USING THE FUNDAMENTALS OF ENGINEERING (FE) EXAMINATION AS AN OUTCOMES ASSESSMENT TOOL
Using the Fundamentals of Engineering (FE) Examination as an Outcomes Assessment Tool

Steven F. Barrett, Ph.D., P.E.
E. Walter LeFevre, Ph.D., P.E.
John W. Steadman, Ph.D., P.E.
Jill S. Tietjen, P.E.
Kenneth R. White, Ph.D., P.E.
David L. Whitman, Ph.D., P.E.
About NCEES

NCEES is a national nonprofit organization composed of engineering and surveying licensing boards representing all U.S. states, the District of Columbia, Guam, Puerto Rico, and the U.S. Virgin Islands. An accredited standards developer with the American National Standards Institute, NCEES develops, scores, and administers the examinations used for engineering and surveying licensure throughout the United States. NCEES also provides services facilitating professional mobility for licensed engineers and surveyors. Its headquarters is located in Clemson, S.C.
Institutions of higher education are increasingly being encouraged to evaluate their academic programs with reference to a national norm or standard. This pressure may come from state legislators who want to assign cost-benefit labels and measure the effectiveness of higher education, or it may result from accreditation requirements, which are progressively becoming driven by accountability and benchmarking. Whatever the reason, institutions must find practical, objective ways to assess their programs.

Assessment Process

In engineering education, the ABET Engineering Criteria have, for nearly a decade, required a system of evaluation that includes program educational objectives, program outcomes, an assessment process to collect data on the objectives and outcomes, and an evaluation process that shows how the program interprets the collected data. The evaluation process may, and usually does, contain both direct and indirect measures. Direct measures allow the examination or observation of student knowledge against a measurable norm. Indirect measures attempt to ascertain the perceived value of the learning experience. Indirect measures suffer from the fact that assumptions must be made on the results of activities such as exit interviews, focus groups, and questionnaires.

One effective tool for assessing certain aspects of engineering education is the NCEES Fundamentals of Engineering (FE) examination. This exam, developed to measure minimum technical competence, is the first step in the professional licensing of engineers. It is a pass-fail exam that is taken by approximately 50,000 people a year, most of whom are college seniors within one year of graduating or are recent graduates. For licensing, the examinee is only interested in whether he or she passed or failed. For assessment purposes, however, the pass-fail rate is of secondary importance, and the focus is on examinees’ performance in a given subject.

Effective assessment of academic programs requires a set of tools and processes to evaluate various aspects of education. If the tools are to have any value as benchmarks or have credibility on some objective basis, they should make it possible to compare one institution with another. Assessment tools with this comparative value are particularly difficult to obtain. Methods such as portfolios and surveys lack uniformity. And forcing comparisons—by asking an employer to compare graduates of different schools—makes it difficult to ensure objectivity.
As the only nationally normed exam that addresses specific engineering topics, the FE exam is an extremely attractive tool for outcomes assessment. In fact, since 1996, the FE exam has been formatted for the express purpose of facilitating the assessment process. For example, the discipline-specific modules for chemical, civil, electrical, environmental, industrial, and mechanical engineering were developed to include topics from upper-level courses—topics that were not appropriate when students from all engineering disciplines took the same exam. The exam content was revised to better measure students’ knowledge of subjects taught in current junior- and senior-level engineering courses. The topics included in the discipline-specific modules were determined via surveys that were sent to every ABET-accredited engineering program in the United States. The most recent set of exam specifications was introduced in October 2005, and specifications are appropriately adjusted every 6–8 years. For some topics, it is possible to compare results over different exam specifications (for example, Engineering Economics), and for others, it is not (for example, Engineering Probability and Statistics is a new topic for the October 2005 specifications).

FE exam results can be used to assess particular aspects of the following ABET Criterion 3 outcomes: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; (e) an ability to identify, formulate, and solve engineering problems; (f) an understanding of professional and ethical responsibility; and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Although the FE exam does provide some means of assessment, employing the exam as an assessment tool has both advantages and disadvantages; therefore, its widespread use as such should be analyzed carefully. The exam should not, for example, be used to determine the curricular content of any program. Its purpose is to test competency for licensure; it is not intended to force programs to be similar. For licensure purposes, the total score is evaluated rather than the score in any specific subset of questions. Passing the exam does not denote competence in all subjects but instead shows an average minimum competency in several subject areas.

One potential error in using the FE exam results as an assessment tool is focusing on the percentage of students who pass the exam. This criterion is too broad to be effective in improving instruction in specific topics; more specific measures are needed. Too often, the passing rates of individual programs are compared with those of other institutions, and these rates become more important than the subject matter evaluations. Administrators or faculty who select those who are allowed to attempt the exam may be demonstrating this faulty mentality. In such a situation, the focus becomes “teaching to the exam” and not truly assessing how well students have learned the subject matter in the curriculum.
Using the FE Exam as an Assessment Tool

In light of these limitations, how does one properly use the FE exam as an assessment tool? First, the department or program faculty should determine what topics to teach and to what depth and breadth to teach them. This is a major part of the program educational objectives and program outcomes set by each program as required by ABET. After establishing the topics to teach, faculty should set specific goals for student performance and then use the relevant portions of the FE exam to assess the students' knowledge in specific areas, such as water resources, electric circuits, or machine design. The faculty should then compare their goals to the knowledge demonstrated by graduates of the program. This scenario assumes that examinees are not selected to inflate the passing rates and make the school appear superior. In fact, for this assessment process to be valid, the population taking the exam must be representative of the entire population of graduates from the program. Many institutions that currently use the FE exam as one of their assessment tools require that all seniors take the exam and give “a good faith effort” (but not necessarily pass).

Analysis of FE examinees over a number of test administrations has revealed that very few students fail to take the exam seriously. However, motivating students to review materials before the exam, to prepare adequately, and ultimately to do their best work is a legitimate concern. Faculty who have doubts about whether students are putting forth their best efforts should take steps to motivate them, such as informing them of the importance of the results to their future or providing an incentive to pass the exam. Some programs that require all students to take the exam but do not require a passing score for graduation (the process recommended by the authors) offer an incentive to do well by including pass-fail status on students’ transcripts. Clearly, if the results are to be useful for outcomes assessment, the students must be performing in a way that accurately portrays their understanding. It should be noted that the NCEES-provided Subject Matter Report (to be discussed later) is adjusted to remove random guessers so that assessment is not influenced by any examinees not giving a good faith effort.

FE Exam Topic Coverage

To effectively use the FE exam as an assessment tool, faculty should know the specifications for the morning (AM) and afternoon (PM) portions as well as the level of understanding the items are meant to measure. Specifications for the exam are provided in the appendix. As mentioned earlier, periodic changes to the specifications are based in large part on faculty feedback to NCEES surveys.

In addition, assessments will be more meaningful if students take their discipline-specific PM module, which addresses more advanced engineering topics, rather than the Other Disciplines PM module. For those disciplines that are not represented with a PM module, the Other Disciplines module will provide information on basic topics that are relevant to most programs.
The NCEES Subject Matter Report shown as Table 1 summarizes data on EAC/ABET program examinees who took the exam while still enrolled in college and who selected a discipline-specific PM module. This is the statistical group that should be used as a measure of program outcomes. Results are presented for the examinees from a particular program, for examinees nationwide who declared the same major and who chose the same PM module of the exam, and for examinees nationwide from the institution’s Carnegie classification who declared the same major and who chose the same PM module of the exam. As discussed later, this allows the institution’s faculty a choice to compare their students’ performance against either all examinees nationally or only those from the institution’s Carnegie classification.

Table 1. Subject Matter Report for Institution X
October 2009
NCEES Fundamentals of Engineering Examination
ABET-Accredited Programs

Currently Enrolled Engineering
Subject Matter Report by Major and PM Examination
Board: Institution:
Board Code: School Code:
Major: Civil PM Exam: FE Civil

<table>
<thead>
<tr>
<th>AM Subject</th>
<th>#Exam Questions</th>
<th>Institution AVG% Correct</th>
<th>National AVG% Correct</th>
<th>National Standard Deviation**</th>
<th>Prof+ASS/HGC AVG% Correct***</th>
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<td>73</td>
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<td>2.3</td>
<td>71</td>
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<tr>
<td>Engineering Mechanics (Statics)</td>
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<td>59</td>
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<td>46</td>
<td>1.7</td>
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<td>Transportation</td>
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<td>45</td>
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<td>60</td>
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<td>Construction Management</td>
<td>6</td>
<td>62</td>
<td>61</td>
<td>1.3</td>
<td>63</td>
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<tr>
<td>Materials</td>
<td>5</td>
<td>75</td>
<td>67</td>
<td>1.1</td>
<td>67</td>
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</tbody>
</table>

* 0 examinees have been removed from this data because they (1) answered fewer than 10% of the questions or (2) were flagged as a random guesser.
** The standard deviation above is based on number of questions correct, not percentage of questions correct.
*** Indicates schools in your Carnegie classification, see www.carnegiefoundation.org

TERMS AND CONDITIONS OF DATA USE
This report contains confidential and proprietary NCEES data. Any use of the data unrelated to accreditation review requires prior approval by NCEES.
Application of FE Exam Results

Prior to the exam, faculty should determine the expected performance in each topic area, depending on the emphasis of that topic in their program. For example, if a civil engineering program places little emphasis on surveying or transportation, students should be expected to perform accordingly. Conversely, if the program has a strong emphasis on structural analysis, one would expect a much higher performance in this area compared to the national average. For more conclusive results, faculty should also consider performance over several administrations of the FE exam rather than from just one test administration. The form of this expected performance will depend on the analysis method chosen, a variety of which have been developed to examine the data from the Subject Matter Report with regard to program assessment. The three methods described in this paper are as follows:

- Percentage-Correct Method
- Ratio Method
- Scaled-Score Method

Percentage-Correct Method

This method utilizes the “raw” data (percentage correct) directly from the Subject Matter Report. For example, assume that Institution X requires all graduating seniors in civil engineering to take (but not necessarily pass) the FE exam with the Civil PM module and that the faculty expect students’ collective performance to be as follows:

- Correctly answer at least 70 percent of the AM questions directly related to their major (Engineering Economics, Ethics and Business Practices, Fluid Mechanics, Mathematics, Strength of Materials, Engineering Probability and Statistics, and Statics), correctly answer at least 50 percent in the other topics in which the students have had at least one class, and no expectation in the other topics that are not directly covered in the curriculum (Electricity and Magnetism).

- Correctly answer at least 70 percent of the PM questions that are emphasized in Institution X’s program (Hydraulics and Hydrologic Systems, Structural Analysis, Structural Design, Soil Mechanics and Foundations, and Surveying) and at least 50 percent in the other civil engineering topics (Construction Management, Environmental Engineering, Transportation, and Materials).
Assume that the results for these students are represented by the Subject Matter Report shown in Table 1. A bar graph of the students’ performance can easily be generated (see Figure 1). The assessment based on this one administration only (recognizing that a conclusive assessment will require evaluation of several exam administrations) yields the following:

- For the AM subjects, the civil engineering students met all of the goals set by the faculty except for reaching the 70 percent level on Engineering Probability and Statistics, Strength of Materials, and Fluid Mechanics. In the assessment process, the faculty must determine if the expectations were too high or if the topic area needs attention. In these subjects, perhaps the expectations were too high since students nationally did not answer at the 70 percent level. In addition, the students correctly answered a higher percentage of the questions on these topics than students nationally. In any event, any topics in which the goal is not met need to be tracked over additional administrations of the FE exam, and factors such as instructional methods, texts, and teaching mechanisms need to be evaluated.

- In the PM subjects, the students met the expectations in Surveying, Hydraulics and Hydrologic Systems, Environmental Engineering, Transportation, Construction Management, and Materials. They fell below the expectations in Soil Mechanics and Foundations, Structural Analysis, and Structural Design. Since all of these latter topics are emphasized in Institution X’s program, the faculty will need to track the topics over additional administrations of the FE exam, or they may need to reevaluate their possibly high expectations.

It should be noted that expectations of faculty typically exceed actual performance of their students on the FE exam.

Figure 1. Percentage correct for a specific exam date
In many cases, the percentage-correct method produces unrealistic and perhaps unobtainable expectations for the students’ performance (as mentioned previously concerning the topics of Soil Mechanics and Foundations, Structural Analysis, and Structural Design). Moreover, the results of this method will be affected by the difficulty of a particular version of the FE exam. As an alternative to the percentage-correct method, faculty should consider using the ratio method to aid in developing reasonable expectations. For this method, the ratio of the performance at Institution X to the national performance is calculated for each topic area. The faculty can develop appropriate expectations on this scale, determining how much above or below the national average is acceptable for their students.

While a graph similar to Figure 1 can be developed for the October 2009 exam, it is more informative to graph the performance on individual topics over time. Figures 2 and 3 show such graphs for student performance in two areas emphasized by Institution X. Figure 2 shows data only since October 2005 because this was a new topic area for the October 2005 specifications. Figure 3 shows data since October 1996 because this topic has always been part of the specifications.
Regarding these two examples, one could draw the following conclusions:

- Institution X initially assumed that its civil engineering students should score 10 percent higher in Probability and Statistics than the national average for civil engineering students. (Recall that the Subject Matter Report only reports national performance data for students in the same major.) The authors would argue, however, that this is a somewhat lofty and perhaps unobtainable goal for Institution X.

- After three exam administrations below the expectation level for Probability and Statistics, the faculty made two modifications. The first was a re-examination of the goal described above. Given that Institution X’s students have no additional coursework in this subject beyond what would normally be taught elsewhere, the faculty adjusted their expectation and set a new goal for their students to meet the national average for this subject. This type of “close the loop” feedback is certainly acceptable. It also appears that some modification was made to the curriculum (such as a change in instructor, textbook, or course design), since the ratios since April 2007 have been at or above the faculty expectation level except for one exam administration.

- For Structural Analysis (Figure 3), note that Institution X has an expectation that its students perform at a ratio of 1.05. This is due to the fact that it emphasizes this subject material and perhaps requires the students to take more structural analysis courses than would be expected at other institutions. One can see that the performance on this subject is sporadic, with ratios above 1.20 and as low as 0.75. One possible explanation for this sporadic performance can be accounted for in the scaled-score approach discussed next. This type of performance also points out a suggestion that is made by the authors—put the subject matter on a “watch list” if it falls below the expected goal for two consecutive exam administrations, but do not attempt a curricular change in a subject matter area unless the students’ performance has been below the expected goal for three consecutive exam administrations.

- In an effort to smooth out the performance—especially in subjects that might be covered very late in the curriculum—one can also average the October and April results over a particular academic year and plot the yearly average ratios. This is shown in Figure 4 for the Structural Analysis topic. Even with this technique, the results indicate that Institution X should be developing curricular changes to make sure that the students’ performance improves in the near future.
In addition to program-specific assessments, one can use the FE exam to assess collegewide issues in common subjects such as mathematics and chemistry. If all students at a particular institution take the exam, it is not difficult to merge the results of the various Subject Matter Reports into a spreadsheet that generates collegewide results. This is probably a more effective way for an engineering college to work with their colleagues in the math and science departments than for each program to work with them individually. Figure 5 shows the all-college results for Institution X in Mathematics. This institution has worked with the department of mathematics and, over the recent years, that department has made improvements including a new textbook and a commitment to use fewer graduate students as instructors in the calculus sequence. One can see that, while there has been some recent steady improvement, the students still are not meeting the faculty-set expectation of reaching the national average.
Scaled-Score Method

The concept of the scaled-score method became possible following the April 2001 exam. The Subject Matter Report for that administration included standard deviation data for the first time. The standard deviation is based on the number of questions correct, not on the percentage correct, and is generated from the test scores of a specific group of examinees. In Table 1, for example, the relevant group would be the civil engineering majors who selected the Civil PM module at the October 2009 administration. Thus, for this group, the national performance for Engineering Economics could be stated as having a mean $\bar{x} = 0.69 \times 10 = 6.9$ questions correct and a standard deviation $\sigma = 2.3$ questions. Further examination of Table 1 reveals that in all subjects, $\pm 3\sigma$ effectively covers the entire range from 0 percent correct to 100 percent correct.

The scaled score was developed to allow institutions to do the following:

» Present the data in a form that represents the number of standard deviations above or below the national average for each topic (as compared to the percentage above or below the national average given by the ratio method).

» Allow a range of uncertainty in the institution’s performance to account for small numbers of examinees.

The scaled score is defined as follows:

$$\text{Scaled score} = \frac{\# \text{ correct at Univ X} - \# \text{ correct nationally}}{\text{national standard deviation}} = \frac{\# \text{ of questions} \times \left(\% \text{ correct at Univ X} - \% \text{ correct nationally}\right)}{100 \times \text{national standard deviation}}$$
The range of uncertainty comes from the following derivation:

From the concept of confidence interval on a mean:

The mean of a population ($\mu$) is related to the mean of a sample size $n$ ($\bar{x}$) by

$$\bar{x} - Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \leq \mu \leq \bar{x} + Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

or, the confidence interval on $\mu$ is $\pm Z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$.

Let $Y_{Univ} = \bar{x}_{Univ} \pm Z_{\alpha/2} \frac{\sigma_{Univ}}{\sqrt{n_{Univ}}}$

$Y_{Univ} - \bar{x}_{Natl} = \bar{x}_{Univ} - \bar{x}_{Natl} \pm Z_{\alpha/2} \frac{\sigma_{Univ}}{\sqrt{n_{Univ}}}$.

Since NCEES does not provide standard deviation data for individual institutions, it will be assumed that the national standard deviation can be substituted for the institution's standard deviation. In that case,

$$\frac{Y_{Univ} - \bar{x}_{Natl}}{\sigma_{Natl}} = \frac{\bar{x}_{Univ} - \bar{x}_{Natl}}{\sigma_{Natl}} \pm \frac{Z_{\alpha/2}}{\sqrt{n_{Univ}}}.$$

Normally, for a 99% confidence interval $Z_{\alpha/2}$ would be 2.58. However, in this case, the uncertainty would be so large that the analysis results (see below) for all subjects would indicate that no action needs to be considered. The authors feel that this is unreasonable and suggest using a value of $Z_{\alpha/2} = 1.0$. This allows a reasonable amount of uncertainty based on the number of students taking the exam at any specific institution.

Therefore, the scaled score is calculated as

$$\text{Scaled score} = \frac{\bar{x}_{Univ} - \bar{x}_{Natl}}{\sigma_{Natl}} = \frac{\# \text{ of questions for a topic } \times (\% \text{ correct at Univ } X - \% \text{ correct nationally})}{100 \times \text{national standard deviation}}.$$

And the range of uncertainty for the scaled score is

$$\pm \frac{1}{\sqrt{\# \text{ of takers at Univ } X}}.$$
For the same topics previously discussed, the scaled-score graphs and some observations are as follows:

- For Probability and Statistics, a ratio goal of 1.1 translated to a scaled-score goal of 0.25, and a ratio goal of 1.0 translated to a scaled-score goal of 0.0.

- Even with the range of uncertainty, the October 2005 through October 2006 results (shown in Figure 6) still indicated that curricular changes were needed for this subject. After the changes discussed earlier, the scaled-score approach shows that the students have been above the goal (within the range of uncertainty).

- For Structural Analysis (shown in Figure 7), a ratio goal of 1.05 translated to a scaled-score goal of 0.12. Using the ratio method, the students’ performance fell below the expected goal for five consecutive exam administrations (April 2007 through April 2009). However, using the scaled-score approach, the goal was reached for April 2008, which indicated that this subject should simply remain on the “watch list.” October 2009 results seem to indicate that the students are, once again, achieving at the expected level.
In making an assessment using the FE exam results, faculty must also consider that some students may not have taken the coursework before taking the FE exam. For example, some students take structural design in the spring semester of their senior year; therefore, those who take the FE in October of their senior year will not be prepared for that subject area. A sample FE exam exit questionnaire is shown in Table 2. Completed questionnaires may provide some insight into these factors and allow faculty to consider such in making their assessment.

### Table 2. Sample exit questionnaire for FE exam

This questionnaire is designed to determine your perception of your preparedness for the topic areas on the FE examination. The department will use the information as part of our outcomes assessment. Individual responses will be confidential. Indicate your confidence in answering the questions in each topic area by placing an X in the column that best describes your preparedness. Also indicate how many credit hours you have completed in each area.

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<tr>
<th>Subject Area</th>
<th>AM</th>
<th>Very</th>
<th>Adequately</th>
<th>Minimally</th>
<th>Unprepared</th>
<th>Credit Hours</th>
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<td>Soil Mechanics and Foundations</td>
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<td>Materials</td>
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<tr>
<td>Do you believe you passed FE?</td>
<td>Yes</td>
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<td></td>
<td>No</td>
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</table>
Effective assessment should result in continuous program improvement. Faculty should evaluate the results of student performance in individual subject areas. Doing so will identify those areas in which students are performing below the goals established by the faculty and perhaps significantly below national or state averages. Evaluations should instigate not only the necessary changes in textbooks, teaching mechanisms, and laboratory procedures but also the possible reallocation of faculty to improve student performance. In one documented case in which FE exam results were used, student performance was significantly below the national average in Hydraulics and Hydrologic Systems. The department head was surprised because the student evaluations for the course had been very good over several years. However, upon investigation, he found that the laboratory procedures used to reinforce the theory were shallow and the performance demand on the students was low. The laboratory procedures and depth of instruction were improved over several semesters without lessening instruction on the theory. The most recent exam administrations indicate a significant improvement in student performance in this area. A point that cannot be overemphasized is that for assessment purposes, the results of multiple exam administrations should be considered and the exam content compared to the course content.

There are some other criticisms of using the FE exam data that should be addressed. One criticism is that only sample questions are provided to faculty, making it difficult for them to determine the level of knowledge required in the actual exam. NCEES cannot release exam questions without compromising its data bank and requiring exam development volunteers to produce significantly more questions for the exam. Faculty could, however, use an exit questionnaire such as the one in Table 2 to learn more about the level of learning and preparation of their students by subject area. This questionnaire could also provide information about students who take the exam before taking certain coursework and can be used to determine other information such as whether transfer students have taken courses at other institutions.

A second criticism is that information on student learning is incomplete because at many institutions, not all engineering students take the FE exam. Also, some students are not held accountable for the results, while students who voluntarily take the FE exam are usually highly motivated. One method of compensating for the variability in student attitude would be to make comparisons only within peer groups. For example, instead of comparing the institution’s students with the national average, one might use the results from the institution’s Carnegie comparator that are included on the Subject Matter Report.
Current Usage

In 2010, NCEES surveyed 380 EAC/ABET institutions that receive the Subject Matter Report to determine how many institutions use the FE exam as an assessment tool. Of the 84 respondents:

- 30 (36%) indicated that some or all departments require students to take (but not necessarily pass) the FE to graduate
- 49 (58%) responded that they encourage students to take the FE
- 5 (6%) indicated that the students who wish to take the FE do so of their own volition

In addition, 70 institutions answered the question, “Does your program use the FE exam as part of your ABET assessment?” Of these, 57 institutions (81%) indicated that the FE is used for ABET assessment by at least some university departments.

Conclusions

After much experience using the FE exam for outcomes assessment, the authors find it to be a useful part of a balanced assessment program that includes other standardized tests, assessment tools, alumni surveys, and placement data. The FE exam is particularly important because it is the only nationally normed test of upper-level engineering knowledge. The detailed reports of performance by subject area provide information that can help to evaluate a program’s success in achieving the outcomes specified by ABET. Over time, these reports can also help programs document the effects of curriculum revisions, teaching innovations, and other actions taken to improve student mastery of engineering topics.

Based on their experience, the authors conclude the following:

- Engineering programs should seriously consider using the FE exam subject-level performance data as part of their program assessment, with proper regard for the caveats described.
- A program will gain the most from using the FE exam as an assessment tool if it requires all students to take the exam, particularly the discipline-specific PM exam, and if faculty establish specific goals for their programs.
- State licensing boards should be proactive in working with academic programs to stress the use and value of the FE exam as an assessment tool.
- Institutions must remember that the primary purpose of the FE exam is to assess minimal technical competence. Other assessment tools need to be used to assess higher-level theories or critical thought that might be the focus of some portion of an institution’s program.
FE exam specifications as of April 2009

MORNING SESSION SPECIFICATIONS
Listed below are the topics that the common morning portion of the examination will cover and the percentage of questions. The morning session consists of 120 questions that count 1 point each for a total of 120 points.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>15%</td>
</tr>
<tr>
<td>Engineering Probability and Statistics</td>
<td>7%</td>
</tr>
<tr>
<td>Chemistry</td>
<td>9%</td>
</tr>
<tr>
<td>Computers</td>
<td>7%</td>
</tr>
<tr>
<td>Ethics and Business Practices</td>
<td>7%</td>
</tr>
<tr>
<td>Engineering Economics</td>
<td>8%</td>
</tr>
<tr>
<td>Engineering Mechanics (Statics)</td>
<td>6%</td>
</tr>
<tr>
<td>Engineering Mechanics (Dynamics)</td>
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</tr>
<tr>
<td>Strength of Materials</td>
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</tr>
<tr>
<td>Material Properties</td>
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</tr>
<tr>
<td>Fluid Mechanics</td>
<td>7%</td>
</tr>
<tr>
<td>Electricity and Magnetism</td>
<td>9%</td>
</tr>
<tr>
<td>Thermodynamics</td>
<td>7%</td>
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</table>

AFTERNOON SESSION SPECIFICATIONS
Listed below are the topics that the discipline-specific modules cover and the percentage of questions. The afternoon session consists of 60 questions that count 2 points each for a total of 120 points.

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<thead>
<tr>
<th>Chemical</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Chemistry</td>
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</tr>
<tr>
<td>Material/Energy Balances</td>
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<tr>
<td>Chemical Engineering Thermodynamics</td>
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<td>Fluid Dynamics</td>
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<tr>
<td>Heat Transfer</td>
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<tr>
<td>Mass Transfer</td>
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</tr>
<tr>
<td>Chemical Reaction Engineering</td>
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<td>Process Design and Economic Optimization</td>
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</tr>
<tr>
<td>Computer Usage in Chemical Engineering</td>
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<tr>
<td>Process Control</td>
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<tr>
<td>Safety, Health, and Environmental</td>
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<tr>
<td>Surveying</td>
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</tr>
<tr>
<td>Hydraulics and Hydrologic Systems</td>
<td>12%</td>
</tr>
<tr>
<td>Soil Mechanics and Foundations</td>
<td>15%</td>
</tr>
<tr>
<td>Environmental Engineering</td>
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<tr>
<td>Transportation</td>
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<tr>
<td>Structural Analysis</td>
<td>10%</td>
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<tr>
<td>Structural Design</td>
<td>10%</td>
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<tr>
<td>Construction Management</td>
<td>10%</td>
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<tr>
<td>Materials</td>
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<tr>
<td><strong>ELECTRICAL</strong></td>
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<tr>
<td>Circuits</td>
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<tr>
<td>Power</td>
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<tr>
<td>Electromagnetics</td>
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<tr>
<td>Control Systems</td>
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<tr>
<td>Communications</td>
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<tr>
<td>Signal Processing</td>
<td>8%</td>
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<tr>
<td>Electronics</td>
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<tr>
<td>Digital Systems</td>
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<tr>
<td>Computer Systems</td>
<td>10%</td>
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<th><strong>ENVIRONMENTAL</strong></th>
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<th><strong>OTHER DISCIPLINES</strong></th>
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<tr>
<td>Water Resources</td>
<td>25%</td>
<td>Advanced Engineering Mathematics</td>
<td>10%</td>
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<tr>
<td>Water and Wastewater Engineering</td>
<td>30%</td>
<td>Engineering Probability and Statistics</td>
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<tr>
<td>Air Quality Engineering</td>
<td>15%</td>
<td>Biology</td>
<td>5%</td>
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<tr>
<td>Solid and Hazardous Waste Engineering</td>
<td>15%</td>
<td>Engineering Economics</td>
<td>10%</td>
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<tr>
<td>Environmental Science and Management</td>
<td>15%</td>
<td>Application of Engineering Mechanics</td>
<td>13%</td>
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<td></td>
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<td>Engineering of Materials</td>
<td>11%</td>
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<td></td>
<td></td>
<td>Fluids</td>
<td>15%</td>
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<td></td>
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<td>Electricity and Magnetism</td>
<td>12%</td>
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<td></td>
<td></td>
<td>Thermodynamics and Heat Transfer</td>
<td>15%</td>
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<tr>
<th><strong>INDUSTRIAL</strong></th>
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<tbody>
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<td>Engineering Economics</td>
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<tr>
<td>Probability and Statistics</td>
<td>15%</td>
<td></td>
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<tr>
<td>Modeling and Computation</td>
<td>12%</td>
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<td>Industrial Management</td>
<td>10%</td>
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<tr>
<td>Manufacturing and Production Systems</td>
<td>13%</td>
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<tr>
<td>Facilities and Logistics</td>
<td>12%</td>
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<tr>
<td>Human Factors, Productivity, Ergonomics, and Work Design</td>
<td>12%</td>
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<td></td>
</tr>
<tr>
<td>Quality</td>
<td>11%</td>
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</table>
REPORT AUTHORS

Steven F. Barrett, Ph.D., P.E.

Steven F. Barrett is an associate professor of electrical and computer engineering at the University of Wyoming. He has served on the NCEES PE Electrical and Computer exam development committee since 2000. He is also an ABET Engineering Accreditation Commission program evaluator and a member of the IEEE Licensure and Registration Committee.

E. Walter LeFevre, Ph.D., P.E.

E. Walter LeFevre (1932–2009) was a University of Arkansas faculty member for over 40 years and a former dean of its college of engineering. He served on NCEES exam development committees for 24 years. He was a past president of the Arkansas Board of Licensure for Professional Engineers and Professional Surveyors as well as a former NCEES Southern Zone vice president. He was also a past president of the National Society of Professional Engineers and a former ABET national board member.

John W. Steadman, Ph.D., P.E.

John W. Steadman is dean of the University of South Alabama College of Engineering. He also taught at the University of Wyoming for 32 years, 14 of which he was head of the electrical and computer engineering department. He is a past president of NCEES and IEEE-USA and an emeritus member of the Wyoming Board of Registration for Professional Engineers and Professional Land Surveyors. He has served on NCEES exam committees since 1986.

Jill S. Tietjen, P.E.

Jill S. Tietjen is a consulting electrical engineer in the electric utility industry. She is a past national president of the Society of Women Engineers as well as a former NCEES Western Zone vice president and commissioner for the ABET Engineering Accreditation Commission. She is an emeritus member of the Colorado State Board of Licensure for Architects, Professional Engineers, and Professional Land Surveyors.

Kenneth R. White, Ph.D., P.E.

Kenneth R. White retired as head of the New Mexico State University Civil Engineering Department in 2007, after 37 years of service at NMSU. He is a former chair of the NCEES Examinations for Professional Engineers and PE Civil exam committees and a former NCEES Western Zone vice president. He is an emeritus member of the New Mexico Board of Licensure for Professional Engineers and Professional Surveyors.

David L. Whitman, Ph.D., P.E.

David L. Whitman is professor of electrical and computer engineering at the University of Wyoming. He is the 2009–10 NCEES president and a member of the Wyoming State Board of Registration for Professional Engineers and Professional Land Surveyors. He has been involved with NCEES FE exam preparation for the past 15 years.