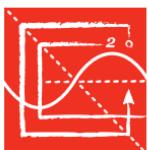




# EDUCATION

**The right tool  
for the right job—**

The FE as an Outcomes  
Assessment Tool.



**NCEES**

*advancing licensure for  
engineers and surveyors*



# NCEES

*advancing licensure for  
engineers and surveyors*

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

2018



### 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

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

## 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 how students perform on individual exam areas.
- Because there are over 55,000 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 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 doesn't change much at a given institution from exam to exam.
  - Criterion for assessment should focus more on the **changes** in results over time 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.



## Current ABET Outcomes Assessment Possible with FE Exam: (a)-(k)

- 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



## ABET Outcomes Assessment Possible with FE Exam (cont.)

- (e) An ability to **identify, formulate, and solve engineering problems**
- (f) An understanding of **professional and ethical responsibility**
- (k) An ability to use the techniques, skills, and modern **engineering tools** necessary for engineering practice





## EAC New Definitions

- Complex engineering problems
  - Involving wide-ranging technical issues
  - Having no obvious solution
  - Including many component parts
- Engineering design
  - Devising a system, component, or process to meet desired needs and specifications within constraints



## EAC New Definitions

- Basic science
  - Fundamentals of natural phenomena
  - Chemistry and physics
  - Life, earth, and space sciences
- College-level mathematics
  - At or above introductory calculus
  - Includes calculus, differential equations, probability, statistics, linear algebra, and discrete mathematics



## New ABET Outcomes Assessment Possible with FE Exam: (1)-(7)

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





## New 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



## New ABET Outcomes Assessment Possible with FE Exam (cont.)

- (6) An ability to develop and conduct appropriate experimentation, **analyze and interpret data**, and use engineering judgment to draw conclusions



## Computer-Based Testing (CBT) Format

- The FE became a CBT exam in January 2014
  - Shorter in time and fewer questions
  - Presented in a different format





## Why CBT?

- Candidate convenience
- Quicker score turnaround (7–10 days)
- Uniformity in testing conditions
- Enhanced security
- More innovative way to test
  - Alternative items types (AITs) added in July 2017 to allow for more ways of testing beyond four-part multiple choice



## CBT Format (cont.)

- 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
    - Brief post-exam survey
  - Total of 110 questions



## CBT Format (cont.)

- Testing opportunities
  - Testing windows
    - January–March
    - April–June
    - July–September
    - October–December
- Test center locations
  - Pearson VUE test centers





# 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/>



## CBT 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*
  - Computer-based practice exams



## CBT Format (cont.)

**Test - Candidate Name** \_\_\_\_\_

**Time Remaining: 05:17:45**

**Questions:** \_\_\_\_\_

**Flag for Review** **Mark as Correct**

**FE Reference Handbook**

**FE Reference Handbook**

The FE exam and this handbook are both the metric version of the U.S. Engineering Handbook (USC-X), the USCS's official handbook of engineering data. The USC-X is available online at [www.usc-x.org](http://www.usc-x.org).

The peak force is that force which produces one g-unit of load. Thus,  $F_p = 21.2 \text{ lb}_f$  (lb-force). The expression  $21.2 \text{ lb}_f = 1 \text{ g}$  is not correct because the peak force would be  $21.2 \text{ lb}_f$ , not  $21.2 \text{ lb}_f/\text{g}$ . In fact, it is the peak force that is equal to  $21.2 \text{ lb}_f$ . The peak force is also equal to  $21.2 \text{ N}$  (newton).

$F_p = 21.2 \text{ lb}_f$  is the peak force,  $\sigma_p = 21.2 \text{ psi}$  is the peak stress,  $W_p = 21.2 \text{ lb}_f \cdot \text{in}$  is the peak weight, and  $21.2 \text{ lb}_f \cdot \text{in}$  is the peak moment.

It is important to note that the peak force is not the average force. The average force is the force produced by a uniformly varying magnitude. However, one is required to determine a constant or uniform force.

The peak force is the maximum value of a periodic wave. The peak frequency is the maximum value of a periodic wave. The peak amplitude is the maximum value of a periodic wave. The peak force is the maximum value of a periodic wave.

If the problem asks for the peak force, the answer is the maximum value in the equation, as required to determine a constant or uniform force.

**MECHANICAL PREFIXES**

Symbol	Prefix	Symbol	Common Prefix Equivalents
$\text{m}$	milli	$\text{g}$	$1 \text{ mg} = 1 \text{ milligram}$
$\mu$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{n}$	milli	$\text{g}$	$1 \text{ g} = 1 \text{ gram}$
$\text{p}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{f}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{a}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{pico}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{atto}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{zepto}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$
$\text{yocto}$	micro	$\text{kg}$	$1 \text{ kg} = 1 \text{ kilogram}$

**TEMPERATURE CONVERSIONS**

Symbol	Unit	Symbol	Unit
$T^{\circ}\text{F}$	degrees Fahrenheit	$T^{\circ}\text{K}$	kelvin
$T^{\circ}\text{C}$	degrees Celsius	$T^{\circ}\text{R}$	degrees Rankine
$T^{\circ}\text{R}$	degrees Rankine	$T^{\circ}\text{K}$	kelvin
$T^{\circ}\text{K}$	kelvin	$T^{\circ}\text{C}$	degrees Celsius
$T^{\circ}\text{R}$	degrees Rankine	$T^{\circ}\text{F}$	degrees Fahrenheit

**IDEAL GAS LAW**

The universal gas law, designated by the symbol  $PV = nRT$ , relates the pressure, temperature, and number of moles of air to the volume. When the ideal gas law is applied to a single mole of air, the result is the ideal gas law,  $PV = RT$ , where  $R$  is the universal gas constant. The universal gas law applies to all gases, except those affected by chemical reactions, phase changes, or magnetic fields. The ideal gas law applies to all gases, except those affected by chemical reactions, phase changes, or magnetic fields.

**FUNDAMENTAL CONSTANTS**

Quantity	Symbol	Value	Units
electron charge	$e$	$1.602 \times 10^{-19}$	Coulomb (statcoulomb)
gravitational constant	$G$	$6.674 \times 10^{-11}$	N m <sup>2</sup> /kg <sup>2</sup> (N m <sup>2</sup> /Coulomb <sup>2</sup> )
gas constant	$R$	$8.314$	J/K (J/mole K)
gravitational acceleration	$g$	$9.80665$	m/s <sup>2</sup> (m/s/msec)

The continuous harmonic sine signal is given below:

When  $(t - t_0)/T_0 = 1$  ms

The minimum sample frequency  $f_s$  required to prevent aliasing of a continuous signal is:

- A. 1 sample per 4 sec
- B. 1 sample per 2 sec
- C. 1 sample per 1 sec
- D. 1 sample per 1 ms

**FE Exam**

**NCEES**

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

## CBT 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 no longer has a common morning portion (breadth module)
    - Selected exam topics that were previously on the breadth module are now tested within each discipline-specific exam.



## FE Electrical and Computer Engineering Exam Specification

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



## Comparison of Level 2 Specifications—Mathematics Subject Area

- |                                   |                       |
|-----------------------------------|-----------------------|
| <b>FE Electrical and Computer</b> | <b>FE Civil</b>       |
| A. Algebra and trigonometry       | A. Analytic geometry  |
| B. Complex numbers                | B. Calculus           |
| C. Discrete mathematics           | C. Roots of equations |
| D. Analytic geometry              | D. Vector analysis    |
| E. Calculus                       |                       |
| F. Differential equations         |                       |
| G. Linear algebra                 |                       |
| H. Vector analysis                |                       |





# FE Civil Engineering Exam Specification—Example of Engineering Design

## 13. Structural Design

- A. Design of steel components (e.g., codes and design philosophies, beams, columns, beam-columns, tension members, connections)
- B. Design of reinforced concrete components (e.g., codes and design philosophies, beams, slabs, columns, walls, footings)



## 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



**NCEES**  
advancing licensure for  
engineers and surveyors

Name of Institution:		EXAMPLE	
Major:	Civil	FE Examination:	Civil
No. Examinees Taking <sup>2</sup>	21	ABET Comparative Index <sup>3</sup>	1.00
No. Examinees Passing	20	ABET Comparative Performance Index	0.99
Percent Examinees Passing	84%	ABET Comparative Deviation	0.32
		Ratio Score <sup>4</sup>	0.37
		Score Range <sup>4</sup>	0.13
		Uncertainty Range for Score <sup>4</sup>	±0.10
Number of Exam Questions	Institution Average Index <sup>3</sup>	ABET Comparative Index	Ratio Score <sup>4</sup>
Mathematics	4	10.4	10.1
Probability and Statistics	4	10.4	10.1
Computer Fundamentals	4	12.0	11.1
Ethics and Professional Practice	4	10.7	10.4
Engineering Economics	4	10.7	10.4
Statics	4	10.7	10.4
Dynamics	4	10.9	10.3
Mechanics of Materials	4	9.7	9.3
Materials	4	9.7	9.3
Fluid Mechanics	4	10.0	9.9
Hydraulics and Hydrologic Systems	8	9.7	9.4
Structural Analysis	6	9.7	9.9
Electrical Analysis	6	9.4	9.9
Geotechnical Engineering	9	9.5	2.1
Environmental Engineering	6	9.5	2.1
Environmental Engineering	6	8.9	2.7
Surveying	4	11.3	10.9
Surveying	4	8.4	8.1

1. 8 examinees have been removed from this data because they were flagged as a random guesser.  
 2. Total number of first-time examinees taking the exam.  
 3. Performance Index is based on a 0-13 scale.  
 4. These scores are provided for reporting and assessment purposes. See the NCEES publication entitled Using the PEas an Outcomes Assessment Tool at <http://ncees.org/peasguide/outcome-resources>.

## TERMS AND CONDITIONS OF DATA USE

This report contains confidential and proprietary NCEES data. The report itself may not be provided to third parties or used for any purpose other than that intended by the report recipient except with express permission from NCEES.

1. This report is intended for internal use only and is not intended for public release.

2. Performance Index is based on a 0-13 scale.

3. This report is intended for internal use only and is not intended for public release.

4. These scores are provided for reporting and assessment purposes. See the NCEES publication entitled Using the PEas an Outcomes Assessment Tool at <http://ncees.org/peasguide/outcome-resources>.

## Subject Matter Report (cont.)

- Reports are generated twice a year.
  - In July for the January–May testing period (Spring)
  - In January for the July–November testing period (Fall)
- The report is specific to
  - An institution,
  - Students within an engineering degree program at that institution, and
  - 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 0–15.
- The Performance Index is indirectly 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.
  - Any one examinee's set of questions may be harder or easier than another examinee's set.



## 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 examinees who took the FE or PE exam more than 12 months after graduation.



## Specifics of Using the FE Exam for Outcomes Assessment





## Getting Started

- **Faculty** should be involved.
- 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
a. An ability to apply knowledge of mathematics through differential equations, science, ...	<b>Math</b>
b. An ability to design and conduct ...	None
c. An ability to design a system, component, ...	<b>Structural Design</b>
d. An ability to function on multidisciplinary teams	None
e. An ability to identify, formulate, and solve engineering problems	<b>Engineering Mechanics, Strength of Materials, Fluid Mechanics, Structural Analysis</b>
f. An understanding of professional and ethical responsibility	<b>Ethics and Professional Practice</b>
g. An ability to communicate effectively	None
h. The broad education necessary to understand the impact of engineering ...	None
i. A recognition of the need for, and an ability to engage in life-long learning	None
j. A knowledge of contemporary issues	None
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	<b>Computational Tools, Surveying</b>
l. An ability to apply knowledge of technical areas appropriate to civil engineering	<b>Environmental Engineering, Hydraulics/Hydrology, Soil Mechanics and Foundations, Structural Design, Transportation</b>



## 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



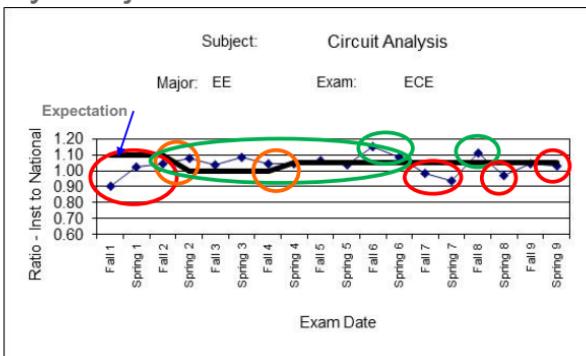


## Ratio Method

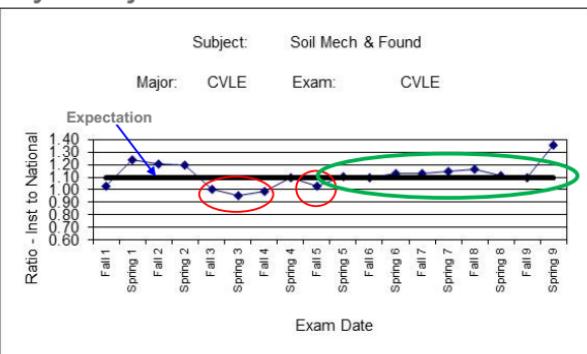
- The ratio score is simply the ratio between the program's performance index (P.I.) in any topic area and the P.I. of the comparator performance.
  - Ratio score = Program P.I./Comparator P.I.



## Comparison of Ratios by Subject Area

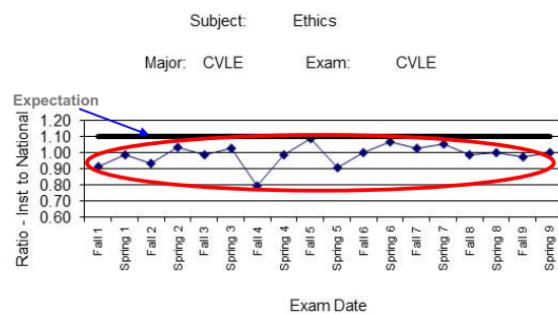


## Comparison of Ratios by Subject Area



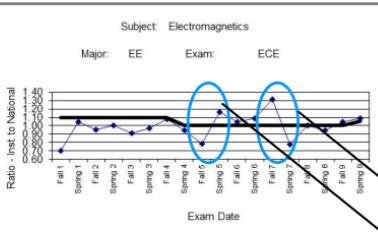


## Comparison of Ratios by Subject Area

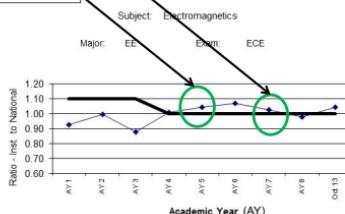


NCEES

## Effect of Academic Year Averaging



Causes a smoothing of the data—note the Fall/Spring 5 and Fall/Spring 7 results compared to the AY 5 and AY 7 academic year results.



## Scaled Score Method

Define Scaled Score (S.S.)

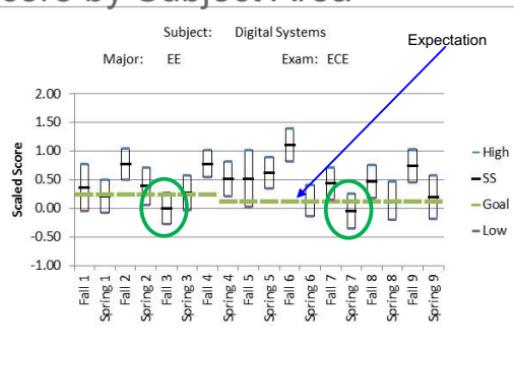
$$S.S. = \frac{PI \text{ for Univ X} - PI \text{ comparator}}{PI \text{ comparator standard deviation}}$$

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

NCEES

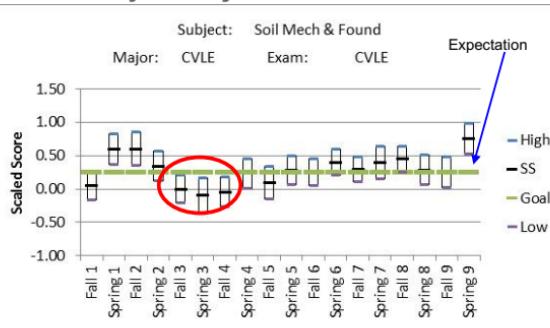


## Comparison Using Scaled Score by Subject Area



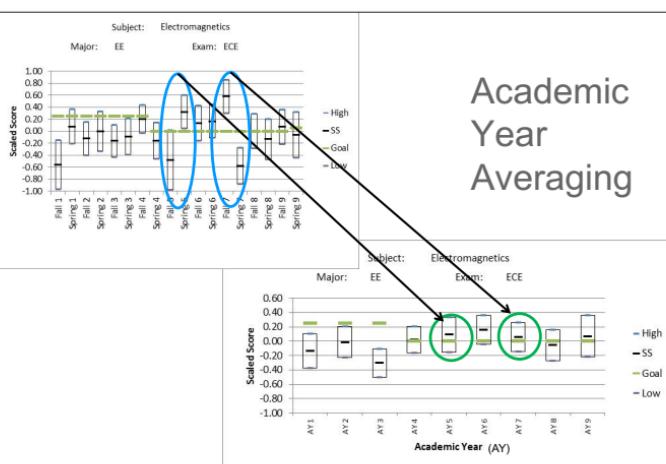
NCEES

## Comparison Using Scaled Score by Subject Area



NCEES

## Academic Year Averaging



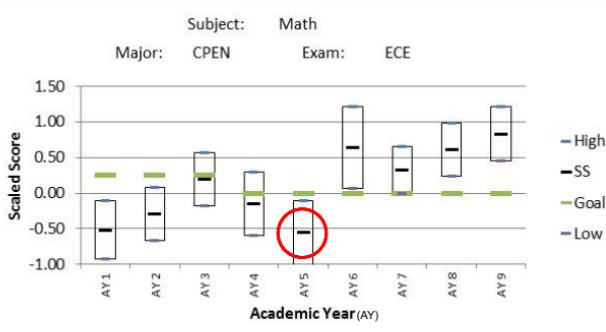
NCEES



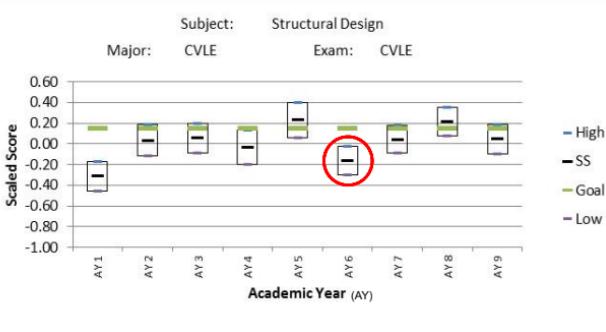
## Examples of Assessing Some of the ABET (a)–(k) Outcomes



Ability to Measure ABET (a) Math and Science



Ability to Measure ABET (c) Design



---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

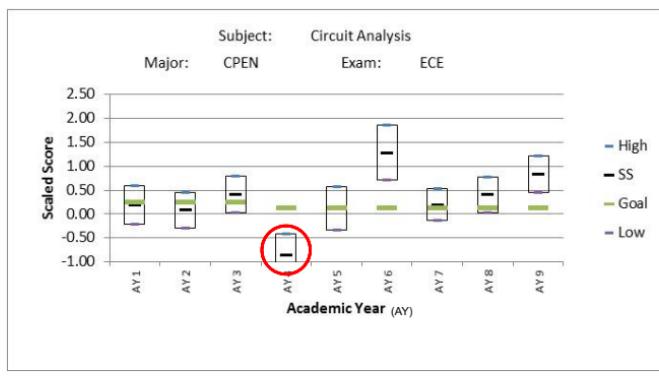
---

---

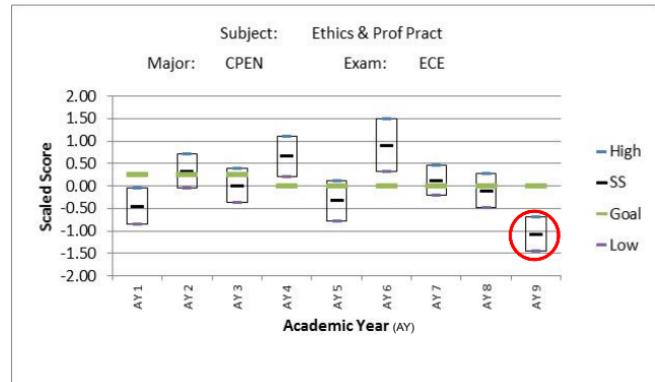
---

---

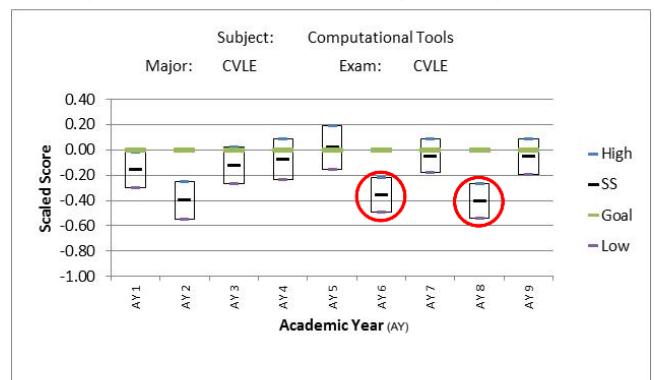
### Ability to Measure ABET (e) Solve Engineering Problems



### Ability to Measure ABET (f) Ethical Responsibility



### Ability to Measure ABET (k) Engineering Tools



---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

---

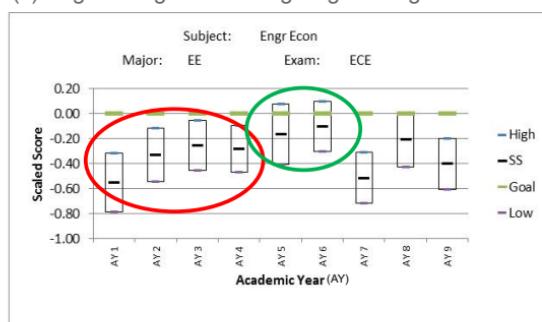
---

---

---

---

Ability to Measure ABET (e) Solving Engineering Problems or (k) Engineering Tools Using Engineering Economics



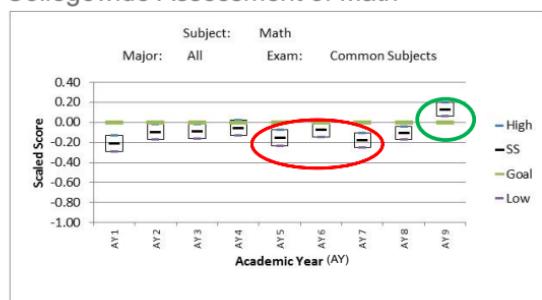
- Lectures on engineering economics were added to the senior design sequence during AY 5.



Collegewide assessment  
is possible.



Collegewide Assessment of Math

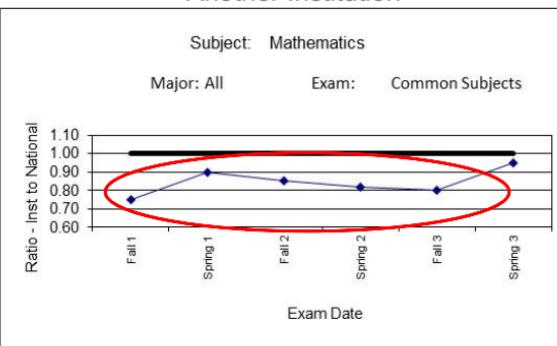


- Math agreed in AY 6 to make changes to the calculus sequence, including discontinuing the use of graduate students as instructors. Took 3 years for positive results.





## Collegewide Assessment of Math— Another Institution



- Long-term issue. Math has agreed to incorporate applied mathematics assignments with results pending.



## 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.



## Conclusions (cont.)

- 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](mailto:fereports@ncees.org)

Download today's presentation 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](mailto:cwarren@ncees.org)

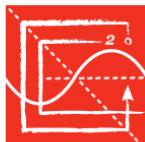


## Questions?





**Discover more.**  
[ncees.org/education](http://ncees.org/education)



**NCEES**

**National Council of Examiners  
for Engineering and Surveying®**  
P.O. Box 1686, Clemson, S.C. 29633  
864.654.6824