EDUCATION

The right tool for the right job— The FE as an Outcomes Assessment Tool.

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Introduction

Institutions of higher education are increasingly being encouraged to evaluate their academic programs with reference to a national norm or standard. This pressure may be a result of accreditation requirements, or it may come from state legislators who want to assign cost-benefit labels and measure the effectiveness of higher education.

One available program-assessment tool is the NCEES Fundamentals of Engineering (FE) exam. Approximately 55,000 people take this exam each year. Most of them are college seniors within one year of graduating or are recent graduates. Developed to measure minimum technical competence, the FE exam is the first step in the professional licensing of engineers. The exam's design also allows it to be used to assess competency in particular curriculum areas.

FAQ

Frequently Asked Questions

What content is included in the FE exam, and who prepares it?

The FE exam was developed to evaluate fundamental knowledge of mathematics, applied science, and engineering principles. The FE is administered as seven freestanding, discipline-specific exams: Chemical, Civil, Electrical and Computer, Environmental, Industrial, Mechanical, and Other Disciplines. Each one contains 110 multiple-choice questions and is administered as a computer-based exam at Pearson VUE test centers throughout the country. The FE exam specifications are developed from a survey of faculty from ABET-accredited engineering programs and practicing engineers. Actual exam questions are prepared by NCEES volunteers consisting of licensed practitioners and licensed engineering educators.

What are the advantages of using the FE exam in my institution's outcomes assessment process?

Effective outcomes assessment requires a set of tools to evaluate various aspects of the educational experience. At least some of those tools should enable comparison with graduates from other institutions if they are to have any value as benchmarks or credibility on an objective basis. As the only nationally normed exam addressing specific engineering topics, the

FE is an extremely effective tool for outcomes assessment. The FE exam allows an institution to focus on specific goals in selected topic areas. The detailed reports of performance by subject area provide information that can help evaluate success in achieving the program's outcomes as specified by ABET. Over time, these reports can also help the program document the effect of curriculum revisions, teaching innovations, and other actions taken for program improvement.

What data is available, and how can my institution obtain it?

NCEES provides an institution- and degree-specific report, known as the Subject Matter Report, which details the performance of

- Currently enrolled students at your institution who take the FE exam (average percentage of correct questions)
- Students nationally (average percentage of correct questions and standard deviation in each topic area)

Using these comparators, programs can gauge their students' performance against national averages. NCEES sends these reports to institutions electronically. To find out who is receiving the report for your institution, you can email NCEES at fereports@ncees.org.

Should pass rates be used as a measure of program outcomes?

Pass rates are not a good measure of program outcomes because they are based on a minimum technical competency criterion developed for licensure purposes. A more effective approach is to use data from several administrations to analyze student performance on topics consistent with your program's goals.

What can be done to prompt students to take the exam and to put forth their best effort?

Encouragement by faculty is the most effective technique. Some programs require students to take the exam. Others set up an incentive system, such as paying for the exam if passed or recognizing students who pass the exam.

Won't the use of FE exam results in assessment force all programs to look alike and cause the professor to teach to the exam?

Faculty should select topics and goals relevant to their particular program and use only these in assessment. They should determine the desired performance level based on their curriculum. Because the exam samples only the knowledge in an extensive subdiscipline, it would be impossible to teach to the exam.

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EFFECTIVE AND EFFICIENT USE OF THE FUNDAMENTALS OF ENGINEERING EXAM FOR OUTCOMES ASSESSMENT

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Overview

- Applicability of the FE exam for assessment
- ABET student outcomes that can be measured
- Computer-based FE exam format
- Various methods to use FE exam results for outcomes assessment
- Self-study examples and closing the loop
- Questions and answers

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Applicability of the FE Exam for Assessment

- It is a direct method of objective assessment with comparisons of institutional results against national results.
- Assessment does not use pass rates but rather how students perform on individual exam areas.
- Because there are over 50,000 FE examinees per year, it provides high reliability.

Applicability (cont.)

- Should my institution require the FE exam as a graduation requirement?
  - Many institutions currently do this to measure their full graduating class.
  - This requires a good-faith effort, which is generally determinable only through the amount of time spent on the exam or through the random-guessing analysis done by NCEES.

Applicability (cont.)

- What if my institution doesn't require the FE exam as a graduation requirement?
  - A self-selecting group can still be useful for assessment.
  - Anecdotal information indicates that the self-selecting group does not change much at a given institution from exam to exam.
  - Criterion for assessment should focus more on the changes in results over time compared to program-set targets rather than just the comparisons to national data.

Applicability (cont.)

- Summary
  - The FE is the only nationally normed examination addressing specific engineering topics currently available.
  - The FE is the only assessment tool available to compare the performance of students in one program with students from other programs.
  - The FE can be used as an assessment tool with a pool of all graduates or with a self-selecting pool.

ABET Outcomes Assessment Possible with FE Exam

(1) An ability to **identify, formulate, and solve complex engineering problems** by **applying principles of engineering, science, and mathematics**

- FE results can be used to show a program's ability to provide a foundation of technical knowledge in engineering, science, and mathematics that is necessary for solving complex problems.

ABET Outcomes Assessment Possible with FE Exam

(2) An ability to **apply engineering design** to produce solutions that meet specified needs with consideration of the public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

ABET Outcomes Assessment Possible with FE Exam (cont.)

(4) An ability to **recognize ethical and professional responsibilities in engineering situations** and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

FE Exam Format

- The FE uses a computer-based testing (CBT) format, with testing facilities provided by Pearson VUE testing centers.
- The FE exam is available to your students throughout the year.

Test Center Locations

- Nearly 300 Pearson VUE test center locations are available throughout the United States.
- Specific sites near your institution can be located from the NCEES website at the following URL:
  - http://ncees.org/exams/test-center-locations/

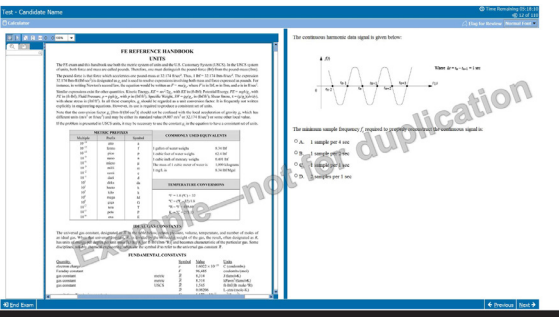
FE Exam Format

- Length
  - The appointment time at test centers is 6 hours.
    - Tutorial–8 minutes
    - Nondisclosure agreement–2 minutes
    - Exam time–5 hours, 20 minutes with a 25-minute scheduled break after approximately 55 questions
  - Total of 110 questions

FE Exam Format (cont.)

- *FE Reference Handbook*
  - Provided electronically with the exam as a searchable PDF
  - Available for free download and for purchase as a hard copy at http://ncees.org/engineering/fe/
- *NCEES Examinee Guide*
- Practice exams available for each discipline

FE Exam Format (cont.)



FE Exam Format (cont.)

- Content of the exam
  - 7 free-standing discipline-specific exams
    - Chemical
    - Civil
    - Electrical and Computer
    - Environmental
    - Industrial and Systems
    - Mechanical
    - Other Disciplines

FE Electrical and Computer Exam Specifications—Updated in 2020

- Mathematics
- Probability and Statistics
- Ethics and Professional Practice
- Engineering Economics
- Properties of Electrical Materials
- Circuit Analysis (DC and AC Steady State)
- Linear Systems
- Signal Processing
- Electronics
- Power Systems
- Electromagnetics
- Control Systems
- Communications
- Computer Networks
- Digital Systems
- Computer Systems
- Software Engineering

FE Civil Exam Specification–Example of Engineering Design

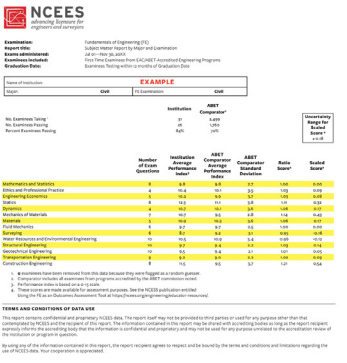
11. Structural Engineering
    G. Design of steel components (e.g., codes and design philosophies, beams, columns, tension members, connections)
    H. Design of reinforced concrete components (e.g., codes and design philosophies, beams, columns)

Other Exam Specifications

- Available at http://ncees.org/engineering/fe/

So, what actual data are available, and what can you do with the data?

Subject Matter Report



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Examination: Fundamentals of Engineering (FE)
Report title: Subject Matter Report by Major and Examination
Exams administered: Jul 01—Nov 30, 20XX
Examinees included: First Time Examinees from EAC/ABET-Accredited Engineering Programs
Graduation Date: Examinees Testing within 12 months of Graduation Date

Name of Institution:		EXAMPLE	
Major:	Civil	FE Examination	Civil

	Institution	ABET Comparator[2]
No. Examinees Taking:	31	2,499
No. Examinees Passing	26	1,960
Percent Examinees Passing	84%	78%

Uncertainty Range for Scaled Score[4]: ±0.08

	Number of Exam Questions	Institution Average Performance Index[1]	ABET Comparator Average Performance Index[2]	ABET Comparator Standard Deviation	Ratio Score[3]	Scaled Score[4]
Mathematics and Statistics	8	9.8	10.7	2.7	1.06	0.06
Ethics and Professional Practice	4	10.4	10.1	2.3	1.03	0.03
Engineering Economics	5	10.2	9.9	2.7	1.05	0.05
Statics	8	11.3	11.1	3.8	1.11	0.10
Dynamics	4	10.7	10.1	3.6	1.08	0.07
Mechanics of Materials	7	10.7	9.5	4.8	1.14	0.13
Materials	5	10.2	10.3	3.6	1.06	0.07
Fluid Mechanics	6	9.7	9.7	2.5	1.00	0.00
Surveying	6	8.7	9.2	3.2	0.95	-0.05
Water Resources and Environmental Engineering	10	10.5	10.4	3.3	1.01	0.01
Reinforced Engineering	10	9.2	9.8	2.5	0.94	-0.06
Geotechnical Engineering	10	9.5	9.4	2.1	1.01	0.01
Transportation Engineering	5	9.4	9.6	2.2	0.98	-0.02
Construction Engineering	8	11.5	9.5	3.7	1.21	0.54

1. ★ examinees have been removed from this data because they were flagged as a random guesser.
2. Comparator includes all examinees from programs accredited by the ABET commission noted.
3. Performance index is based on a 0-13 scale.
4. These scores are made available for assessment purposes. See the NCEES publication entitled Using the FE as an Outcomes Assessment Tool at https://ncees.org/engineering/evaluator-resources/

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Subject Matter Report (cont.)

- Reports are generated twice a year.
  - In July for the January–June testing period (spring)
  - In January for the July–December testing period (fall)
- The report is specific to the following:
  - An institution
  - Students within an engineering degree program at that institution
  - The discipline-specific exam that those students completed

Subject Matter Report (cont.)

- Data are provided for all examinees testing within 12 months of graduation (either before or after graduating).
- Only first-time takers are included.
- Random guessers are removed from the report.
- National performance data, with standard deviation information, are also provided for the same degree program and same discipline-specific exam.

Subject Matter Report (cont.)

- For each topic, the students' performance is given as a Performance Index on a scale of 0 to15.
- The Performance Index is <u>indirectly</u> related to the average number of questions answered correctly.
- This is necessary because each examinee receives a different set of questions within each topic area.

Subject Matter Report (cont.)

- Getting the data
  - NCEES sends links to reports directly to an institution via email.
  - If you don't know, NCEES can tell you who receives your institution's reports.
  - Reports also include information on the specific institution's examinee who took the FE or PE exam more than 12 months after graduation.

Specifics of Using the FE Exam for Outcomes Assessment

Getting Started

- Involve faculty.
- Identify areas of strength.
- Acknowledge areas that are not emphasized.
- Set program-specific goals for each area.

Table from Self-Study Showing the Use of the FE as One Measure for a Specific Outcome

Outcome	Applicable FE Exam Category
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	**Mathematics and Statistics, Geotechnical Engineering, Transportation Engineering, Water Resources and Environmental Engineering**
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and societal contexts	**Structural Engineering, Engineering Economics**
3. An ability to communicate effectively with a range of audiences	None
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal concerns	**Ethics and Professional Practice**
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	None
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	None
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies	None

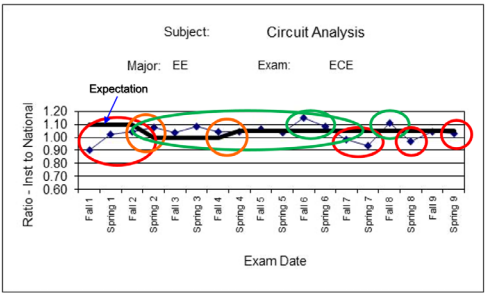
Suggested Analysis Techniques

- Choose your longitudinal time basis.
  - Performance from multiple examination windows
  - Academic year performance
- Choose your presentation method.
  - Ratio method
  - Scaled score method

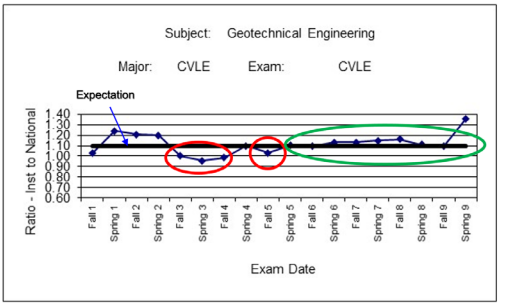
Ratio Method

- The ratio score is simply the ratio between the program's performance index (P.I.) in any topic area and the P.I. of the comparator performance.
  - Ratio score = Program P.I./Comparator P.I.

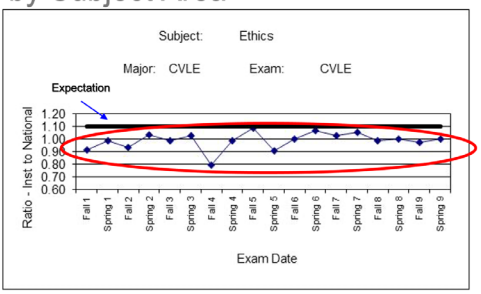
Comparison of Ratios by Subject Area



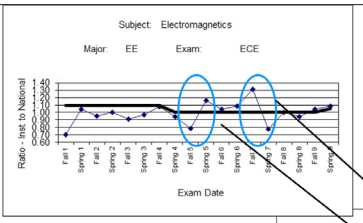
Comparison of Ratios by Subject Area

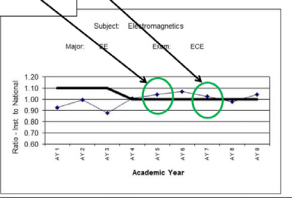


Comparison of Ratios by Subject Area



Effect of Academic Year Averaging





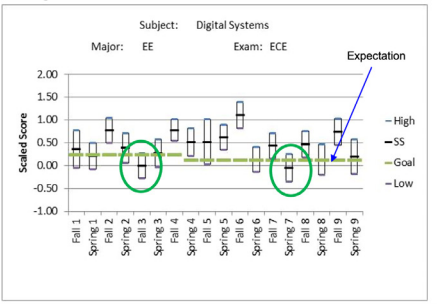
Causes a smoothing of the data—Note the fall/spring 5 and fall/spring 7 results compared to the academic year 5 and academic year 7 results.

Scaled Score Method

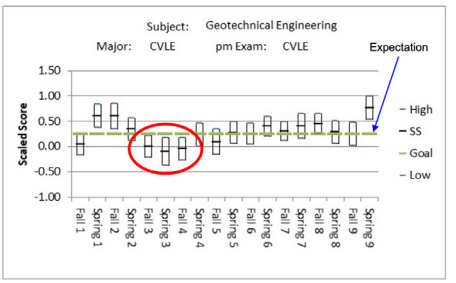
$$S.S. = \frac{\text{PI for Univ X} - \text{PI comparator}}{\text{PI comparator standard deviation}}$$

$$\pm \frac{1}{\sqrt{\text{\# of takers at Univ X}}}$$

Comparison Using Scaled Score by Subject Area



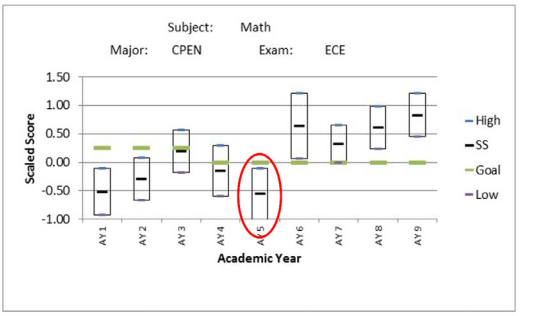
Comparison Using Scaled Score by Subject Area



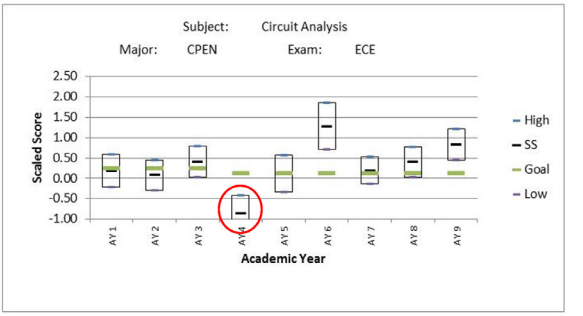
Academic Year Averaging

Examples of Assessing Some of the ABET (1)–(7) Outcomes

Outcome 1: Ability to Apply Math and Science



Outcome 1: Ability to Solve Engineering Problems



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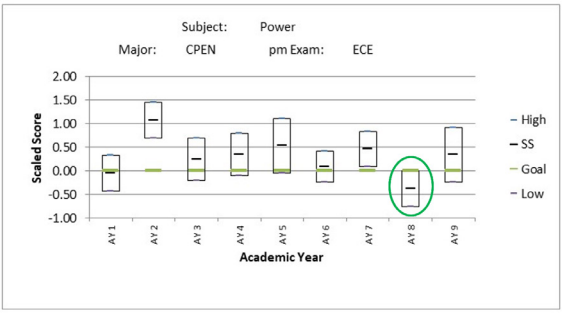
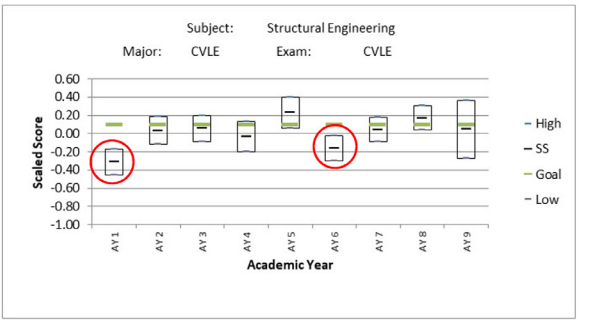


Outcome 2: Ability to Apply Engineering Design



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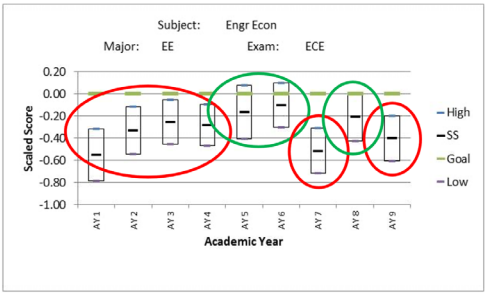
Outcome 2: Ability to Apply Economic Factors in Design



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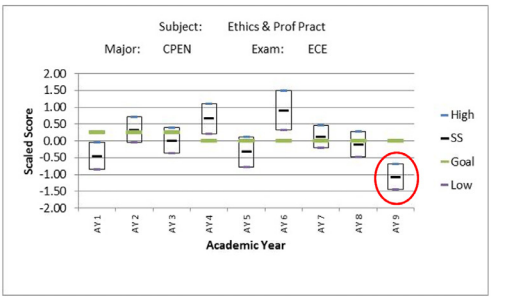
Outcome 4: Ability to Recognize Ethical Responsibility



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Conclusions

- Discipline-specific assessment information can be gleaned from this exam.
- FE exam provides a direct, quantitative assessment technique.
- The Subject Matter Report provides comparative data.
- NCEES sends a link to the Subject Matter Report directly to your institution via email.
- Thus, the FE exam is one effective assessment tool to be used as part of your institution's full assessment package.

Additional Resources

- For more information on reports, email fereports@ncees.org.
- NCEES publishes a white paper and several accompanying documents that describe in detail how engineering departments can use the FE exam to assess program outcomes.
- Available for free download at
  - http://ncees.org/engineering/educator-resources/

Additional Resources

For further information, contact

Cheryl Warren, Ph.D., P.E.
NCEES Exam Development Engineer
800-250-3196, ext. 5472
email: cwarren@ncees.org

Questions?

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National Council of Examiners for Engineering and Surveying®
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