NCEES

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

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Overview

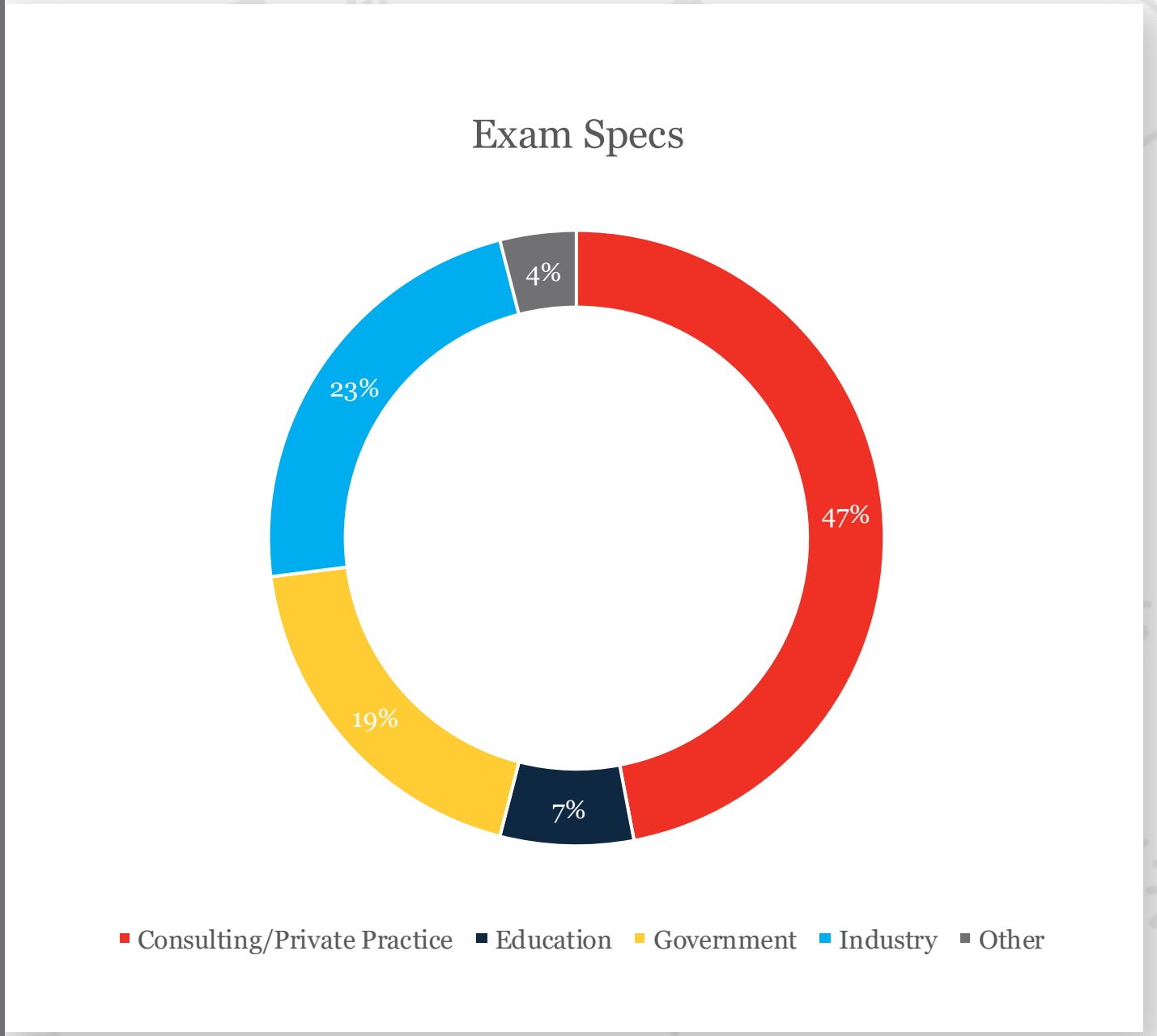
- Applicability of the FE exam for assessment
- ABET student outcomes that can be measured
- Computer-based FE exam format
- Various methods to use FE exam results for outcomes assessment
- Self-study examples and closing the loop
- Questions and answers

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 of the FE exam for Assessment

- Exam specifications are directly tied to the engineering profession.
  - Specifications are set using a Professional Activities and Knowledge (PAKS) study.
  - Study input is solicited from practicing engineers in industry, academia, and government.
  - The study is conducted on a regular basis to keep exam specifications up to date.



Applicability of the FE Exam for Assessment

- 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 of the FE Exam for Assessment

- 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 of the FE Exam for Assessment

- 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.

Short Survey

- Show of hands:
  1. Does your program currently use the FE exam as one of your assessment tools?
  2. If you use the FE exam as an assessment tool, does your program require that all graduates take the FE exam, or do you just utilize the self-selecting group?
     - Require all graduates
     - Use a self-selecting group

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

- Many of the FE exams have specifications that deal directly with components of engineering design.

ABET Outcomes Assessment Possible with FE Exam

(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

- All of the FE exams have questions on engineering ethics and professional responsibilities.

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

- *FE Reference Handbook*
  - Provided electronically with the exam as a searchable PDF
  - Available for free download at http://ncees.org/engineering/fe/
- *NCEES Examinee Guide*
- Practice exams are available for each discipline in two different formats
  - Interactive exams to be used on a computer that contain 50 items and solutions that are representative of the computer-based exam format.
  - E-book exams that contain 50 items and solutions in a PDF document.

FE Exam Format (cont.)

Test - Candidate Name

Time Remaining 05:18:10

12 of 110

Calculator

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FE REFERENCE HANDBOOK

UNITS

The FE exam and this handbook use both the metric system of units and the U.S. Customary System (USCS). In the USCS system of units, both force and mass are called pounds. Therefore, one must distinguish the pound-force (lbf) from the pound-mass (lbm).

The pound-force is that force which accelerates one pound-mass at 32.174 ft/sec^2. Thus, 1 lbf = 32.174 lbm-ft/sec^2. The expression 32.174 lbm-ft/(lbf-sec^2) is designated as g_c and is used to resolve expressions involving both mass and force expressed as pounds. For instance, in writing Newton's second law, the equation would be written as $F = ma/g_c$, where F is in lbf, m in lbm, and a is in ft/sec^2.

Similar expressions exist for other quantities. Kinetic Energy, $KE = mv^2/2g_c$, with KE in (ft-lbf); Potential Energy, $PE = mgh/g_c$, with PE in (ft-lbf); Fluid Pressure, $p = \rho gh/g_c$, with p in (lbf/ft^2); Specific Weight, $SW = \rho g/g_c$, in (lbf/ft^3); Shear Stress, $\tau = (\mu/g_c)(dv/dy)$, with shear stress in (lbf/ft^2). In all these examples, g_c should be regarded as a unit conversion factor. It is frequently not written explicitly in engineering equations. However, its use is required to produce a consistent set of units.

Note that the conversion factor g_c [lbm-ft/(lbf-sec^2)] should not be confused with the local acceleration of gravity g, which has different units (m/s^2 or ft/sec^2) and may be either its standard value (9.807 m/s^2 or 32.174 ft/sec^2) or some other local value.

If the problem is presented in USCS units, it may be necessary to use the constant g_c in the equation to have a consistent set of units.

METRIC PREFIXES		
Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{1}	deka	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

COMMONLY USED EQUIVALENTS	
1 gallon of water weighs	8.34 lbf
1 cubic foot of water weighs	62.4 lbf
1 cubic inch of mercury weighs	0.491 lbf
The mass of 1 cubic meter of water is	1,000 kilograms
1 mg/L is	8.34 lbf/Mgal

TEMPERATURE CONVERSIONS
°F = 1.8 (°C) + 32
°C = (°F – 32)/1.8
°R = °F + 459.69
K = °C + 273.15

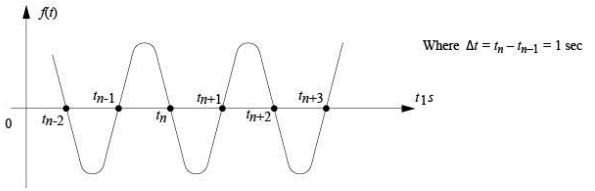
IDEAL GAS CONSTANTS

The universal gas constant, designated as $\overline{R}$ in the table below, relates pressure, volume, temperature, and number of moles of an ideal gas. When that universal constant, $\overline{R}$, is divided by the molecular weight of the gas, the result, often designated as R, has units of energy per degree per unit mass [kJ/(kg·K) or ft-lbf/(lbm-°R)] and becomes characteristic of the particular gas. Some disciplines, notably chemical engineering, often use the symbol R to refer to the universal gas constant $\overline{R}$.

FUNDAMENTAL CONSTANTS

Quantity		Symbol	Value	Units
electron charge		e	1.6022×10^{-19}	C (coulombs)
Faraday constant		F	96,485	coulombs/(mol)
gas constant	metric	$\overline{R}$	8,314	J/(kmol•K)
gas constant	metric	$\overline{R}$	8.314	kPa•m^3/(kmol•K)
gas constant	USCS	$\overline{R}$	1,545	ft-lbf/(lb mole-°R)
		$\overline{R}$	0.08206	L-atm/(mole-K)

The continuous harmonic data signal is given below:



Where $\Delta t = t_n - t_{n-1} = 1$ sec

The minimum sample frequency f_s required to properly reconstruct the continuous signal is:

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

End Exam | Previous | Next

FE Exam Format

- 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

NCEES
advancing licensure for engineers and surveyors

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]	Uncertainty Range for Scaled Score[4]
No. Examinees Taking[1]	31	2,499	± 0.18
No. Examinees Passing	26	1,760	
Percent Examinees Passing	84%	70%	

	Number of Exam Questions	Institution Average Performance Index[3]	ABET Comparator Average Performance Index	ABET Comparator Standard Deviation	Ratio Score[4]	Scaled Score[4]
Mathematics and Statistics	8	9.8	9.8	2.7	1.00	0.00
Ethics and Professional Practice	4	10.4	10.1	3.5	1.03	0.09
Engineering Economics	5	10.2	9.9	3.7	1.03	0.08
Statics	8	12.3	11.1	3.8	1.11	0.32
Dynamics	4	10.7	10.1	3.6	1.06	0.17
Mechanics of Materials	7	10.7	9.5	2.8	1.14	0.43
Materials	5	10.9	10.3	3.6	1.06	0.17
Fluid Mechanics	6	9.7	9.7	2.5	1.00	0.00
Surveying	6	8.7	9.2	3.1	0.95	-0.16
Water Resources and Environmental Engineering	10	10.5	10.9	3.4	0.96	-0.12
Structural Engineering	10	9.7	9.4	2.2	1.03	0.14
Geotechnical Engineering	10	9.5	9.4	2.1	1.01	0.05
Transportation Engineering	9	9.2	9.0	2.2	1.02	0.09
Construction Engineering	8	11.5	9.5	3.7	1.21	0.54

1. **0** 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 0-15 scale.
4. These scores are made available for assessment purposes. See the NCESS publication entitled Using the FE as an Outcomes Assessment Tool at https://ncees.org/engineering/educator-resources/.

Subject Matter Report

- 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

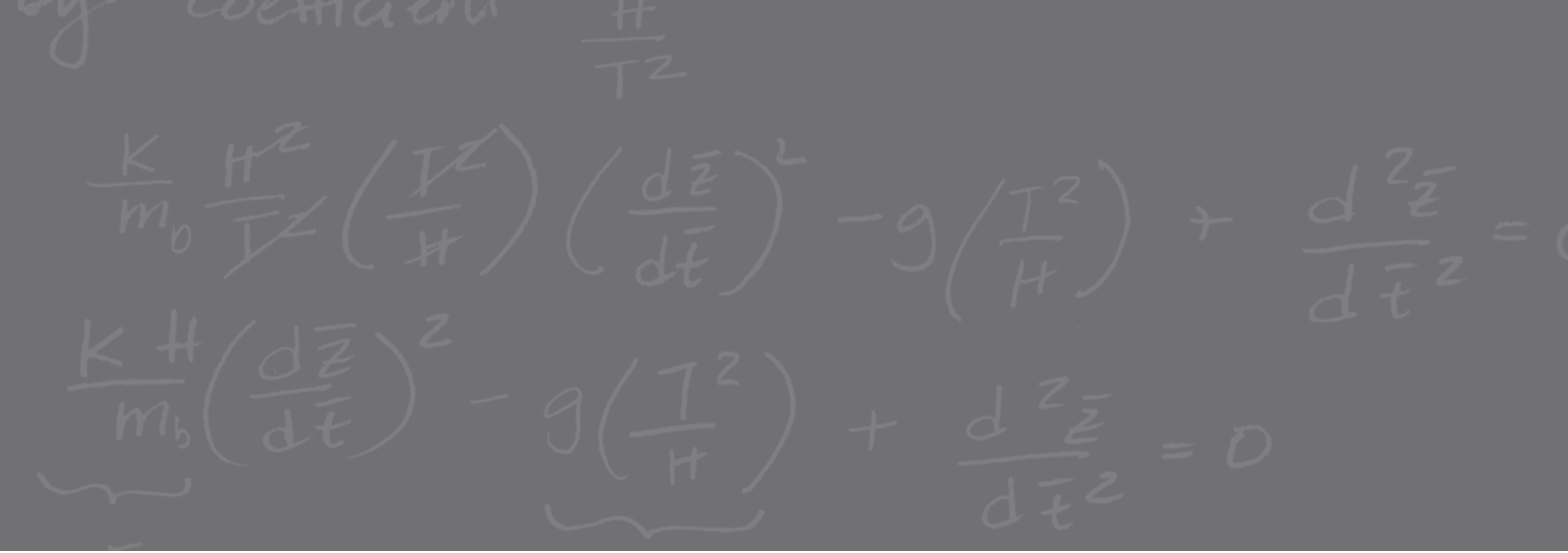
- Data are provided for all examinees testing within 12 months of graduation (either before or after graduating).
- Only first-time takers are included.
- Random guessers are removed from the report.
- National performance data, with standard deviation information, are also provided for the same degree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

Subject Matter Report

- For each topic, the students' performance is given as a Performance Index on a scale of 0 to 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.

Subject Matter Report

- 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

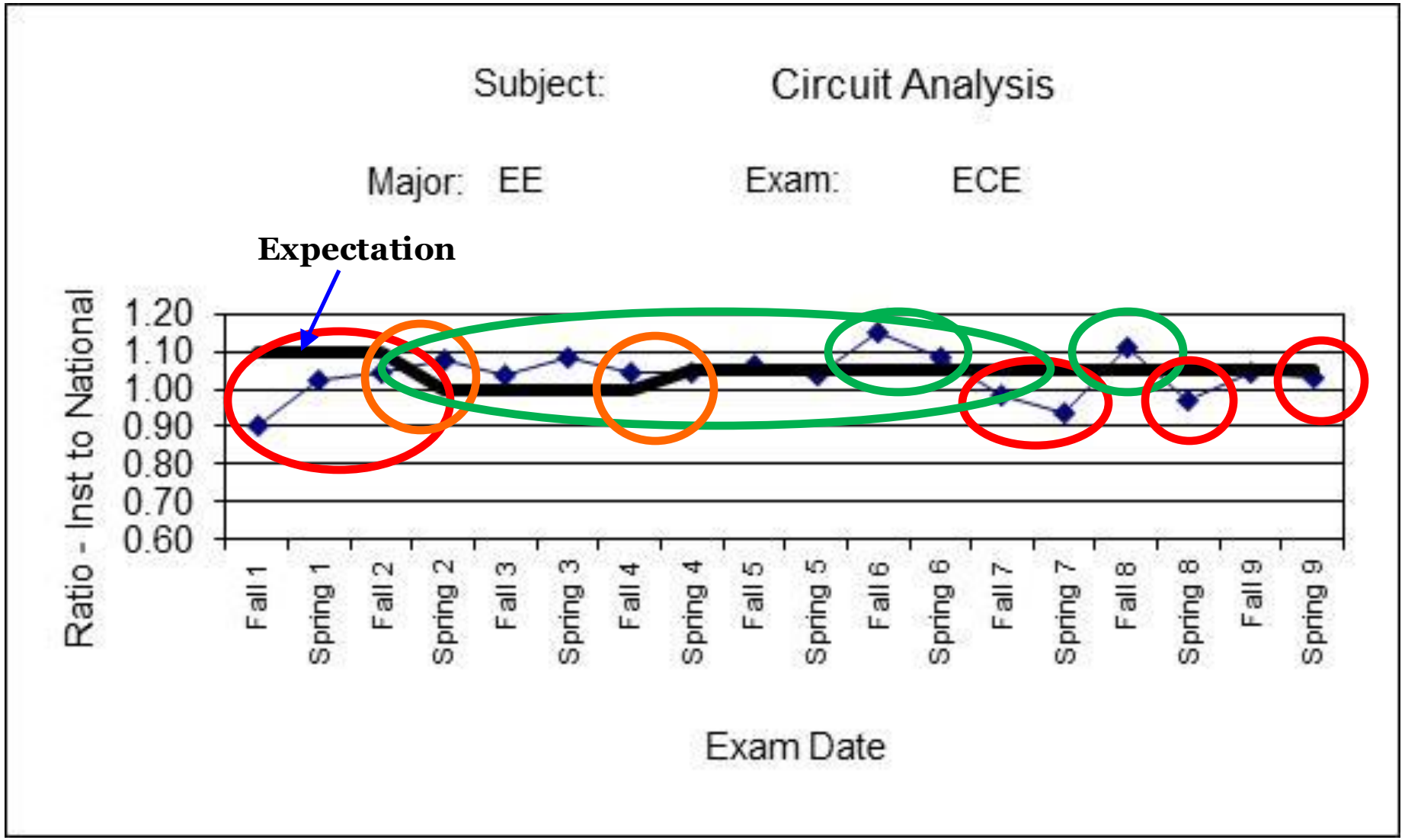
Suggested Analysis Techniques

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

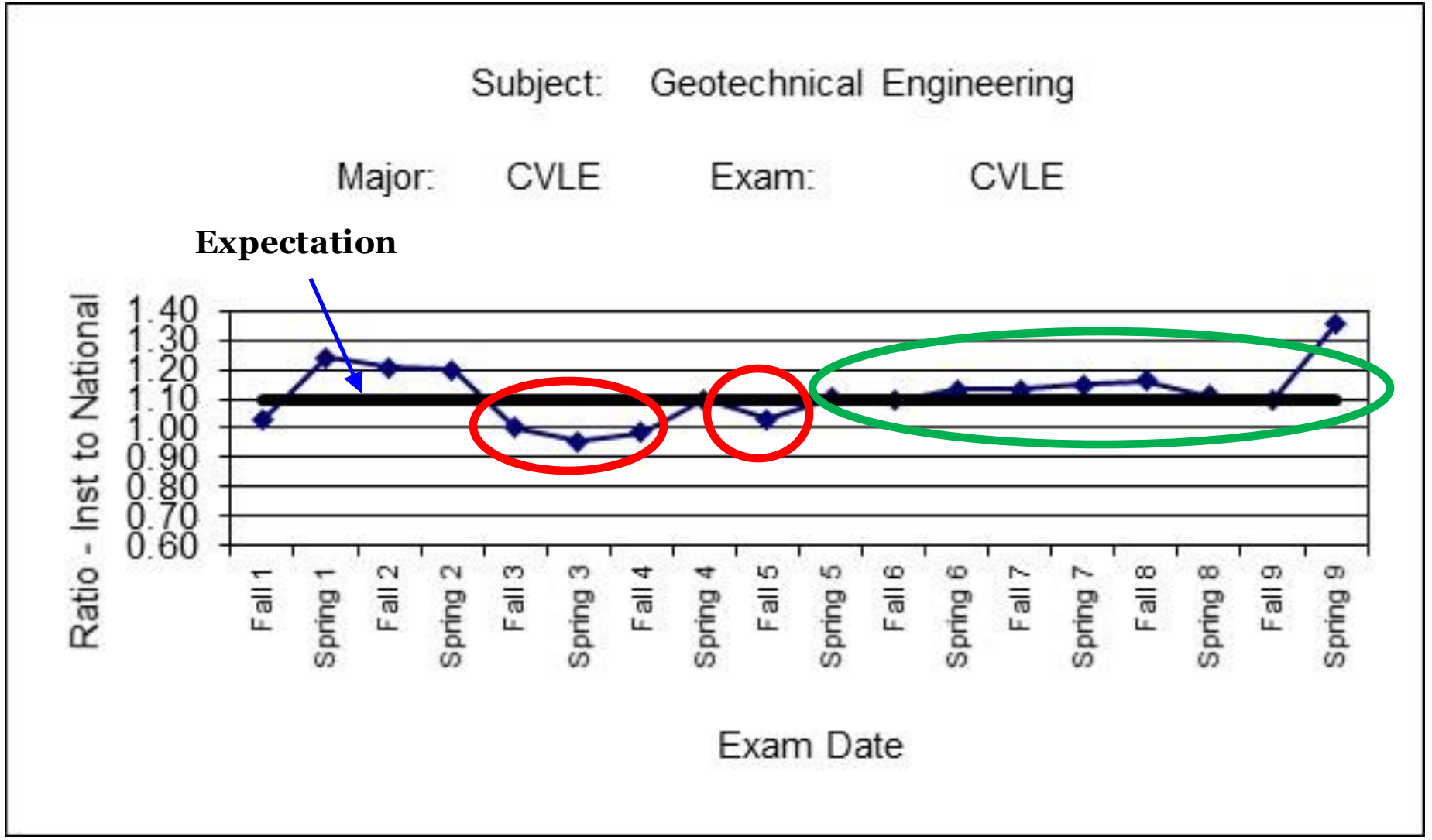
Ratio Method

- 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.

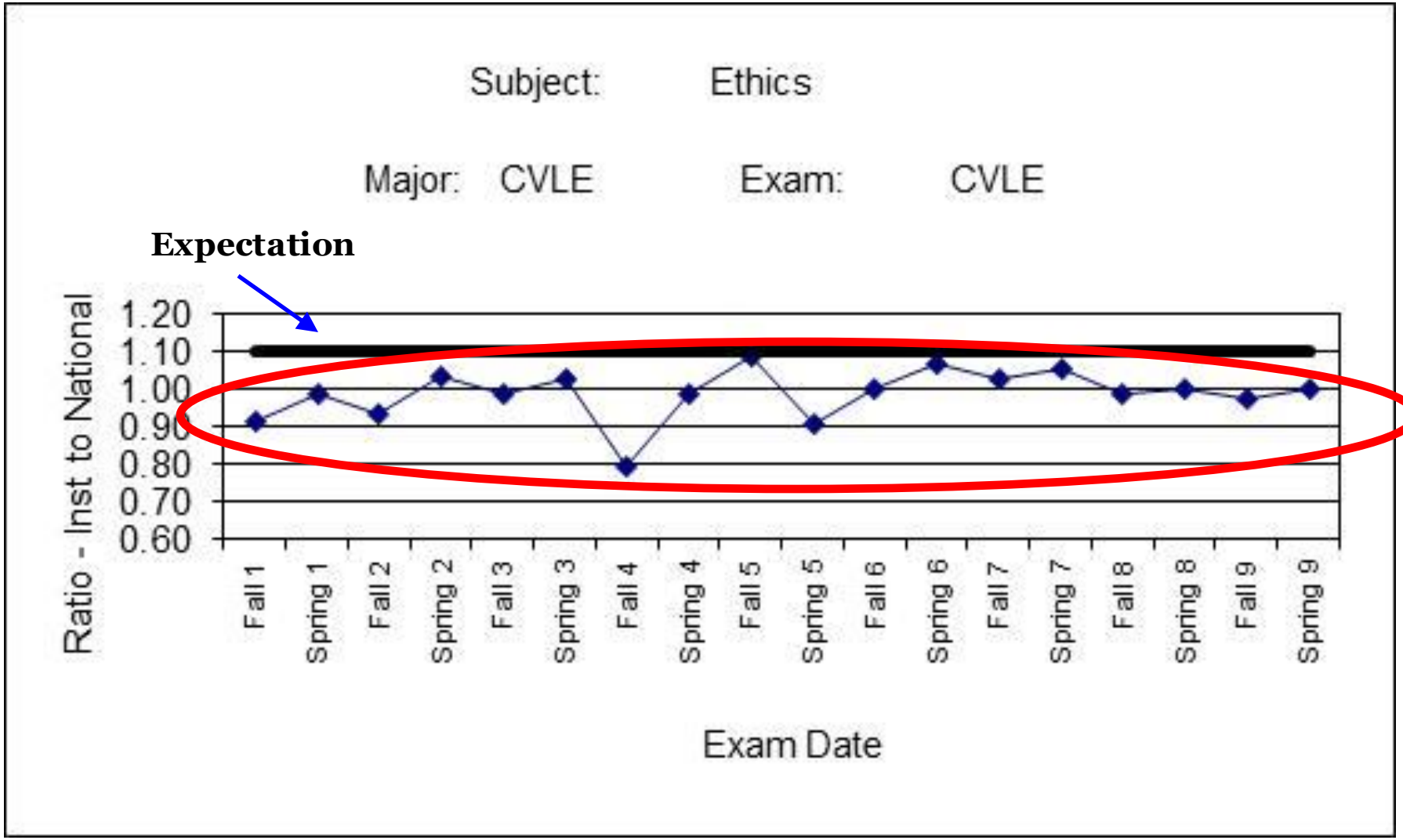
Comparison of Ratios by Subject Area



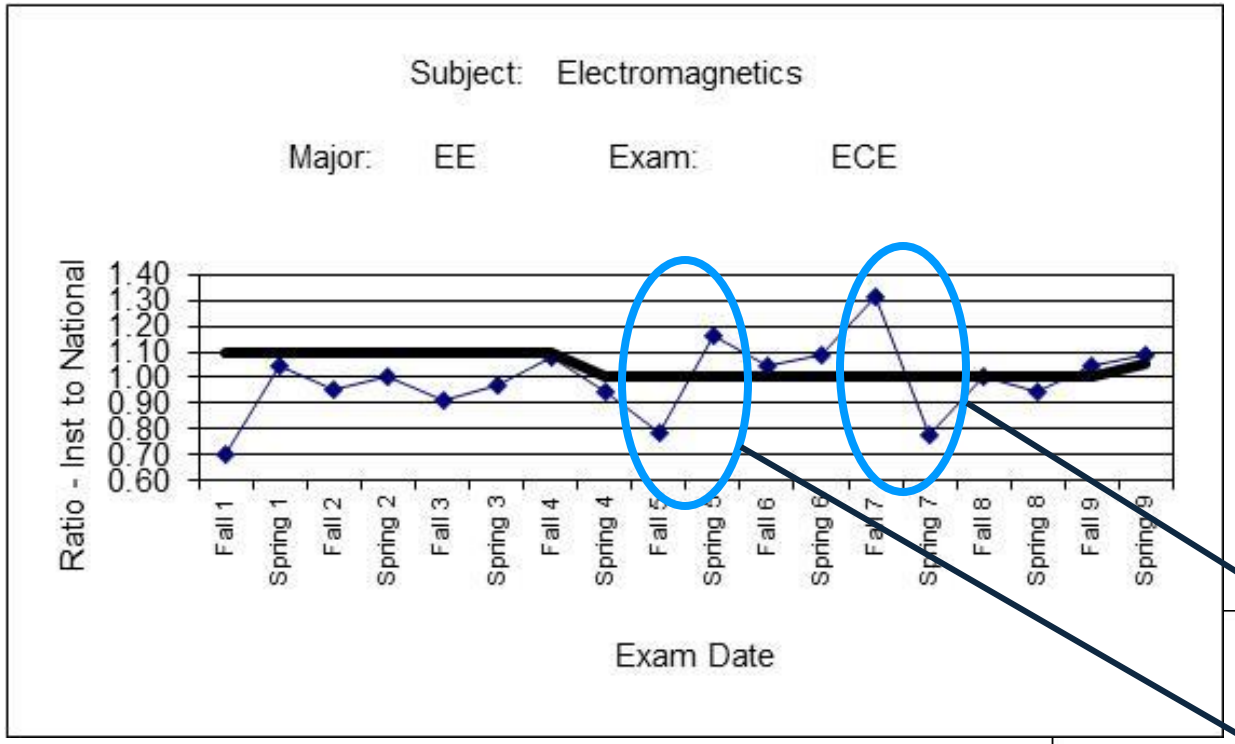
Comparison of Ratios by Subject Area

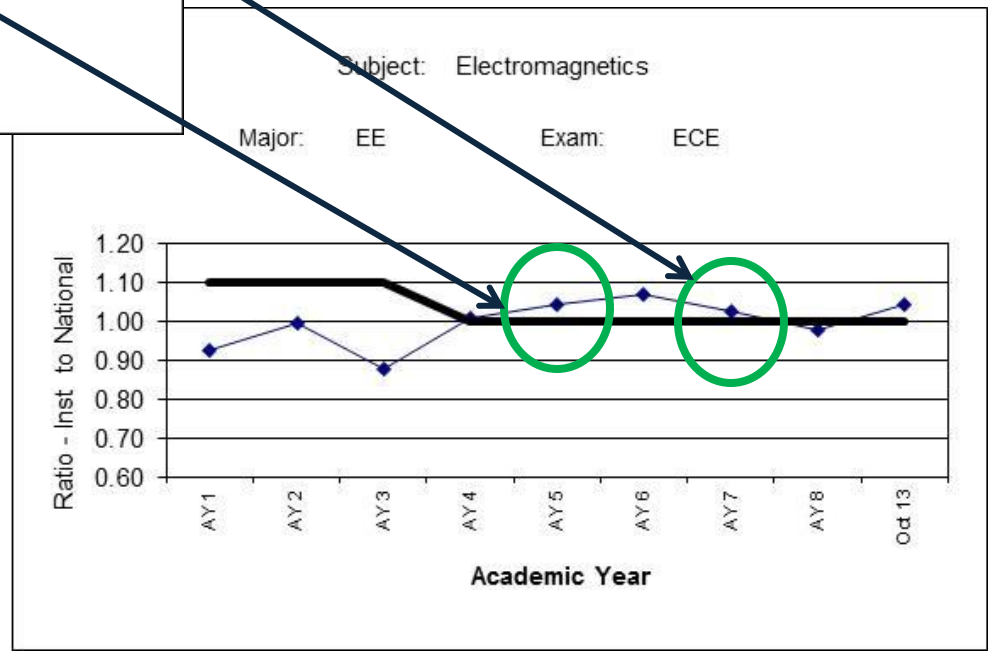


Comparison of Ratios by Subject Area



EFFECT OF ACADEMIC YEAR AVERAGING





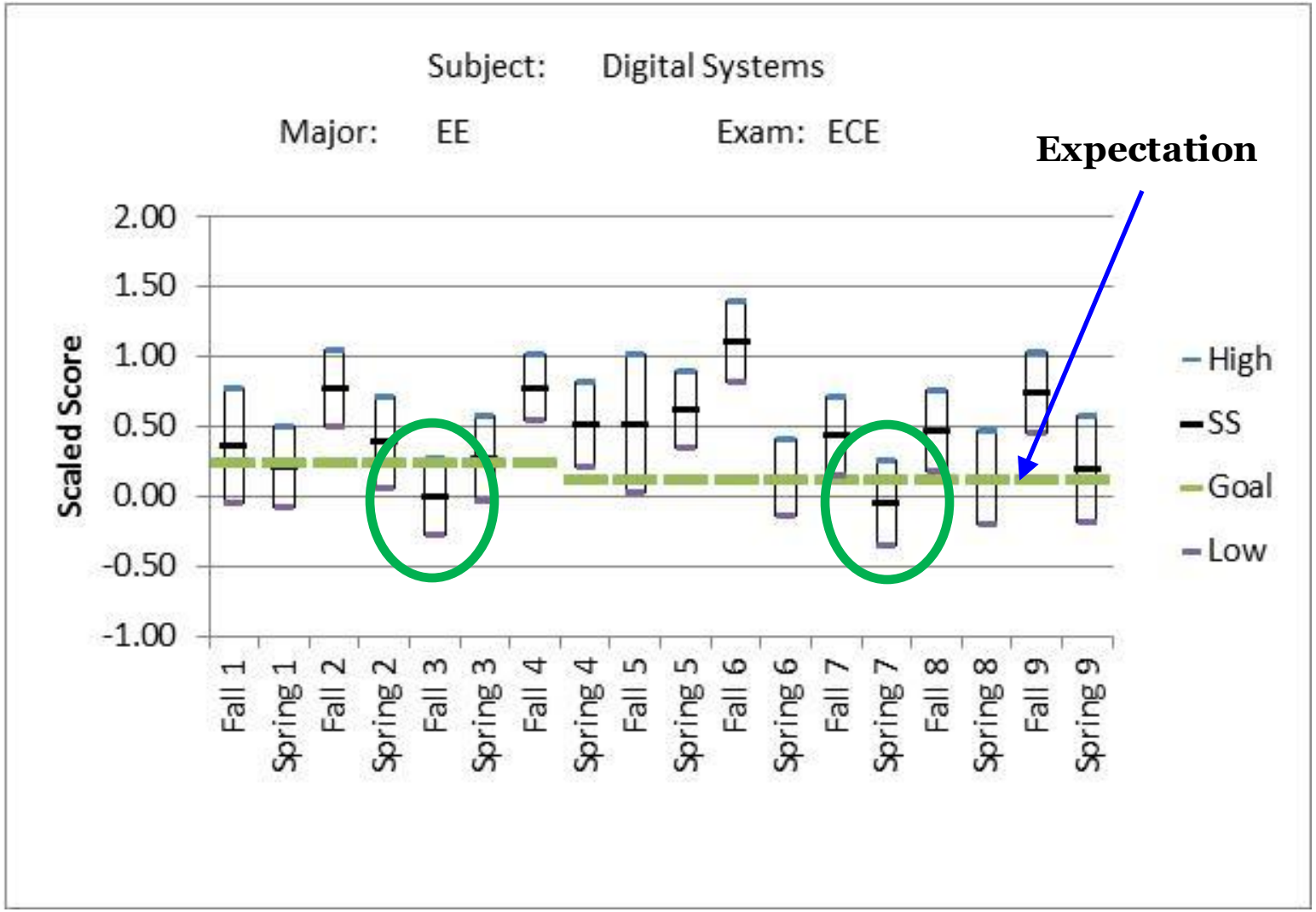
Causes a smoothing of the data—Note the fall/spring 5 and fall/spring 7 results compared to the academic year 5 and academic year 7 results.

Scaled Score Method

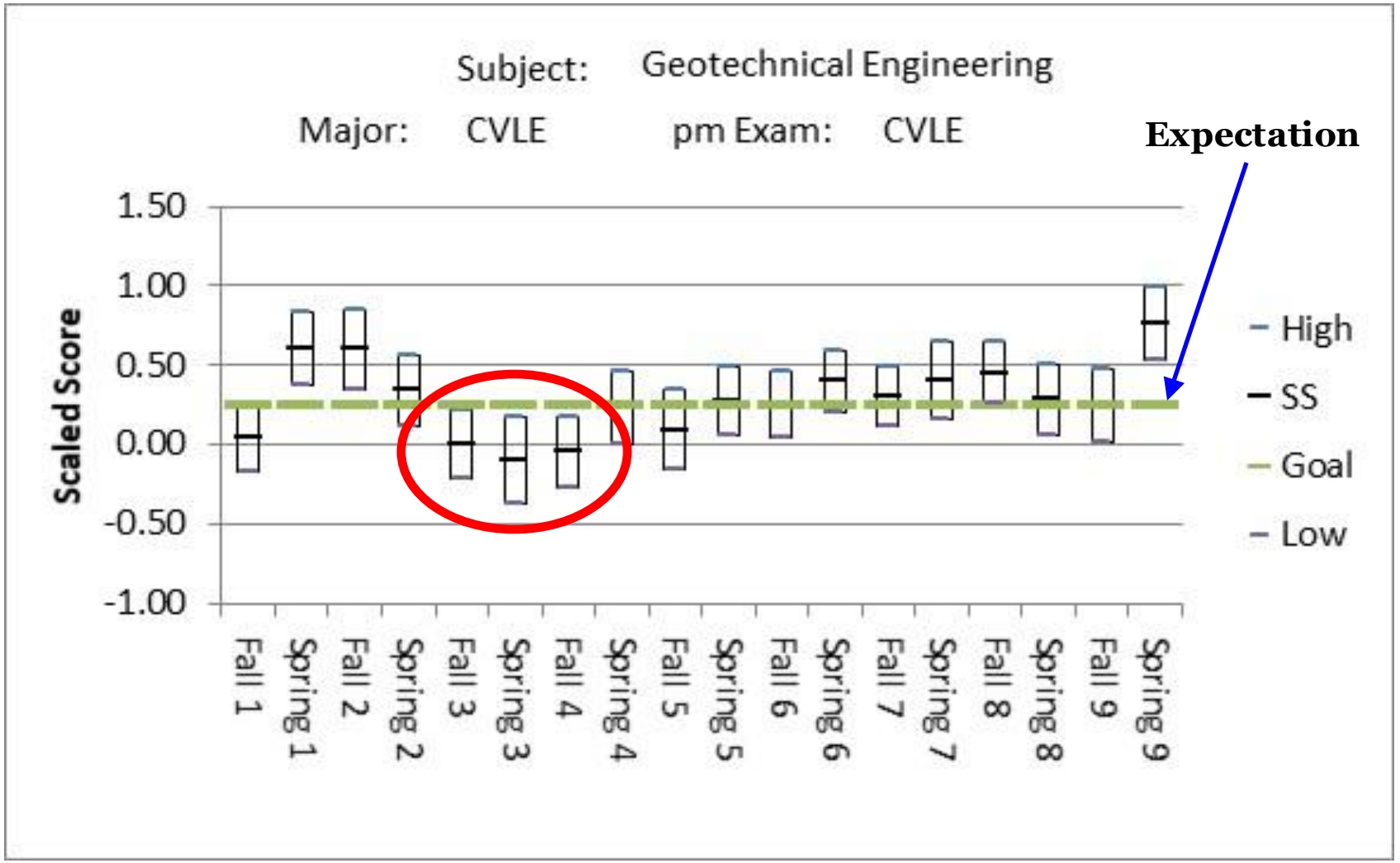
$$\text{S.S.} = \frac{\text{P.I. for Univ X} - \text{P.I. comparator}}{\text{P.I. comparator standard deviation}}$$

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

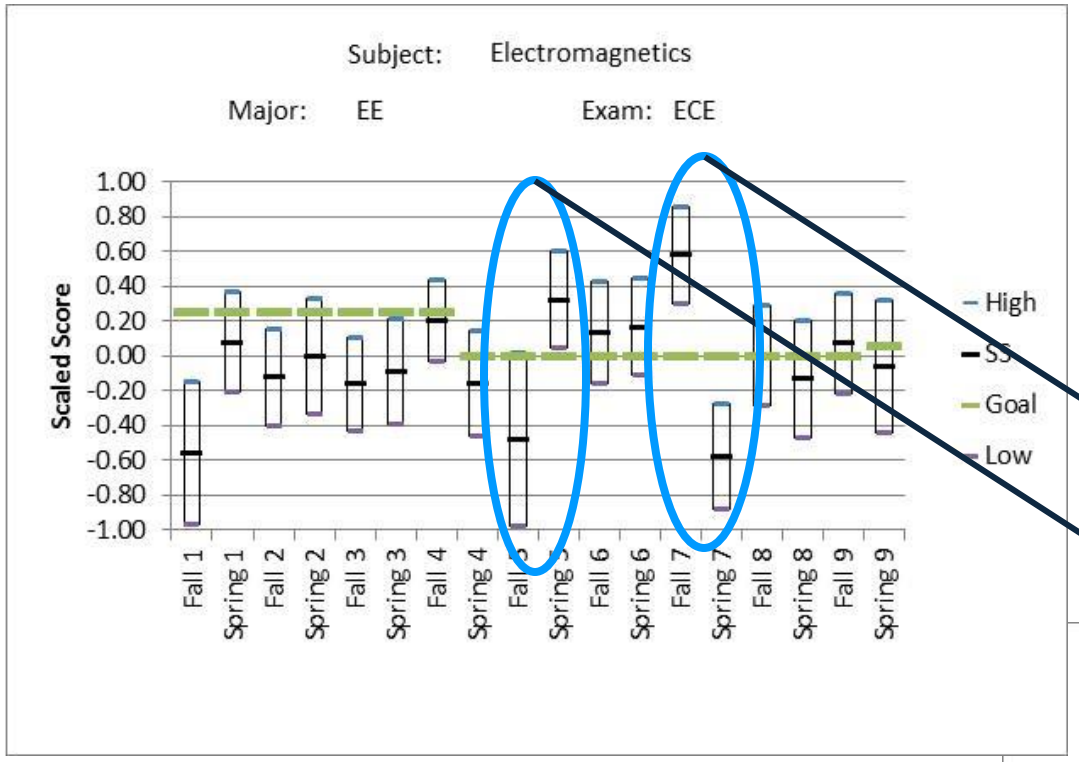
Comparison Using Scaled Score by Subject Area

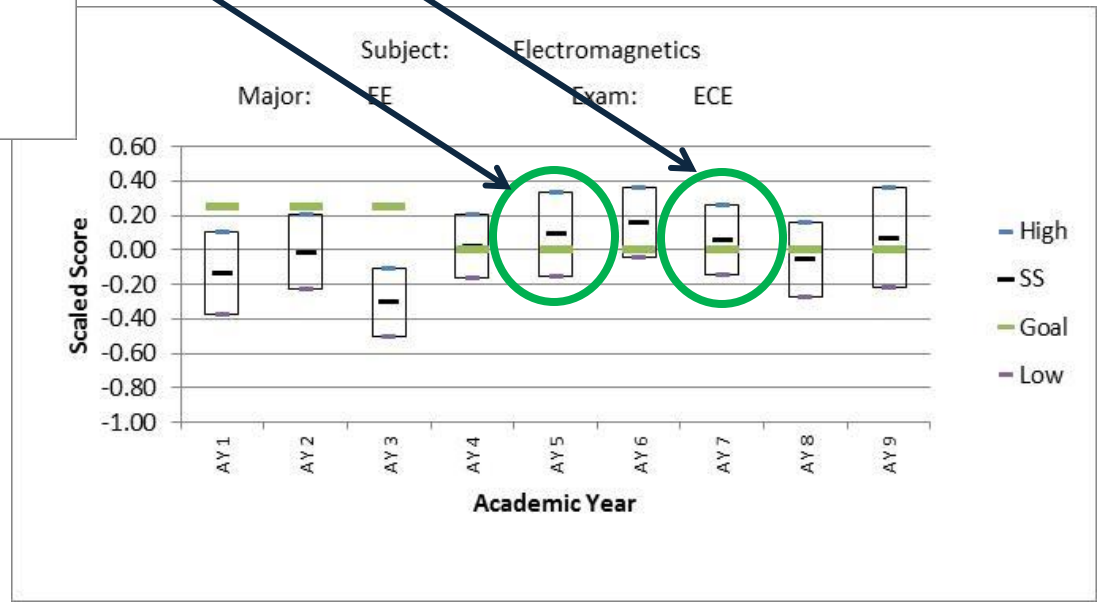


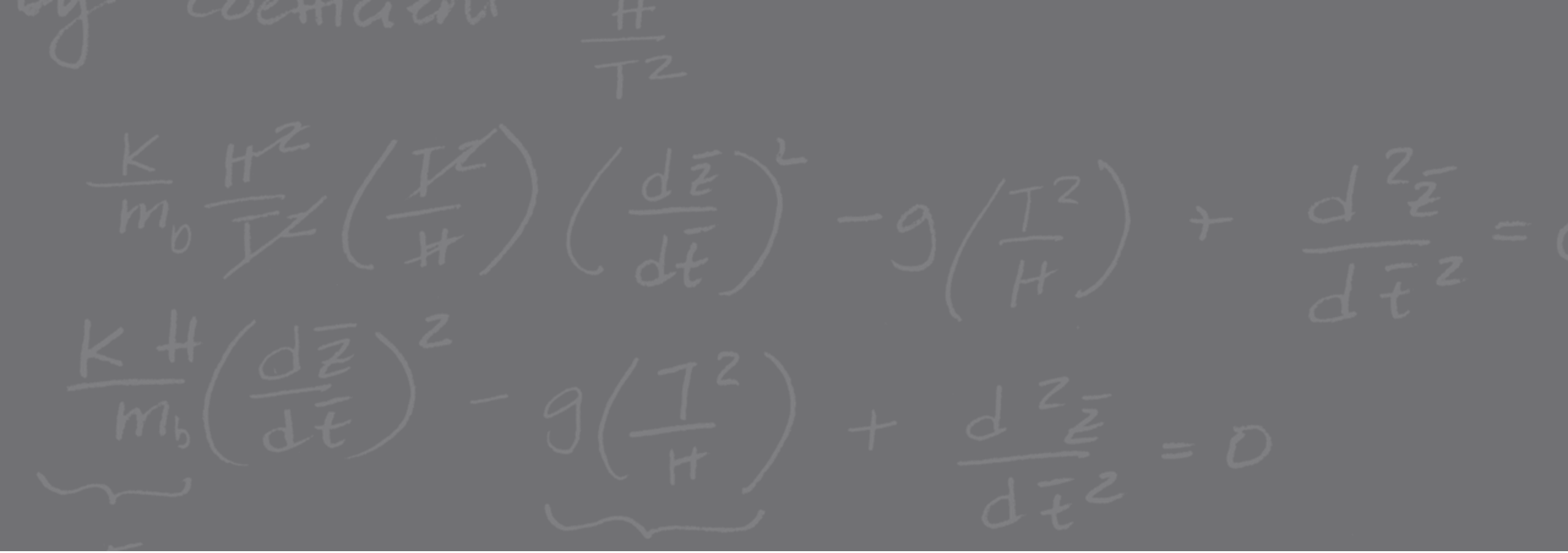
Comparison Using Scaled Score by Subject Area



ACADEMIC YEAR AVERAGING

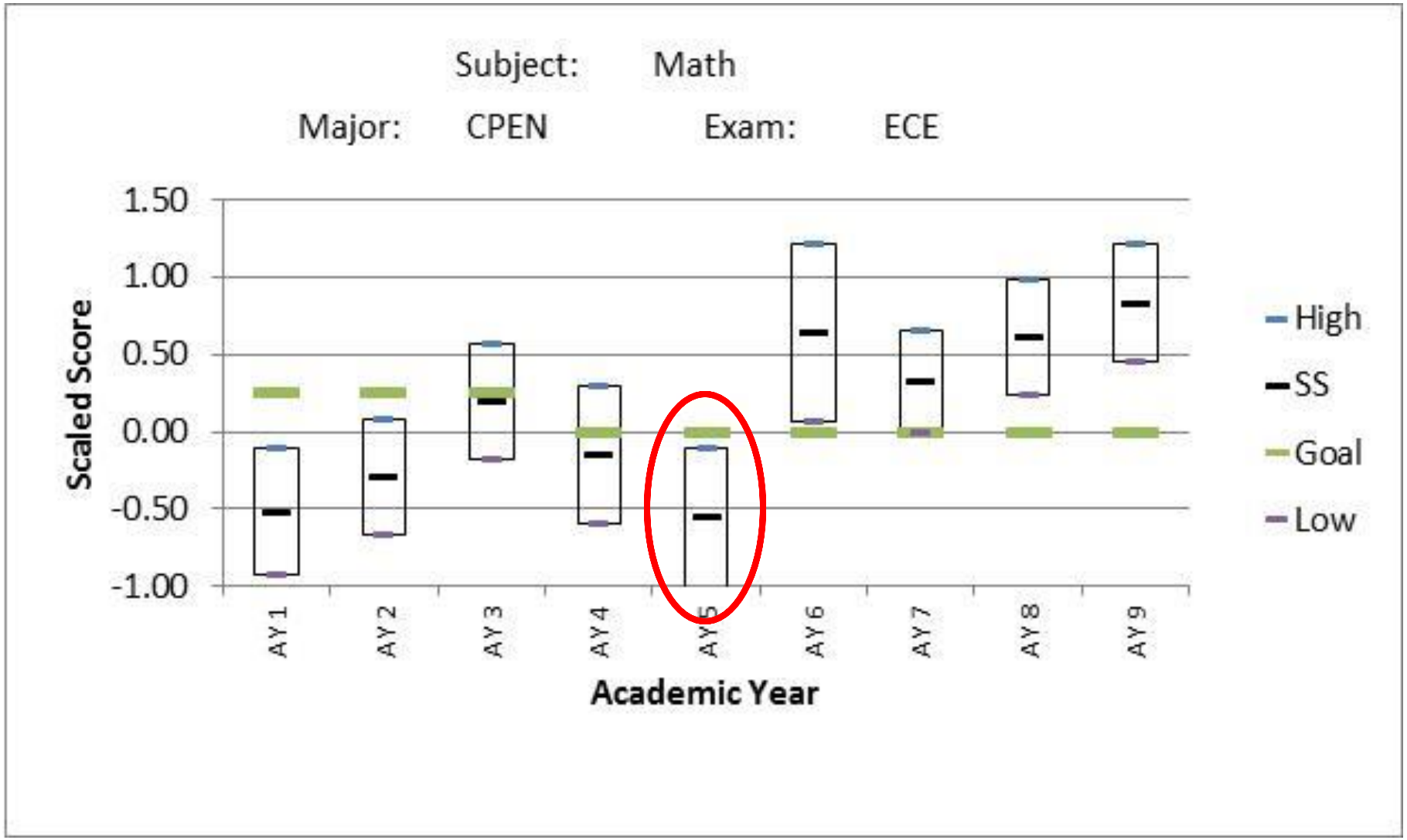




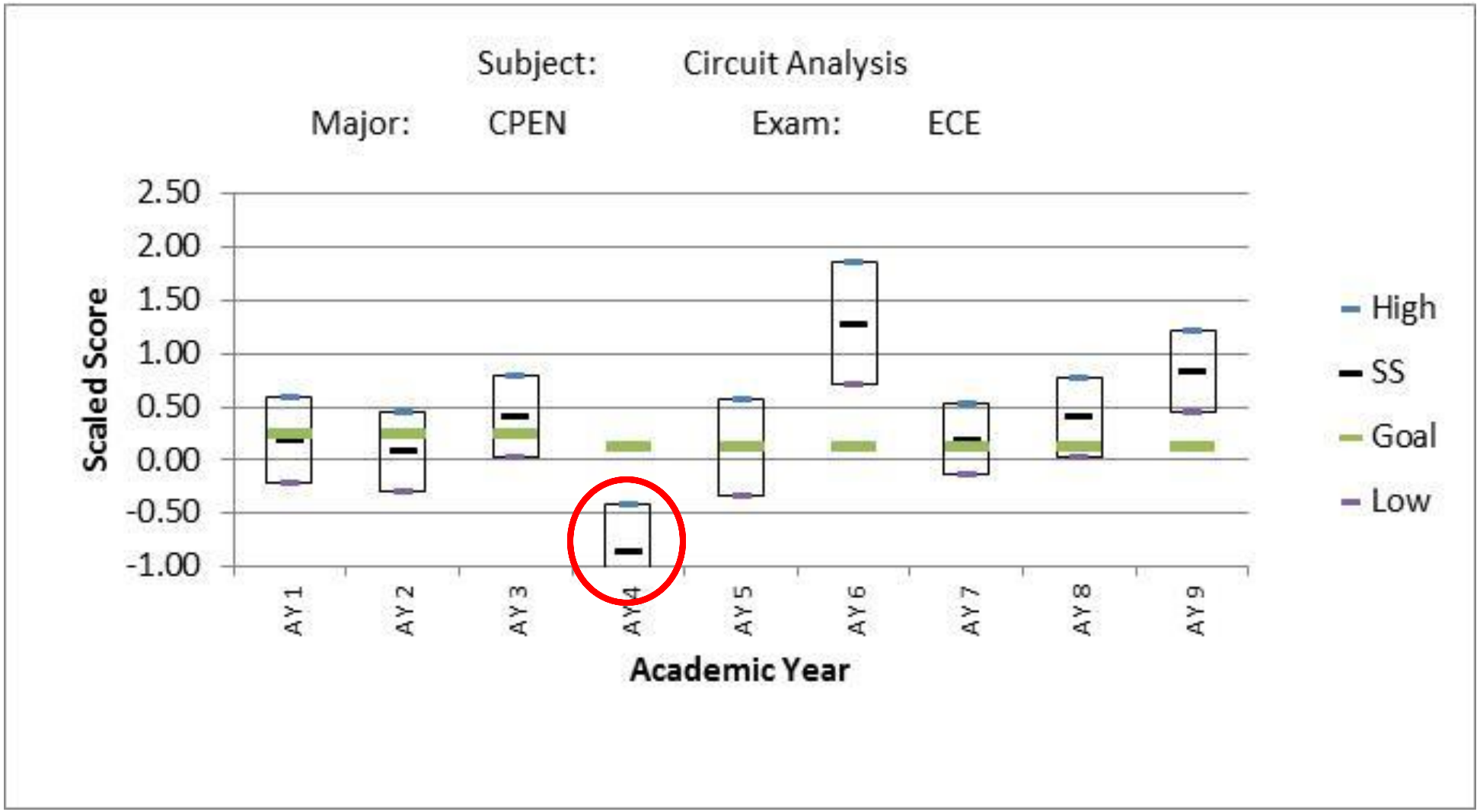


EXAMPLES OF ASSESSING SOME OF THE ABET (1)–(7) OUTCOMES

Outcome 1: Ability to Apply Math and Science



Outcome 1: Ability to Solve Engineering Problems



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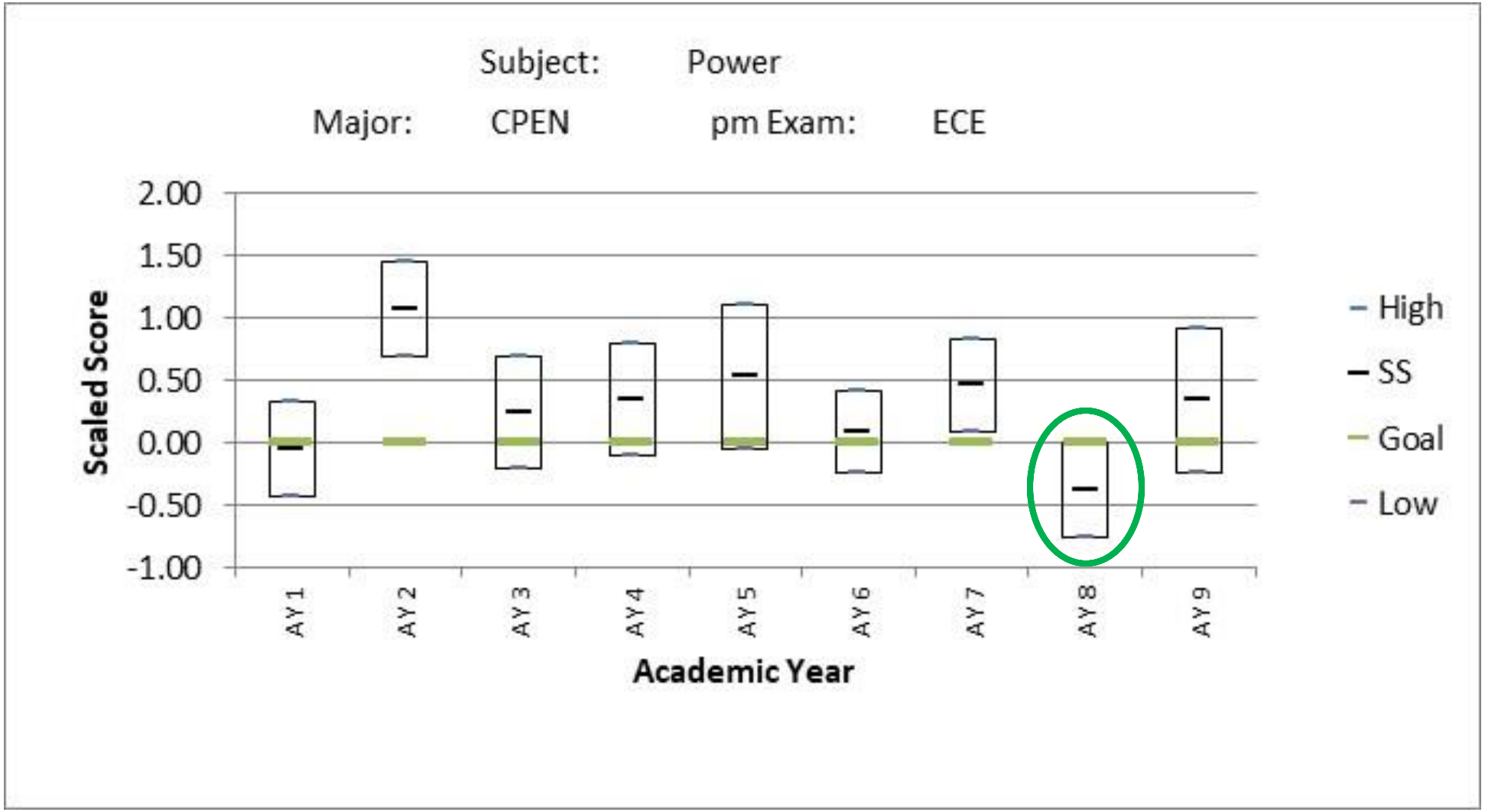
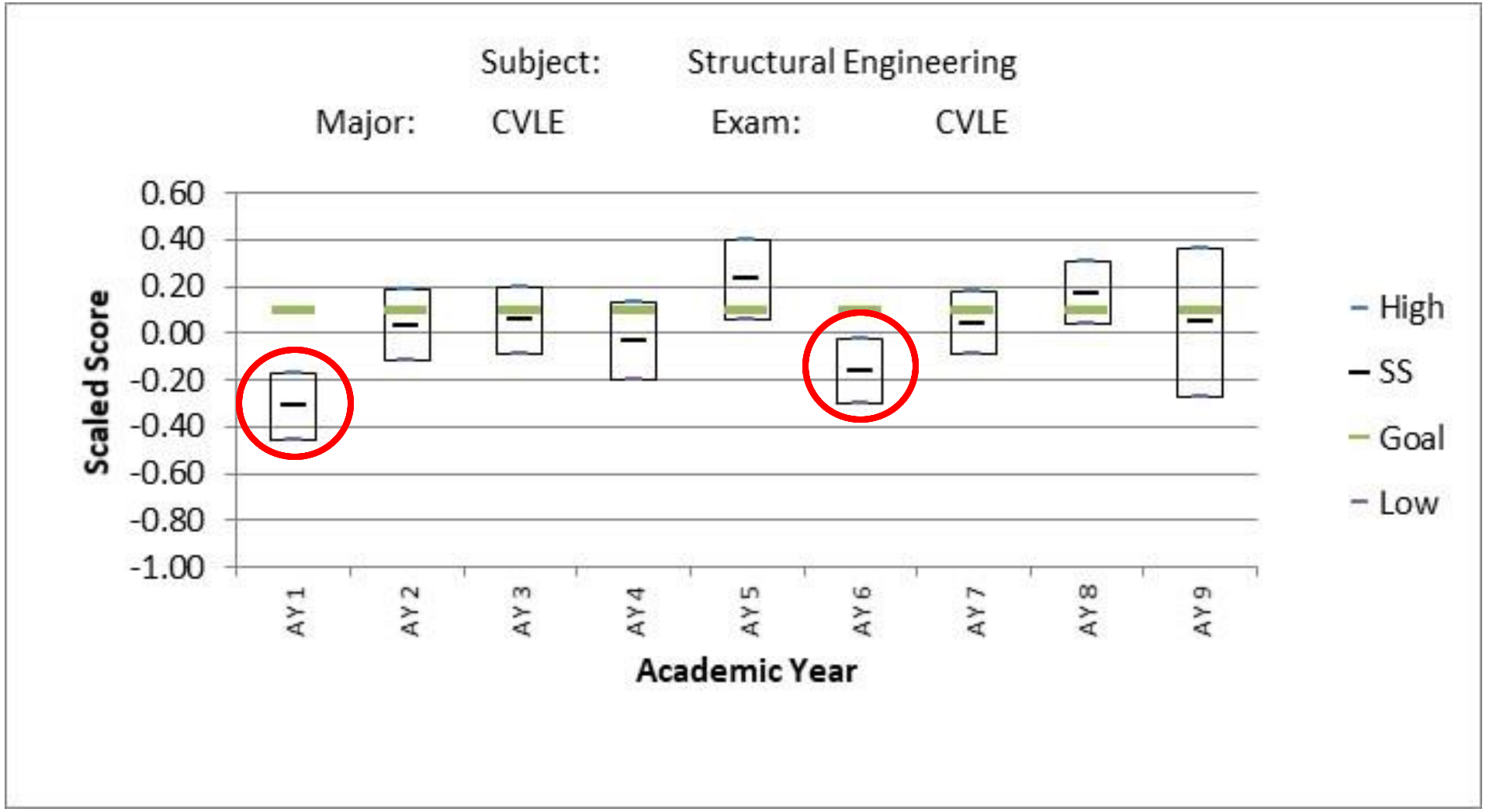
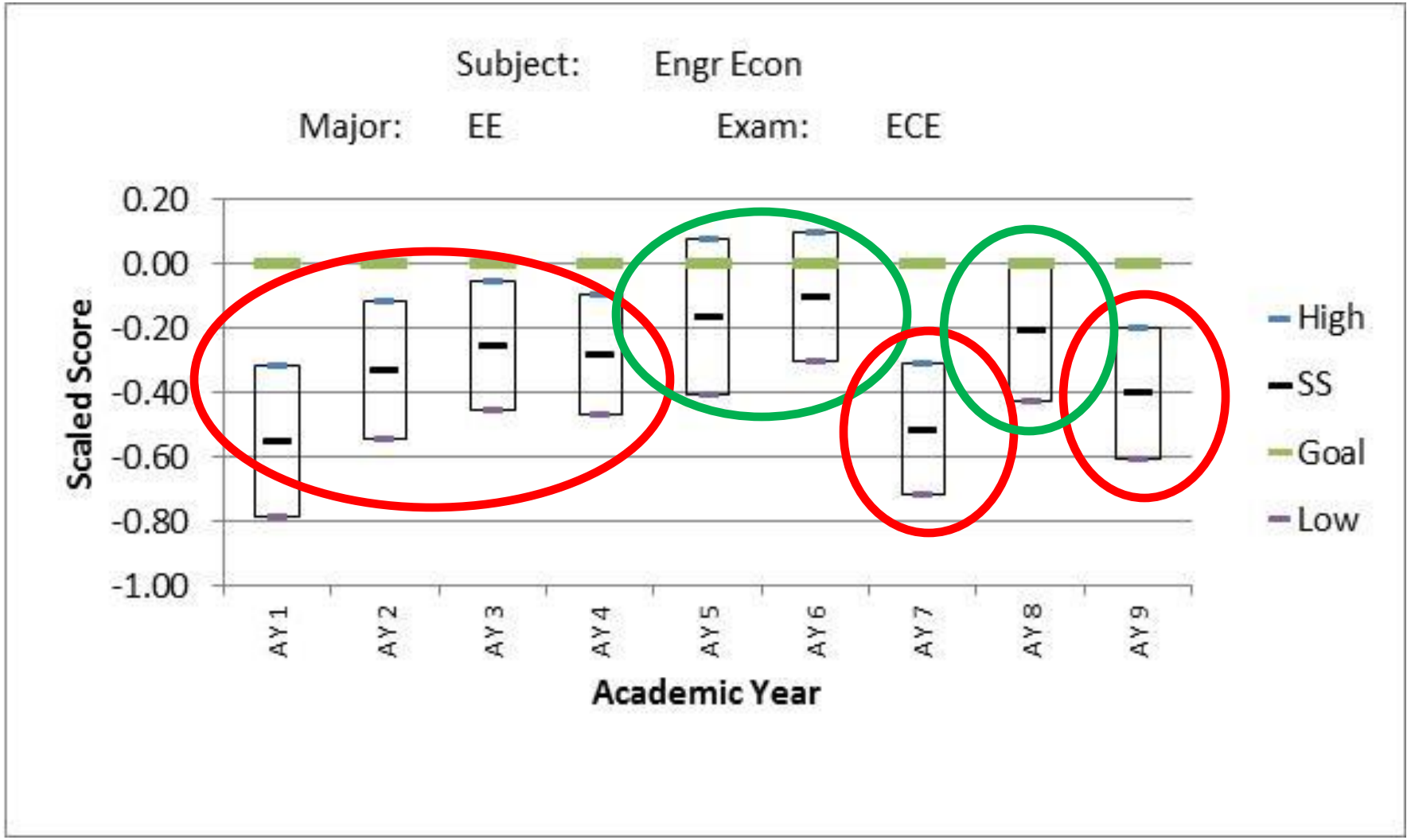


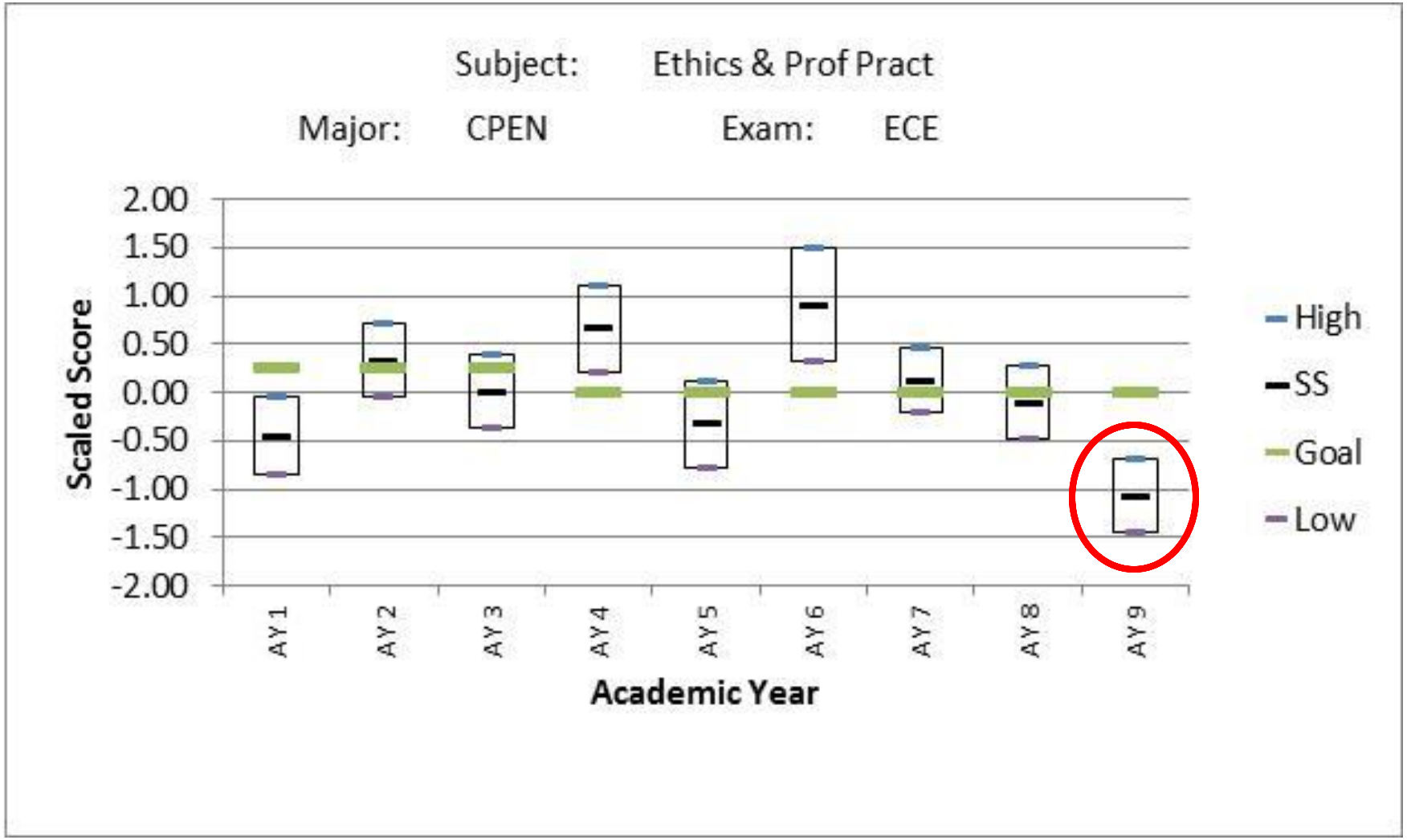
Outcome 2: Ability to Apply Engineering Design



Outcome 2: Ability to Apply Economic Factors in Design



Outcome 4: Ability to Recognize Ethical Responsibility



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 <u>one</u> 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
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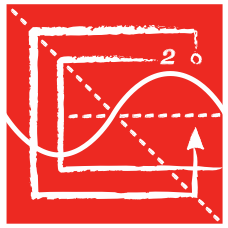
Questions?



NCEES

advancing licensure for engineers and surveyors