# AC 2011-83: HOW DO CIVIL, ELECTRICAL, AND MECHANICAL ENGINEERING STUDENTS COMPARE? - ETHICALLY SPEAKING

**Brock E. Barry, U.S. Military Academy**

Dr. Barry is an assistant professor and course director in the Department of Civil & Mechanical Engineering at the U.S. Military Academy at West Point. He predominately teaches in the area of engineering mechanics. His current areas of research include professional ethics, economic factors influencing engineering education, identity development, and non-verbal communication. Dr. Barry is a licensed professional engineer with multiple years of consulting experience.

**JoAnna C. Whitener, United States Military Academy at West Point**

Dr. Whitener is an assistant professor and statistical consultant in the Department of Mathematical Sciences at the U.S. Military Academy at West Point. She predominately teaches in the area of statistics. Her current areas of research include statistics education, Bayesian theory and methods, and adaptive designs in clinical trials.

# How do Civil, Electrical, and Mechanical Engineering Students Compare? - Ethically Speaking


## Abstract

This study is a continuation of prior research and publication in the area of professional and ethical responsibility in the undergraduate engineering curriculum. The current study investigated disciplinary differences in performance on the ethics and professionalism section of the Fundamentals of Engineering Examination. This included application of descriptive and inferential statistics to appraise previously identified differences between the civil engineering, electrical engineering, and mechanical engineering aggregate performance on the ethics and professionalism section of the Examination. While this investigation does not portend to identify which discipline generates the most ethical or professional engineers, it does clearly identify which discipline in this institutional sample is the best at preparing its students for the ethics and professionalism section of the Fundamentals of Engineering Examination and discusses the associated implications.


## Introduction

The ethics-based and professionalism-based decisions made by the modern engineer have a much broader potential for impact on society than at any time prior in history. Accordingly, the engineering educator must make certain that students in engineering programs receive sufficient training in technological decision making, as well as training in the process of making sound professional and ethical decisions. Such training in the undergraduate engineering curriculum is an important part of the process of educating individuals for a future of professional practice with a consideration for the safety, health and welfare for the communities they serve.

As it is now an engrained part of the undergraduate engineering education process, the ABET Engineering Criteria 2000 (EC2000) introduced a significant change in the amount and type of professional and ethical education in the undergraduate curriculum. Specifically, ABET Criterion 3.f required accredited engineering programs to provide instruction and assessment in professional and ethical responsibility, but at the same time the outcomes-based wording of Criterion 3 allowed individual programs to preserve a distinctive focus or mission.

As part of a previously completed research program, a mixed-methods (quantitative-qualitative) research program was designed and implemented to evaluate the methods of incorporating ethics and professionalism in the engineering curriculum. In particular, the nature of the relationship between curriculum model used and outcomes on a nationally administered, engineering-specific standardized examination was the focus of the study. The study's population included engineering students enrolled at nine southeastern public universities between October 1996 and April 2005. The institutions are partners in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) project. The curriculum models used by the participating programs were identified and defined for the period of the study and a quantitative process was implemented to compare those models relative to performance on the ethics and professionalism section of the Fundamentals of Engineering (FE) Examination. The FE Examination is a nationally administered, engineering-specific examination generated and governed by the National Council of Examiners for Engineering and Surveying (NCEES). The FE Examination is the only nationally administered examination designed to align with the intended knowledge gained as part of an ABET-accredited program. The student-level database authorized for use in this study by NCEES contains a sorted population of nearly 10,000 individuals.

Multiple noteworthy outcomes of the prior study have been reported and presented previously. The outcomes include discussion of time-on-task relationships, institutional variations, and chronological correlations. Although disciplinary differences were not a primary focus of the previously completed study, statistically significant differences were observed between the aggregate performance of the civil engineering, electrical engineering, and mechanical engineering members of the study's population. Additional statistical analysis illustrated that electrical engineering and civil engineering students perform better on the ethics and professionalism section of the FE Examination than they do on the Examination as a whole. Conversely, mechanical engineering students tend to score lower on the ethics and professionalism section of the examination than they do on the Examination as a whole.

The current study, presented within this manuscript, investigated disciplinary differences in performance on the ethics and professionalism section of the FE Examination. This included application of descriptive and inferential statistics to appraise previously identified differences between the civil engineering, electrical engineering, and mechanical engineering aggregate performance on the ethics and professionalism section of the Examination. The research questions used in performance of the current study was: "Are there statistically significant differences between performance on the ethics and professionalism section of the Fundamentals of Engineering Examination among civil, electrical, and mechanical engineering undergraduate students?" and, in addition, "if statistically significant differences are identified, what are the potential implications?"

## Literature Review

Following is a brief review of the literature related to this study. For a more in-depth discussion of the cognate literature, the reader is referred to prior publications generated as part of this line of research (Barry, 2009; Barry & Ohland, 2009, 2011). The literature summary contained herein focuses on the FE Examination as a research tool, the definition of the engineering sub-disciplines, and prior research in the area of ethical variations between academic disciplines.

*Fundamentals of Engineering Examination* – While the well-documented process of developing and implementing ABET EC 2000 was on-going, a concurrent effort was started in 1994 to restructure the FE Examination such that "it more broadly measures outcomes of the total engineering education experience" (Joint Task Force on Engineering Education Assessment, 1996). Specifically, the goal was to ensure that the FE Examination aligned with the then soon to be rolled out EC 2000. This effort was undertaken by representatives from NCEES, ABET, the American Society for Engineering Education (ASEE), the ASEE Engineering Deans Council (EDC), and the National Society of Professional Engineers (NSPE). Largely as a result of those efforts, the FE Examination is now well recognized as the only nationally administered, engineering-specific assessment of the outcomes required by EC 2000. NCEES encourages the use of the FE Examination as a general research and assessment tool. However, it is also recognized that the Examination's primary purpose is to measure minimum technical competency required for professional licensure of engineers (Kliewer, 2001; LeFevre, Steadman, Tietjen, White, & Whitman, 2005; National Council of Examiners for Engineering and Surveying, 2008).

*Engineering Sub-Disciplines* – For purposes of this study, the curriculum descriptions for civil engineering, electrical engineering, and mechanical engineering have been defined based on the 2004-2005 Criteria for Accrediting Engineering Programs (ABET, 2004). The interested reader is referred to that document for a detailed description.

*Ethical Variation Between Academic Disciplines* – The research detailed within this document includes an assessment of students' understanding of professional and ethical responsibility across disciplines. Several studies have previously been conducted to determine if academic major (discipline) affect the development of moral reasoning.

The well-known and often cited study by Pascarella & Terenzini (2005) identify several studies that provide insight into the influence of a chosen academic discipline on moral reasoning. For example, Jeffery (1993) compared the ethical development of accounting students, non-accounting business students, and liberal arts students. Jeffrey's study showed that among the research population, accounting students generated the highest moral reasoning scores on a standardized assessment. In another study conducted by Cummings, Dyas, Maddux & Kochman (2001), a comparison was made between preservice teacher education students and a composite sampling of a diverse set of academic majors. Notably, that study indicated that preservice teacher education students scored below the general population college students. A comparison between multiple academic majors by McNeel (1994) showed that psychology, nursing, and English majors obtained higher moral reasoning scores than their peers in business and education majors.

This literature appears to lack a consensus on whether students with a certain level of ethical reasoning are attracted to particular academic major or if the curriculum content within those academic majors helps define a student's level of ethical reasoning. McNeel (1994) states that the "highest growth took place in majors that focus on understanding humans and/or majors that include a central integration of ethical considerations within the content of a professional course of study" (p. 34). The work of Cummings, et al. (2001) also supports McNeel's connection between growth of ethical reasoning and curriculum content. Whereas Jeffrey (1993) suggests that the score variation between the academic majors represented in her study are not the result of curriculum content.

Pascarella & Terenzini (2005) imply that the experience of attending college results in an increase in the use of principled reasoning to judge moral issues. Specifically, "…college attendance is associated with a humanizing of values and attitudes concerning the rights and welfare of others" (Pascarella & Terenzini, p. 348). Several other well known sources support the belief that moral development can be stimulated through educational experiences (Killen & Smetana, 2006; Kohlberg, 1981; Rest, 1994). Thus, it could be concluded that variations in curriculum content would influence the level of moral development.

## Methods

*Prior Research* – The current study is a continuation of prior research in the area of professional and ethical responsibility in the field of engineering. Previously completed research was conducted to determine if a relationship exists between the curriculum model used to satisfy ABET Criterion 3.f and outcomes on the ethics and professionalism portion of the FE Examination. The study's population included engineering students enrolled at one of nine southeastern public universities between October 1996 and April 2005. The institutions were partners in the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) project. MIDFIELD contains records for nearly 860,000 unique students and permits investigation of a broad range of research questions. In support of the prior line of research, a mixed-methods (quantitative-qualitative) research program was designed and implemented. The qualitative aspects of the study focused on research questions related to the impetus and considerations given to curriculum changes made by the 23 engineering programs that participated in the study. The qualitative research questions were investigated through a process of semi-structured interviews conducted with program representatives and evaluation of 49 ABET Self-Study accreditation documents. The curriculum models used by the participating programs were identified and defined for the period of the study and a quantitative process was implemented to compare those models relative to performance on the ethics section of the FE Examination. A student-level dataset of subject scores was obtained for the FE Examination for all of the participating programs. Statistical techniques were used to evaluate the relationship between curriculum methods and examination performance.

In prior analysis, the student-level subject scores associated with each student were normalized relative to their performance on the examination as a whole in order to reduce bias. The new measure, called a Tarquin′ score, was based on the work of (Wicker, Quintana, & Tarquin, 1999). In essence, this adjustment accounts for a correction of the ethics score relative to overall performance on the FE Examination.

An Analysis of Variance (ANOVA) was performed to determine if a statistically significant difference existed between the mean value of the dependent variable (Tarquin′) and several other variables. The variables under consideration were the academic institution, undergraduate major, administration time (pre- and post- curriculum changes) and the amount of required applicable content. The amount of required applicable content refers to the number of required courses and the weighted percent of required course credits. A statistically significant relationship was identified between the Tarquin' values and both the amount of required applicable content and the undergraduate major. A significant relationship was also identified between Tarquin′ values and administration time for both conditions of required applicable content. Thus, there is a noticeable difference between Tarquin′ values prior to and after changes were made to the curriculum. Moreover, a Tukey pairwise comparison was performed for various independent variables. The analysis showed that electrical engineering and civil engineering students generated statistically similar Tarquin' values for the ethics section of the FE Examination and higher Tarquin' values than did their counterparts in mechanical engineering. Specifically, civil engineering and electrical engineering student scored higher on the ethics section of the FE Examination than they did on the examination as a whole; while mechanical engineering students scored lower on the ethics portion of the examination than they did on the examination as a whole. However, it cannot be directly stated from the prior study that civil engineering and electrical engineering students scored higher on the ethics section of the FE Examination than did their mechanical engineering peers. Disciplinary differences were not a primary focus of the previously completed study.

While the prior study identified a statistically significant relationship exists between the amount of required applicable content (measured in terms of the number of required courses and the weighted percent of required course credits) and student performance eon the professional ethics section of the FE Examination, it also revealed a lack of structure among the amount of applicable content. That is, a larger amount of required applicable content did not always outperform a small number of required courses. One explanation suggested for this observation is that the influence of instruction quality confounded the relationship to the amount of required application content; both quality and quantity are important.

*Current Research* – Rather than using the Tarquin′ score to examine student performance on the ethics section of the FE Examination, an alternative method is to employ student-level raw scores in the ANOVA procedure. As before, our goal was to determine if a statistically significant difference exists between the mean value of the dependent variables (raw ethics score) and several other independent variables. It is not necessary to normalize the ethics score when performing an ANOVA test as we are examining the difference of this score in the presence of the other independent variables. Using the raw scores not only makes the analysis less complicated, but the interpretation of results is also more straightforward.

The variables under consideration were the academic institution, undergraduate major, administration time (pre- and post- curriculum changes) and the amount of required applicable content. Moreover, the overall raw student score was divided into an ethics portion and a non-ethics portion to make further comparisons.

## Results

The ANOVA procedure is sufficiently robust to accommodate this dataset and several runs were performed to determine if statistical significance exists between the raw ethics scores and other factors. Table 1 presents the ANOVA output for the variables under consideration in this study.

**Table 1. ANOVA for Raw Ethics Score**

| Source | DF | SS | MS | F | p-value |
|---|---|---|---|---|---|
| Academic Institution | 7 | 103.965 | 14.852 | 14.10 | 0.000 |
| Undergraduate Major | 2 | 6.640 | 3.320 | 3.15 | 0.043 |
| Administration | 1 | 502.323 | 502.323 | 476.94 | 0.000 |
| Number of Courses | 1 | 3.312 | 3.312 | 3.15 | 0.076 |
| Courses (pre/post change) | 1 | 8.082 | 8.082 | 7.67 | 0.006 |
| Error | 9758 | 10278.326 | 1.053 | | |
| Total | 9771 | | | | R-sq = 7.89% |

In addition to the variables above, we also considered the students' performance on the non-ethics portion of the test to determine if this factor influenced their raw ethics score. These results are presented in Table 2, below.

**Table 2. ANOVA for Raw Ethics Score with the addition of Non Ethics Scores**

| Source | DF | SS | MS | F | p-value |
|---|---|---|---|---|---|
| Academic Institution | 7 | 61.438 | 8.777 | 8.39 | 0.000 |
| Undergraduate Major | 2 | 19.558 | 9.779 | 9.35 | 0.000 |
| Administration | 1 | 402.176 | 402.176 | 384.60 | 0.000 |
| Number of Courses | 1 | 4.689 | 4.689 | 4.38 | 0.034 |
| Courses (pre/post change) | 1 | 10.328 | 10.328 | 9.88 | 0.002 |
| Non Ethics Score | 1 | 74.463 | 74.463 | 71.21 | 0.000 |
| Error | 9758 | 10203.864 | 1.046 | | |
| Total | 9771 | | | | R-sq = 8.56% |

Tukey pairwise analyses of the mean raw ethics score were performed to investigate the relationship between undergraduate majors. Results are given in Table 3.

**Table 3. Pairwise Comparison of Undergraduate Major**

| Tukey Grouping | | Mean Score | Number of Subjects | Undergraduate Major |
|---|---|---|---|---|
| A | | 3.6789 | 5088 | Civil Engineering |
| A | B | 3.6530 | 1366 | Electrical |
| | B | 3.6682 | 3318 | Mechanical |

**Table 4. All Pairwise Comparisons among Undergraduate Major**

Undergraduate Major = Civil subtracted from:

| Undergraduate Major | Difference of Means | SE of Means | T-Value | P-value |
|---|---|---|---|---|
| Electrical Engineering | -0.0728 | 0.03364 | -2.165 | 0.0774 |
| Mechanical Engineering | -0.1080 | 0.02592 | -4.169 | 0.0001 |

Undergraduate Major = Electrical subtracted from:

| Undergraduate Major | Difference of Means | SE of Means | T-Value | P-value |
|---|---|---|---|---|
| Mechanical Engineering | -0.03522 | 0.03693 | -0.9535 | 0.6063 |

## Conclusions & Discussion

While variations in the Tarquin′ number were previously noted between disciplines, it could not be definitively stated that one discipline scored better on the ethics portion of the exam than another. By comparing the raw scores for each discipline, it can be seen that all three perform at a similar level: civil = 3.6789, electrical = 3.653, and mechanical = 3.668. The findings in Table 3 illustrate that civil engineering students scored higher on the ethics portion of the FE Examination than both electrical and mechanical engineering students, but only by a small percentage. A Tukey pairwise comparison further investigated the relationship among the undergraduate majors. The results of the pairwise comparison illustrate that civil engineering students perform at a statistically similar level as do electrical engineering students. Further, electrical engineering students perform at a statistically similar level as do mechanical engineering students but, there is a difference in the performance between civil and mechanical engineering students. This distinction between these majors is further illustrated in Table 4. A p-value of 0.001 shows a statistically significant difference between the mean raw scores for civil and mechanical engineering students while a p-value of 0.6063 show no statistical difference between mechanical and electrical engineering students. Moreover, a p-value of 0.0774 suggests a marginal difference between students in the civil and electrical engineering fields.

The ANOVA associated with the current study produced statistically significant p-values for all factors considered in this study, including undergraduate major. However, the results from the ANOVA tables above show that the most significant factor is the administration date with an F-statistic of 476.94, followed by academic institution with an F-statistic of 14.10. It is very important to note, however, that although all factors are statistically significant, an R-squared value of 7.89% does not reveal any practical significance. This simply means that only 7.89% of the variation in the ethics score is accounted by the various factors considered. The addition of the non-ethics score as a factor does account for more variation in the dataset, but the R-squared value only increases to 8.56%. Thus, while it can be definitively stated that there is a significant difference between the performance of the civil, electrical, and mechanical engineering (undergraduate major) students, the small R-squared value would suggest that the difference holds no practical significance.

The existence of a statistically significant difference between performance on the ethics and professionalism section of the FE Examination by civil, electrical, and mechanical engineering students, fits well with the literature that has found a connection between academic major and moral development (Cummings et al., 2001; Jeffrey, 1993; McNeel, 1994). However, the lack of practical significance might be explained as an indication that the ethics and professionalism instruction does not vary significantly among these engineering sub-disciplines. Whereas the literature that identified differences between undergraduate majors was comparing more uniquely disparate academic programs (eg. business versus liberal arts). There is an opportunity for additional study to evaluate, if, in fact, the ethics and professionalism instruction varies little between engineering sub-disciplines.

**References**


ABET. (2004). *Criteria for accrediting engineering programs*. Baltimore: ABET, Inc.

Barry, B. E. (2009). *Methods of incorporating understanding of professional and ethical responsibility in the engineering curriculum and results from the fundamentals of engineering examination.* Purdue University, West Lafayette.

Barry, B. E., & Ohland, M. W. (2009). *Engineering ethics curriculum incorporation methods and results from a nationally administered standardized examination: background, literature, & research methods*. Paper presented at the American Society for Engineering Education Annual Conference & Symposium.

Barry, B. E., & Ohland, M. W. (2011). ABET criterion 3.f: how much curriculum content is enough? *Science and Engineering Ethics, in publication*.

Cummings, R., Dyas, L., Maddux, C. D., & Kochman, A. (2001). Principled Moral Reasoning and Behavior of Preservice Teacher Education Students (Vol. 38, pp. 143-158).

Jeffrey, C. (1993). Ethical development of accounting students, non-accounting business students, and liberal arts students. *Issues in Accounting Education, 8*(1), 86-96.

Joint Task Force on Engineering Education Assessment. (1996). A framework for the assessment of engineering education. Retrieved October 31, 2007

Killen, M., & Smetana, J. G. (2006). *Handbook of moral development*. Mahwah, N.J.: Lawrence Erlbaum Associates, Publishers.

Kliewer, R. M. (2001). *The fundamentals of engineering (FE) examination as an outcomes assessment tool for engineering technology programs.* Paper presented at the 2001 American Society for Engineering Education Annual Conference & Exposition, Albuquerque, New Mexico.

Kohlberg, L. (1981). *Essays on moral development* (1st ed.). San Francisco: Harper & Row.

LeFevre, W., Steadman, J. W., Tietjen, J. S., White, K. R., & Whitman, D. L. (2005). *Using the fundamentals of engineering (FE) examination to assess academic programs*. Clemson: National Council of Examiners for Engineering and Surveying.

McNeel, S. P. (1994). College teaching and student moral development. In J. R. Rest & D. Narvâaez (Eds.), *Moral development in the professions: Psychology and applied ethics* (pp. 27-49). Hillsdale, N.J.: L. Erlbaum Associates.

National Council of Examiners for Engineering and Surveying. (2008). *Exam development procedures manual: Exam development, scoring, and general procedures*: NCEES.

Pascarella, E. T., & Terenzini, P. T. (2005). *How college affects students : a third decade of research* (2nd ed.). San Francisco: Jossey-Bass.

Rest, J. R. (1994). Background: Theory and research. In J. R. Rest & D. Narvâaez (Eds.), *Moral development in the professions: Psychology and applied ethics* (pp. 1-26). Hillsdale, N.J.: L. Erlbaum Associates.

Wicker, R. B., Quintana, R., & Tarquin, A. (1999). Evaluation model using Fundamentals of Engineering Examination. *Journal of Professional Issues in Engineering Education and Practice, 125*(2), 47-55.