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ABET, Inc. (formerly known as the Accreditation Board for Engineering and Technology, 1997, p.1, p.2) includes in their criteria for accrediting engineering programs a requirement that graduates must demonstrate an understanding of professional and ethical responsibilities based on economic, environmental, ethical, social, and political constraints. Although ABET criteria provides an extrinsic rationale for addressing ethics issues in engineering education, the most compelling rationale is the omnipresent nature of ethical issues in engineering practice for which students are preparing. The ethical problems that engineers encounter throughout their careers influence the businesses they work for, the public at large, and the health and safety of society[1]. Engineering ethical problems arise in routine engineering practice and are often integrated with technical, engineering issues.

If ethics instruction is essential to the preparation of engineers, then the engineering education community must determine the goals and methods for best preparing engineering students for practice. Haws[2] argued that engineering programs not only push their students to become concerned about the public health and safety of others, but also to 1) help their students to defend their solutions to ethical problems, 2) acquire the ability to evaluate alternative solutions from different perspectives, and, 3) enhance students’ divergent thinking (e.g., understanding situations from other stakeholders’ points of view). He argued that ethical behavior involves grounding ethical issues in different theoretical approaches, considering multiple options with multiple consequences, and communicating with other stakeholders involved. This assumption is important because ethics problems are ill-structured and defined by multiple perspectives. It is also important because university students are unskilled in solving ill-structured problems with unclear answers. They have learned in their classes that engineering problems usually have correct answers that can be graded for their accuracy. In traditional engineering ethics classes and textbooks, for instance, students may learn about different theoretical approaches to ethics. However, when those theories are applied to everyday cases, the solutions recommended by them may be substantively different. Ethics problems are necessarily situational to some degree. Uniformly applying a set of beliefs cannot work effectively in all contexts. In order to reconcile conflicting perspectives requires argumentation skills, which undergraduate students also lack. So, these studies required engineering students to acquire and apply new skills, including understanding ethical situations from other stakeholders’ points of view, evaluating alternative solutions from different perspectives, arguing for and defending their solutions to ethical problems, all essential skills when solving ethical problems.

The two studies reported here follow up former studies[3] in which the researchers have investigated argumentation strategies to achieve Haws goals for instruction in engineering ethics. Rather than studying professional ethical codes or humanist readings to help students gain a more social and human understanding from perspectives different from engineers, our research studies have required engineering students to analyze and solve
ethical cases based on various moral theories and perspectives in a web-based, problem-centered learning environment, Engineer Your Ethics (EYE).

In the previous study \[3\], we concluded that requiring students to generate arguments in support of solutions to ethical problems and anticipate and rebut alternative solutions provides a useful strategy for engaging engineering students in ethical problem solving. Although argumentation is not the only method for supporting ethics instruction, it is a widely used and powerful strategy for supporting many kinds of learning\[4\]. When constructing arguments in support of solutions to ethics problems, our previous studies demonstrated that students experience difficulties in anticipating and rebutting counterarguments (alternative solutions to solutions to ethics problems). If the correct solution to ethics problems is unclear, requiring students to recognize, evaluate, and address alternative solutions can be a useful strategy for engaging engineering students in ethical problem solving. In this paper, we describe two studies in which we investigated alternative methods for helping engineering students to anticipate and rebut counterarguments.

The research reported in this paper was carried out in the context of a web-based, interactive learning environment, Engineer Your Ethics (EYE). EYE presented everyday ethics problems to students. Each problem scenario was elaborated with personal perspectives on the problem, applications of theories and ethical canons, and various argumentative tasks for engaging ethical problem solving. EYE manifested the conceptual framework \[5\] in which students identify ethical issues by applying different ethical theories and professional codes of ethics, identify stakeholders and their perspectives on the issue, generate solutions according to ethical theories, and make ethical decisions by referring to the various optional solutions, perspectives and theories.

In the EYE environment, Case 1 presented a story about an engineer deciding whether to exempt a few buildings from new building codes in return for approval to hire more building inspectors. Cases 2 (design testing) and 3 (golfing) also included ethical decision-making problems with different contexts from Case 1. Case 1 presented the problem. Enabling learners to examine the case from the perspectives of the different characters, from different theoretical approaches (utilitarian, rights and duty, virtue), and from canons provided by the National Society of Professional Engineers. It is important to note that each perspective presents an application of that perspective, theory, or canon to the specific ethical problem, not just a definition of each. Because ethical problems are ill-structured without definitive solutions, learners need to consider alternative perspectives when constructing their own solution. Knowledge transfer to the new cases relies on that ability. It is also important to note that different perspectives or theories on ethical problems often provide conflicting interpretations, requiring learners to reconcile conflicting beliefs.

In order to support students’ construction of better solutions that considered multiple perspectives, theories, and canons, students needed to construct arguments in support of their solutions, our previous study \[3\] examined alternative approaches for eliciting arguments from engineering students related to ethics cases. They hypothesized that
constructing arguments in support of an ethical claim or evaluating alternative arguments would provide a more generative purpose for considering the alternative perspectives, theories, and canons that were provided to interpret the ethics problems. Alternative instructional treatments that required students to construct their own solutions and justifications (rhetorical or persuasive form of argumentation) or evaluate alternative solutions and justifications (a dialectical form of argumentation) were implemented in the EYE environment and compared with a control group treatment, in which students were instructed to investigate the materials in order to provide a solution to the ethical problem. Previous research found that when students justify their own claims, they produce poorer arguments with fewer counterarguments than when they consider alternative claims and justifications. The results from that experiment showed that argumentation provides a meaningful and engaging task for resolving engineering ethics cases. Students in both experimental treatments produced stronger arguments than the control group students. In the immediate transfer case, students in the experimental conditions generated more theories to support their solutions, identified more counterclaims, and generated more theories to support counterclaims than the control group students. However, there were no significant differences between the evaluate treatment and the construct treatment on the quality of arguments on the delayed transfer case. The effects of the alternative treatments faded in the delayed transfer case. Consistent with other research, students in this study failed to adequately consider and support counterclaims, providing more elaborate support for their own solutions. Because the ability to generate and use counterarguments is widely regarded as a hallmark of good argumentation, the two experiments reported in this paper sought to compare methods for increasing the level of counterargumentation while solving engineering ethics problems.

Experiment 1

In order to enhance dialectic argumentation, researchers have contrasted the effects of rhetorical and dialectic strategies. Persuasion instructions reduce the number of counterarguments generated by students. Students actually believed that if they identify counterarguments, it would make their own argument less persuasive. When instructed to produce counterclaims (reasons others may disagree with you) and rebuttals (why are those reasons wrong), students were in fact able to produce more counterclaims, rebuttals, and reasons to support their rebuttals. In the first experiment, we investigated alternate methods for eliciting stronger counterarguments as a pedagogical strategy (not an ethical or philosophical strategy) for helping students recognize and address alternative solutions and perspectives. In this study, the treatment asked all participants to write as many reasons as possible why others might disagree with a given solution. We compared the effects of those self-generated counterarguments on the quality of their arguments with counterarguments generated by peers.

Fifty undergraduate engineering majors, enrolled in two separate sections of a required first-year engineering education course at a major southeastern university, participated in this study. The sample population consisted of 42 males and 8 females (12 freshmen, 28
sophomores, 6 juniors, and 4 seniors). There was no significant difference in the class rank (2.0 = rising sophomore) of participants in the self-argument group ($M = 2.2$) and the other-argument group ($M = 2.07$).

The version of Engineering Your Ethics (EYE) used in this study consisted of three everyday ethics cases that participants were required to solve. Case 1 presented a story about an engineer deciding whether to exempt a few buildings from new building codes in return for approval to hire more building inspectors. Cases 2 (design testing) and 3 (golfing) also included ethical decision-making problems with different contexts from Case 1. Case 1 presented the problem (Figure 1). Clicking on each link displayed on the right side of Figure 1 (Perspectives of Characters, Theoretical Approaches, and Ethical Canons) presented interpretations of each ethical dilemma from different personal, theoretical or canonical (National Society of Professional Engineers) perspectives. Each perspective presents an application of that perspective, theory, or canon, not just a definition of each. These different perspectives often provided conflicting interpretations. These resources were removed from Cases 2 and 3, although students were instructed to “consider multiple perspectives, theories, and ethical canons” when completing their responses.

Two alternative approaches to enhancing student construction of counterarguments were tested. When directed to generate a solution to the building inspection and the second (design testing) case, the other-argument treatment included an exemplary solution of the case that was supported by perspectives, theories, and canons but no counterarguments were included. In this treatment, students were required to generate as many counterarguments to that solution as possible. In the self-treatment, Cases 1 and 2 required students to describe what they would do as the engineer in the case and then “write as many reasons as possible why others might disagree with your solution.” In Case 3, completed one week following the initial session, students were presented with a third case where an engineer was betting on golf matches with a vendor. Students were instructed describe what they would do regarding the relationship with the vendor, providing as many reasons to support their solution, and to think of as many reasons as possible why others might disagree with their solution, justifying their solution with perspectives, theories, and/or canons. The purpose of this study was to assess which treatment would generate more counterarguments, and how well students would justify their responses using different perspectives.

Participants’ counterarguments in Cases 1 and 2 were combined and analyzed by two researchers using a rubric that assigned 1 point for an undeveloped counterargument, 2 points for partially developed counterarguments, and 3 points for well developed counterarguments for each of three categories of reasons (perspectives, theories, and canons). Well-developed counterarguments were clearly stated and specifically explained and elaborated, whereas undeveloped counterarguments were neither clearly stated nor specifically explained and elaborated. Partially developed counterarguments included a clear position but lacked specific explanation and elaboration. The inter-rater reliability was moderate for both categories (Cohen’s kappa = .69) and qualities (Cohen’s kappa = .73) of
counterarguments, and the researchers resolved all differences in their coding through discussions.

Participants’ argumentative essays in response to Case 3 were analyzed in two ways: idea units and holistic scores. Each student essay was segmented into discrete ideas (M = 7.14 ideas per essay). Each idea unit was then classified by two researchers as a solution, counterclaim, reason supporting a solution, reason supporting a counterclaim, counterclaims, and rebuttals. In addition, the quality of each idea unit was rated holistically by two raters from 1 (undeveloped) to 5 (well developed) points (see Table 2). The inter-rater reliability was moderate for categorical coding (Cohen’s kappa = .64) and for the holistic quality (Cohen’s kappa = .63) of idea units. Holistic scores were also independently rated by two researchers and determined to be undeveloped (one pint), minimally developed, partially developed, well developed, or fully developed (5 points).

Experiment 1 examined the efficacy of self-generated arguments vs. responses to arguments generated by others in facilitating counterargumentation when solving engineering ethics problems. Counterarguments were assessed in terms of the number of counterarguments, the quality of counterarguments, and the proportion of theories and canons as supporting reasons. We also examined the proportion of theories and canons because the purpose of studying engineering ethics cases is to apply ethical theories and canons and use them for solving authentic problems. A higher proportion of theories and canons indicated that students used more ethical theories and canons than perspectives of stakeholders in order to support their counterclaims.

A multivariate analysis of variance (MANOVA) was carried out with the treatment (self-argument vs. other-argument) as an independent variable and the number of counterarguments, the quality of the counterarguments, and the proportion of theories and canons used to support those arguments as dependent variables. The MANOVA indicated that there were significant differences in counterarguments between the self-argument and other-argument groups. Follow-up statistical analysis revealed significant differences between the two groups in the number of counterarguments and the quality of counterarguments. Students generated more counterarguments and higher quality counterarguments against other-arguments than their own arguments. However, there was no significant difference in the proportion of theories and canons between the self-argument and other-argument groups. In both groups, more than 60% of counterarguments were based on the perspectives of stakeholders rather than ethical theories or canons indicating that students were more concerned about the people than they were any ethical principles.

In the transfer case (golfing), completed one week following the initial session, a MANOVA was carried out with the treatment as the independent variable and argumentation components, the proportion of theories and canons, and holistic scores as dependent variables. There was a significant effect of treatment on the argumentative essays in Case 3. Students in the other-argument group gained higher holistic scores than those in the self-argument group. Unfortunately, there were no other significant effects for
argumentation components and the proportion of theories and canons among supporting reasons. Students in both groups used ethical theories and canons to support fewer than 20% of their claims and counterclaims, and they did not consider on average more than one counterclaim in argumentative essays.

Counterargumentation is widely regarded as a defining attribute of good argumentation \(^{[11-12]}\). Students who constructed counterarguments to another’s argument generated more counterarguments and constructed higher quality arguments than students who constructed counterarguments to their own argument. There was no difference between the groups in terms of the proportion of ethical theories and canons referenced to support their counterclaims. Our findings were similar to Nussbaum and Kardash \(^{[6]}\) who found that a text that outlined numerous arguments on both sides of the issue increased the level of counterargumentation. When prompted to refute the arguments of others, students learn to recognize alternative solutions (What solution might someone else recommend, and how would you respond to their reasons?) and to rebut other arguments \(^{[13]}\). Unfortunately, those effects were not sustained across time in the transfer case.

Experiment 2

When teaching any idea, presenting an example (and preferably two or three) is what effectively communicates the idea to students. Humans naturally induce meaning for concepts from examples. Therefore, Experiment 2 examined the effectiveness of examples in supporting the generation of counterarguments. Examples function as models of performance for students. Schworm and Renkl \(^{[14]}\) found that examples of argumentation are effective for improving declarative knowledge about argumentation. One reason that students may not be able to generate counterarguments is that they do not comprehend the concept of counterarguments. So, in two of the treatments in Experiment 2, we supplied students with examples of counterarguments and investigated whether those examples would enhance transfer. The more typical that an example is of any concept, the more effective it is in communicating the idea \(^{[15]}\), so the examples of counterarguments that were used were the most commonly generated by students in previous studies. In experiment 2, we sought answers to the following research questions:

Question 1: Do counterargument examples support generating counterarguments and rebuttals in the learning session?
Question 2: What are the effects of counterargument treatments on qualities of argumentative essays?

In Experiment 2, 75 college students (42 males and 33 females) enrolled in three separate sections of an introductory engineering course at a southeastern university participated as part of their coursework. All participants were first-year college students and most participants (78%) were Caucasian Americans (10% African American, 7% Asian American, and 5% other).
A quasi-experimental pre- and post-test design was used for this research. Three sections in which participants enrolled were randomly assigned to three treatment options: 21 students in the construct condition, 27 students in the example condition, and 27 students in the combined condition. As a pretest, all participants wrote an argumentative essay on an engineering ethics case problem (Case 1) in the EYE environment without instructional supports and time limitations. Among the three groups, there were no significant differences in initial argumentation skills as assessed by the holistic scores on the pre-test.

All learning activities and tests were carried out in the web-based learning environment during regularly scheduled classes when students logged into the EYE environment. The environment contains four case problems of engineering ethics, which were adapted from the NSPE ethics cases (http://www.niee.org). Case 1 presented a story about an engineer who must decide whether his or her firm would give money to a promotion committee for public works in the possibility that the firm might seek design commissions later. Cases 2 (code enforcement), 3 (golfing with a supplier), and 4 (design testing) also included decision-making problems pertaining to engineering ethics. The learning environment provided resources to support decision-making in Cases 2 and 3. By clicking on the links at the right side of the website, students identified how a case problem could be interpreted by different perspectives, theories, and canons.

Students in the example and combined conditions received different counterargument examples depending on their solution to the case problem. If students chose to exempt a few buildings under construction from a new building code, they received counterarguments stating how others would argue for applying the new building code to every building. Otherwise, the students received reasons why others argue to exempt a few buildings from the new building code.

In the learning session, students individually read a case problem (Case 2, code enforcement) and explored multiple aspects pertaining to the problem by clicking on a list of perspectives, theoretical approaches (utilitarian, right and duty, and virtue), and ethical canons from the National Society of Professional Engineers (NSPE) in the web-based learning environment. Rather than constructing a solution, students selected a decision to the case problem in which an engineer decides whether to accept the offer of his chairman to exempt a few buildings from new building codes for permission to hire more inspectors. After selecting the decision, students carried out different counterargument tasks depending on the treatment conditions. In the example condition, students read two counterargument examples for each category of perspectives, theories, and canons, whereas students in the construct condition received directions to write counterarguments to their own decision in terms of the three aspects. In the combined condition, students read one counterargument example for each category of perspectives, theories, and canons and then constructed a counterargument under each example. After reading and/or constructing counterarguments, all participants constructed a rebuttal to the counterarguments. The immediate post-test was administered right after the learning session. Students wrote an argumentative essay on a new engineering ethics problem (Case 3), using resources of perspectives, theories, and
canons about the problem. One week after the learning session, students wrote an argumentative essay about Case 4 as a delayed post-test without any instructional support. Those activities were completed during normally scheduled class times, and students could use up to one and a half hour in each session.

Two researchers independently analyzed the quality of counterarguments and rebuttals generated by students during the learning session (Case 2) using the same coding scheme as in Experiment 1, counterarguments were rated from 1 (undeveloped) to 3 (well developed) points. Rebuttals to their own counterarguments or examples were rated on a 5-point scale. Inter-rater reliabilities were acceptable for qualities of counterarguments (Cohen’s kappa = .68) and rebuttals (Cohen’s kappa = .59), and disagreements between two researchers were all resolved through discussions.

The quality of argumentative essays was analyzed in terms of idea units and holistic scores. Using the same analysis methods as Experiment 1, idea units were segmented by one researcher and then independently coded by two researchers, using the coding scheme of argumentation components used in the first experiment. Argumentative essays were segmented into a total of 1439 idea units (M = 19.2). The inter-rater reliability was moderate for idea units (Cohen’s kappa = .61), and disagreements between coders were all resolved through discussions. In addition, two researchers independently rated holistic scores of argumentative essays, using the holistic scoring rubric used in the first experiment. The inter-rater reliability about holistic scores was also moderate (Cohen’s kappa = .66), and disagreements between raters were all resolved through discussions.

We examined whether counterargument examples helped students to construct higher quality counterarguments in Case 2 by comparing the idea units and holistic scores from the construct and combined groups. Students in the construct condition did not receive any examples of counterarguments, whereas students in the combined condition generated a counterargument after reading an example. A MANOVA for three categories of counterarguments (perspectives, theories, and canons) indicated that there were no significant differences in the quality of counterarguments between the construct and combined groups. A follow-up analysis showed that students in the combined condition generated higher quality counterarguments that were supported by more ethical canons than those in the construct condition. Although this result indicates that counterargument examples can be beneficial for learning to counterargue, there were no other significant effects of examples in the categories of theories and canons.

In the three conditions, all students constructed rebuttals against their own counterarguments or counterargument examples in Case 2. An analysis of variance (ANOVA) revealed that there was a significant effect of treatment on the quality of rebuttals. Post hoc analysis showed that students in the example condition constructed higher quality rebuttals than those in the construct and combined conditions. However, there was no significant difference in the quality of rebuttals between the construct and combined groups.
The quality of argumentative essays in the immediate transfer (Case 3) and delayed transfer (Case 4) post-tests were assessed in terms of the numbers of argumentation components, the proportion of theories and canons among supporting reasons, and holistic scores. A preliminary analysis showed that there were very few rebuttals \((M = .09)\) separately coded from reasons supporting rebuttals, so the two categories were combined as rebuttals for further data analysis. A multivariate analysis of covariance (MANCOVA) was carried out with treatments as an independent variable and initial argumentation skills (i.e., holistic scores on the pretest) as a covariate. The MANCOVA showed that the covariate of initial argumentation skills significantly influenced qualities of argumentative essay. The treatment variable also significantly influenced qualities of argumentative essays. Follow-up analyses revealed that there were significant effects of counterargument treatments on four argumentation components: reasons supporting solutions, counterclaims, reasons supporting counterclaims, and rebuttals. Students in the construct condition wrote significantly more reasons supporting counterclaims \((p = .012)\), and rebuttals \((p = .004)\) than those in the example condition. In addition, students in the construct condition generated significantly more counterclaims \((p = .003)\), reasons supporting counterclaims \((p = .013)\), and rebuttals \((p < .001)\) in their argumentative essays than students in the combined condition. When it comes to reasons supporting solutions, students in the combined condition generated more reasons than those in the construct \((p = .032)\) and example \((p = .031)\) conditions. Lastly, students in the example condition wrote more counterclaims than those in the combined condition \((p = .025)\). These results indicate that students in the construct condition paid more attention to constructing and refuting counterarguments in the immediate post-test (Case 3) than students in the other conditions. Moreover, holistic scores of argumentative essays in Case 3 were significantly influenced by counterargument treatments and by initial argumentation skills. Students in the construct group acquired higher holistic scores than the example and combined groups \((p < .001)\). However, no significant difference was found among the three groups related to the proportion of theories and canons.

As in Experiment 1, the effects of counterargument treatments disappeared for the delayed post-test (Case 4). A MANCOVA was carried out with treatments as an independent variable and initial argumentation skills as a covariate for the number of argumentation components, the proportion of theories and canons, and holistic scores of argumentative essays. There were no significant effects of initial argumentation skills or counterargument treatment on the quality of argumentative essays in Case 4.

In this second experiment, we sought to evaluate the effects of counterargument examples on students’ ability to generate and rebut counterarguments. Our assumption was that students did not possess adequate concepts or schemas for counterarguments. Not surprisingly, we found that students who were more adept at generating arguments produced the highest quality arguments following treatment. Results also showed that on the transfer tasks, students who constructed counterarguments to their own decisions in terms of perspectives, theories, and canons generated more counterclaims and more reasons
supporting their counterclaims and rebuttals in their argumentative essays than students in the example or combined conditions. They paid more attention to constructing and refuting counterarguments group produced higher quality essays on the immediate post-test than students in the other conditions. Students who generated their own arguments produced were able to generate more counterarguments and to better support them. That is, constructing their own counterarguments was more productive that providing examples of counterarguments, suggesting that students fully understood the concept of counterargument. A likely explanation for this effect is the lack of generative processing among the students attending to examples. Wittrock [16] proposed a theory of generative learning that assumed that learners are not passive recipients of information. Rather, they are active participants in the learning process, working to construct meaningful understanding of information found in the environment. In order to be generative, an activity must involve meaning making in order to qualify as generative. Students in the construct group were more involved in meaning making than those in the example group who were merely attending to examples, rather than constructing their own counterarguments. It is also probable that students had more investment in their own arguments, and those in the example group did not attend to the examples of counterarguments.

As in Experiment 1, the effects of counterargument treatments disappeared for the delayed post-test. In subsequent studies, it will be important to design argumentation strategies that sustain effects over longer periods of time. Treatments that do not transfer to real world ethical situations will not affect the kinds of thinking that ABET envisions in its standards.

General Discussion

Solving engineering ethics problems requires complex and nuanced reasoning. Engineering ethics problems occur commonly during everyday engineering practice. They involve often-conflicting ethical principles and perspectives that are defined by the different roles that engineers play at work and in society, so they typically have no convergent or obviously correct solution (Fleddermann, 2004). In the two experiments described in this paper, we subscribed to the beliefs that engineering programs not only push their students to become concerned about the public health and safety of others, but also to 1) help their students to defend their solutions to ethical problems, 2) acquire the ability to evaluate alternative solutions from different perspectives, and, 3) enhance students’ divergent thinking (e.g., understanding situations from other stakeholders’ points of view) [2]. Because ethics problems have multiple solutions, those arguments must not only pose a solution and support that solution but also anticipate alternative solutions and anticipate the counterarguments in support of those solutions. This was a pedagogical strategy intended to achieve higher levels of engagement in students.

Because counterargumentation is a defining attribute of good argumentation [11-12] we investigate alternative strategies for helping students recognize and address alternative solutions. Students and professional often employ a naïve approach to justifying their
solutions to ill-structured problems such as ethics decisions, defending their own reasoning without recognizing alternative solutions or reasons to justify them. Arguments to ethics problems are necessarily dialogical in nature, so learning to solve engineering ethics problems requires that student learn to anticipate and rebut counterarguments (alternative solutions).

Haws [2] also argued that ethical behavior involves grounding ethical issues in different theoretical approaches, considering multiple options with multiple consequences, and communicating with other stakeholders involved. Therefore, the EYE environment used in these studies provided personal perspectives, ethical theories, and ethical cannons in support of alternative perspectives. Students were responsible for constructing an argument consisting of those perspectives and theories.

In the first experiment, we sought to enhance the quantity and quality of counterarguments in students’ ethical arguments by comparing instructional treatments in which one group constructed counterarguments in response to their own arguments and one in which students constructed counterarguments in response to another’s argument. Not surprisingly, students who responded to another’s argument generated more counterarguments and higher quality counterarguments than students who constructed counterarguments to their own argument. So, posing arguments to solutions to respond to engaged the generation of more counterarguments.

Because students may lack comprehension of what a good counterargument consists of, Experiment 2 investigated the inclusion of examples of counterarguments in the instruction. We found that students did not, in fact, use examples as models for generating their own counterarguments. Rather, students who constructed their own counterargument were more engaged and produced better argumentative essays because they were more intellectually engaged, so they conceived of more counterarguments. Student construction of arguments and counterarguments is a very generative learning process that appears to have been impeded by the provision of examples. Because generative learning activities engage more meaning making, students appear to have more ownership in their own solutions and arguments than they do someone else’s.

Unfortunately in both experiments, students did not sustain treatment effects across time. It is very probable that information presented in other classes interfered with the tentative skills that they developed in these activities. In future research, we hope to investigate more powerful strategies for supporting effective argumentation in support of engineering ethics problems in order to sustain the effects if treatment.

What are the most enduring lessons learned from these studies? Engineers are continuously faced with ethical decisions in their practice. In order to address those decisions, engineers must carefully weigh alternative solutions and ultimately justify the solutions they choose based on ethical standards and canons as well as personal beliefs. In these studies we showed that different learning activities can induce effective strategies of addressing ethics
problems in engineering students. However, in order to be effective, those strategies must be sustained across ethical problems throughout a course as well as in different courses. If engineering students are to naturally consider ethical implications on any engineering problem they encounter, they must learn to address a range of ethical problems in their academic preparations. Our future research will address the effects of ethical problem solving across multiple problem sets.

References