	0.9
6	112 (145)	4.1	0.7	**74.5**	9	3.4	2.1	1.4	0	0	0	4.8

From the distribution of student submissions, the percentage that align with the authors identified IEEE code of ethic most relevant for the case study ranged from 36.5% (case 3) to 89.7% (case 6). Overall, 3 cases had >75% student submissions aligning with the appropriate IEEE code of ethic, 1 case with approximately 50%, and 2 cases less than 50%.

Discussion

The range of student selections for most relevant IEEE code of ethic across the six case studies is not surprising in the context of the students' backgrounds. The majority of students in ECE 121 are in their first-year of the program and have had limited exposure to the ethical reasoning requirements of the profession. They are not expected to have mastered these skills, which is evidenced here by half the cases having with 50% or less of submissions matching the author answer. This continues to support why this practice is being introduced at this early stage to help the ECE students' development of their ethical reasoning skills.

What is interesting in the context of revising future instruction in the course is the distribution of answers and what this may suggest about student misconceptions about the application of the IEEE code of ethics. An exploration of each case (from the case with the highest percentage of submissions that correctly identified the relevant code of ethic to the least) is provided below:

<u>Case 5:</u> Nearly 90% of submissions identified the appropriate IEEE code of ethic for this case, which was focused on giving proper credit to the contributions of others. This suggests that most first-year students have a clear grasp of attribution requirements in the context of engineering design and group work.

Case 1: More than 77% of submissions identified the appropriate IEEE code of ethic for this case, specifically that holding paramount the safety, health, and welfare of the public was the most important aspect. A subset of submissions identified that supporting colleagues and co-workers in following this code of ethics (Code #10) and seeking, accepting, and offering honest criticism of technical work (Code #5) as most relevant. While both codes #10 and #5 do apply in this case, it suggests some students are having trouble identifying the most relevant code that should drive decision making. Specifically, that consideration of the public should always be the primary factor. Future course instruction could provide explicit details on how to evaluate the most important case in situations where one or more can be applied.

Case 6: More than 74% of submissions identified the appropriate IEEE code of ethic for this case, specifically to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist. A subset (~10%) of submissions identified that avoiding unlawful conduct in professional activities, and to reject bribery in all its forms was the most appropriate code of conduct for this case. This suggests some students are having trouble differentiating financial conflicts of interest and illegal activities, which may require further direct instruction to clarify the nuances of a financial conflict of interest and how it can impact decision making.

Case 2: Approximately 50% of submissions identified the appropriate IEEE code of ethic for this case, specifically that holding paramount the safety, health, and welfare of the public was the most important aspect. This percentage of appropriate submissions is lower than Case 1, which had a similar focus on the safety of the public. Comparing the two cases, the language for Case 2 does not explicitly state that installation errors of electrical systems could cause injuries or harm to those who use the system (i.e. the public), while Case 1 had explicit language about this aspect. This suggests that students may struggle with considering the wider implications of the case study beyond the direct wording provided.

Also, there could be misunderstanding about to whom the IEEE code of ethics applies. Only one actor (Robert) in the case study is an engineer and bound to the code of ethics while the second (Elizabeth) is not. A subset of submissions (~19%) selected to undertake technological tasks for others only if qualified by training or experience as the most relevant code of ethic. Which would be appropriate if Elizabeth was an engineer, but is not appropriate here because Robert is an engineer with training relevant for the situation. Further instruction on identifying the actors most relevant to the ethical situation and IEEE code of ethics could help with this misunderstanding.

Case 3: Only 37% of submissions identified the appropriate IEEE code of ethic for this case, which was focused on giving proper credit to the contributions of others. The code of ethic with the second-largest submissions for this case was to avoid unlawful conduct in professional activities, and to reject bribery in all its forms (with ~20% of submissions). This suggests that students do recognize that this case has an ethical challenge but struggle to differentiate the distinctions between an action that is illegal and one that is unethical. There were no details of illegal or unlawful activities in the case study and drawing inspiration from observing the work of others is not unethical; but using others work without giving proper credit is unethical. Further instruction of the differences between unethical and illegal could increase students understanding and ethical reasoning in this case.

Case 4: Only 27% of submissions identified that no IEEE code of ethic was appropriate for this case. The submissions received indicate students struggled with this case the most out of all others. Exploring the range of submissions, this is the only case with submissions for EVERY code of ethic. This could suggest that students were picking at random and using their multiple submissions to find the correct answer; highlighting that they struggled with understanding that this case highlights a poor communication process in a project, but none of the actors acted unethically. Future instruction focused on differentiating a poor process from an ethical challenge could be beneficial for students.

Overall, when submissions indicated students struggled to identify the IEEE code of conduct most relevant to a case study they tended to be for cases when multiple codes could be applied and/or where language did not align perfectly with the IEEE code of conduct. For future iterations of ECE 121, minor revisions in instruction will include further guidance on prioritizing when multiple cases could be applied (i.e. highest priority is always holding paramount the safety, health, and welfare of the public) and recommendation to not just pattern match for words, but instead use the wider context and content of the case. These conclusions are similar to reports by Shuman et. al [8] in their evaluation of student ethical reasoning when developing the PM rubric, noting that students tend to recognize obvious dilemmas but not the subtle (and possibly more serious) dilemmas contained in short cases.

Recall that these practice case studies were to prepare students for an end-of-module problem. Each of these end-of-module problems had a primary ethical problem focused on holding paramount the safety, health, and welfare of the public for fictitious case-studies. These 3 final case-studies were on topics of: 1) electrical safety in a factory, 2) design of electronics using conflict minerals, and 3) design and use of wearable sensors. Each case also had a secondary, more subtle dilemma. For the case on electrical safety in a factory, the secondary dilemmas focused on acknowledging errors and undertaking tasks only if qualified by training or experience. The secondary dilemma for both other cases focused on the implications of technologies on society, and the responsibility of an engineer in improving the understanding of individuals and society about them.

The average student performance on the end-of-module problems, specifically their score towards recognition of the dilemma as assessed by the project team using the PM rubric, for the Year1 and Year 2 cohorts are given in Table 4. These values are the average score of all individual student submissions for each module in each year, with scores from 1 (lowest level of ethical achievement) to 5 (highest level of ethical achievement) assigned to each category. The same project team members graded the submissions in both years.

Table 4. Pittsburg-Mine ratings of students recognition of ethical dilemmas for ECE 121 end-of-module problems in ECE 121			
Group	**Module 1**	**Module 2**	**Module 3**
Year 1	2.811 (N=114)	2.027 (N=103)	2.700 (N=114)
Year 2	3.131 (N=109)	2.514 (N=110)	2.780 (N=112)
Difference (Year2-Year1)	**+0.32**	**+0.487**	**+0.080**

The Year 2 scores are higher than the Year 1 average scores for all cases; with increases of +0.32, +0.487, and +0.08 for modules 1, 2, and 3, respectively. While the statistical significance of these differences is not analyzed here, the increasing trends supports those students in Year 2 demonstrated greater recognition of ethical dilemmas in these problems than the Year 1 counterparts. We attribute some of these gains to the increased practice provided in the course due to the assignment revisions and included case studies. However, it is important to note that in Year 2, the language of the end-of-module prompts (but not the problem information or language) was also revised to improve the clarity which could also have an impact on student performance. Though it is not possible to isolate the change in performance due to each course change in the collected dataset of this study.

Overall, the use of case-studies in ECE 121 to provide first-year students practice at recognizing and identifying ethical dilemmas was successful. Students who had the opportunity to practice these skills demonstrated better recognition of ethical dilemmas in the end-of-module problems when compared to their peers in a previous course iteration who did not use them. We recommend the continued use of these case studies in the course. Further, we would encourage other engineering educators who have course goals to improve student ethical reasoning and recognition of ethical problems to adopt these case studies as low-stakes assignments into their own courses.

Implications

Developmental Stage of Students: Acknowledging that most students in ECE 121 are in their first year and have limited exposure to ethical reasoning is important. It sets realistic expectations for their proficiency in identifying ethical dilemmas and aligns with the rationale behind introducing these practices early in the program. Understanding the developmental stage of students helps tailor instructional strategies to meet their current needs.

Identification of Misconceptions: The analysis highlights specific misconceptions that students may have about the application of the IEEE Code of Ethics. For instance, in Case 2, the difficulty in prioritizing the safety of the public over other considerations is indicated. Similarly, in Case 3, there is a challenge in differentiating between unethical and illegal actions. Recognizing these misconceptions is crucial for targeted instructional interventions to address specific areas of difficulty.

Contextual Understanding: The discussion emphasizes the importance of considering the wider context and content of case studies. Students may struggle when language is not explicit or when implications beyond the provided information need to be considered. This suggests a need for enhanced guidance on evaluating the broader context and implications of ethical decisions.

Differentiation of Roles: The observation that some students misunderstood to whom the IEEE Code of Ethics applies (e.g., only one actor being an engineer) is significant. Providing clarity on the roles and responsibilities of different actors in a scenario could help students make more accurate ethical judgments.

Student Improvement Over Time: The comparison of Year 1 and Year 2 average scores for recognition of ethical dilemmas in end-of-module problems indicates a positive trend. Students in Year 2 demonstrated greater recognition of ethical dilemmas, suggesting that the increased practice and revisions in the course positively influenced their ethical reasoning skills.

Attribution of Gains: While the gains in Year 2 are attributed to increased practice, we acknowledge that other factors, such as language clarity in end-of-module prompts, may also contribute. Isolating the impact of each course change would require further analysis. However, recognizing the multifaceted nature of these improvements informs future instructional decisions.

Plans for Future Teaching

Recommendations for Future Instruction: The insights gained from the analysis provide clear recommendations for refining future instruction. These include providing explicit details on evaluating the most important case in situations with multiple applicable codes, offering guidance on prioritizing ethical considerations, and emphasizing the importance of not just pattern matching for words but understanding the wider context.

Success of Case-Study Approach: The positive impact of using case studies for practice in recognizing and identifying ethical dilemmas is evident. The higher scores in Year 2 suggest that the inclusion of these case studies contributes to improved student performance in ethical reasoning. Encouraging other engineering educators to adopt similar case studies for enhancing ethical reasoning in their courses is a valuable recommendation.

Plans for Future Research

Future analyses will evaluate if there are also differences in the aspects of ethical achievement measured by the PM rubric (but not compared here). Specifically, the use of information, the analysis complexity and depth, the perspectives, and the resolution. The analysis presented here explored only one aspect (recognition of dilemma) but we hypothesize that improvements in this score will also lead to improvements in all other PM aspects, that is students are hypothesized to demonstrate greater ethical achievement overall when they are better able to recognize the dilemma.

Further, additional analyses will explore if there are differences in PM scores not only between years (and the use of case studies in assignments) but also between delivery types (PBL vs. lecture). This further data will contribute to the final analysis to answer our overall research question: **Is PBL a more effective pedagogy (than lecture-based) to teach ethical reasoning in support of social responsibility to freshman ECE students during their primary introduction to the discipline?**

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