Preparing a Successful SSR

Assessment and Evaluation
of
Student Outcomes (SOs)
ABET Criterion 3

And

Making Continuous Improvement
ABET Criterion 4

Association of Thai Professionals in America and Canada

Criterion 3: Student Outcomes SOs

According to ABET SOs :

- Are narrow statements that describe what students are expected to know and be able to do by the time of graduation
- Relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the program

Student Outcomes SOs: 2017-2018

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.
d) An ability to function on multi-disciplinary teams.
e) An ability to identify, formulate, and solve engineering problems.
f) An understanding of professional and ethical responsibility.
g) An ability to communicate effectively.
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.
i) A recognition of the need for, and an ability to engage in life-long learning.
j) A knowledge of contemporary issues.
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Additional outcomes as deemed fit by the program faculty

Student Outcomes SOs: 2019-2020

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics (old *a* + *e*)
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 economic factors (old *c*)
3. an ability to communicate effectively with a range of audiences (old *g*)
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 (old *f* + *h*)
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 (old *d*)
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (old *b*)
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies (old *i* +*j*+*k*)

Additional outcomes as deemed fit by the program faculty

These are applicable to all engineering fields.

Compliance with Criterion 3 Student Outcomes: HOW?

First, Look at the Worksheet used by PEV to assess Compliance for Criterion 3

Checklist Item for Criterion 3 Student Outcomes	C, W, D, or None
Program has documented student outcomes that prepare graduates to attain the program educational objectives	
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 public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3. an ability to communicate effectively with a range of audiences	
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	
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	
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategiesbility to communicate effectively	

In assessing Compliance for Criterion 3:

PEV will:

- How well SOs match with PEOs
- Determine if the students have achieved all SOs 1-7. How this is demonstrated is up to the program. But, some factual assessment data and samples of student work demonstrating achievement of these outcomes will be needed.
- Be looking at the number of instruments included in the assessment of the SOs, and whether there are both direct and indirect measures (see below)
- Be paying close attention to the assessment and evaluation procedures used to demonstrate that the SOs are being achieved. So samples of the evaluated student work should be retained and made available during the site visit.

Assessment of SOs along with the subsequent CQI are the most critical aspect of the entire ABET review process, so strong attention must be paid to this phase of the self-study.

Mapping of PEOs to SOs
Example: Systems and Control Engineering, CWRU

Mapping of Student Outcomes to Program Objectives				
Student Outcomes:	**PEO 1:** Tackle Multidisciplinary problems using Systems Approach	**PEO 2:** Design engineering systems to meet societal needs using systems thinking and systems approach	**PEO 3:** Research on Systems and Control	PEO 4: Effective, ethical, and professional through good communication, leadership and teamwork
(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	✓	✓		
(d) an ability to function on multi-disciplinary teams	✓			✓
(e) an ability to identify, formulate, and solve engineering problems	✓	✓	✓	
(f) an understanding of professional and ethical responsibility				✓
(g) an ability to communicate effectively	✓			✓
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	✓	✓		✓
(i) a recognition of the need for, and an ability to engage in life-long learning	✓	✓	✓	
(j) a knowledge of contemporary issues	✓	✓	✓	
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	✓	✓	✓	✓

Criterion 4: Continuous Improvement

Continuous (Quality) Improvement involves:

- Developing and using appropriate documented processes for assessing and evaluating the extent to which the SOs are being attained
- Systematically utilizing SOs evaluation results as input for the continuous improvement of the program
- Use other relevant information available to assist in continuous improvement

This section should document:

- All processes for regularly assessing and evaluating the extent to which the student outcomes are being attained.
- The extent to which the student outcomes are being attained.
- Describe how the results of these processes are utilized to affect continuous improvement of the program.

Criterion 4: Continuous Improvement

Organization of the section:

Student Outcomes : List and/or describe

- The assessment processes used to gather the data upon which the evaluation of each student outcome is based a table may be used to present this information)
- The frequency with which these assessment processes are carried out
- The expected level of attainment for each of the student outcomes
- Summaries of the results of the evaluation process and an analysis illustrating the extent to which each of the student outcomes is being attained
- How the results are documented and maintained

Continuous Improvement: Describe

- How the results of evaluation processes for the student outcomes and any other available information have been systematically used as input in the continuous improvement of the program.
- The results of any changes (whether or not effective) in those cases where re-assessment of the results has been completed. Indicate any significant future program improvement plans based upon recent evaluations. Provide a brief rationale for each of these planned changes.

Additional Information: Copies of the assessment instruments or materials must be available for review at the time of the visit. Other information such as minutes from meetings where the assessment results were evaluated and where recommendations for action were made could be included.

Compliance with Criterion 4: Continuous Improvement

Checklist for Criterion 4: CONTINUOUS IMPROVEMENT	C, W, D, or none
Regular use of appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained	
Results of evaluations systematically utilized as input for the continuous improvement of the program	
Other information, if available, used to assist in continuous improvement	

Programs are expected to gather assessment data pertaining to the SOs, to evaluate that data, and then to make changes in the program based on that evaluation.

- Show clearly what improvements have been made to the curriculum and supporting resources. Feedback from students, alumni, and faculty will be useful in satisfying criterion
- Highlight new courses, laboratories, and other facilities to demonstrate that criterion 4 is being met.
- It is important to show that some improvement is being regularly made, no matter how good the faculty find their current program to be.

Criterion 4: Continuous Improvement

1. **Choose instruments to assess each SO**
2. Develop an appropriate evaluation scheme to interpret the data collected and convert it to actionable guideline for CQI
3. Develop a schedule to collect data to ensure there is at least one cycle of CQI within the ABET cycle

Assessment of SOs

Choosing instruments to assess each SO

1. **At least 3 instruments for each outcome.**
2. **Mix of direct + indirect instruments (2+1 or 1+2 etc.)**
3. Optimize your efforts and resources: No need to do more than you need to do (e.g. use three instruments as long as they have the right mix). But do what you have to do very well (see how to write a successful SSR later)

Possible Instruments for Measuring SOs

Method	Direct	Indirect
Oral Exit Interviews of Graduating Seniors		√
Embedded Test Questions Pertaining to Specific Outcomes	√	
Faculty Evaluation of Student Portfolios Pertaining to Outcomes	√	
Senior Exit Outcomes Surveys		√
Student Outcomes Focus Groups		√
Classroom Observations of Student Performance by Faculty	√	
Evaluation of Student Course Work by Faculty Committee	√	
Compiled Results from FE Exam	√	
Employer Surveys of Student Performance During Co-op or Internship Cycles		√
Starting Salary, FE Exam Rates, Graduate School Attendance, and Other Senior Exit Data		√
External Advisory Committee (EAC) Student Outcomes Surveys		√

How to choose core courses as direct instruments and how to perform SOs assessment and use the results to do CQI

I. First map each core course to each SO either by using CLOs or by using Performance Indicators (See examples in the Appendix)

II. From the above Core courses-SO map, select 1-3 most suitable core courses to serve as direct instruments for each SO.

III. For each SO,
   - Select one (preferred) or two (max) EMBEDDED question(s) that is/are most appropriate to be used to DIRECTLY measure attainment of the SO in question
   - Develop a schedule to collect at least three rounds of raw scores pertaining to the embedded question and only the embedded question (and not the raw score of the entire exam or assignment). Collect the scores of only students in the program (and not students from other degree programs)

IV. Use the raw scores from the embedded questions above along with data collected for the respective indirect instruments, perform a complete assessment and evaluation to assess the attainment of each SO (to be demonstrated shortly.

V. Finally, from the results of the SO assessment and evaluation above, identify areas for CQI and describe actions to be taken to make continuous improvement

The following are some examples illustrating the process above.

Example Mapping of SOs to Core Courses

Systems and Control Program Required ENGR and EECS Courses

(20xx-20yy) Assessment Cycle, F=Fall, S=Spring)

Program Outcomes	ENGR 131	ENGR 145	ENGR 200	ENGR 210	ENGR 225	GL/ENGR 3	EECS 246	EECS 281	ECS 304/30	EECS 313	EECS 324	EECS 342
(a) Ability to apply knowledge of math, engineering, and science	F/S	F/S	F/S	F/S	F/S		F	F	S	S	F	F
(b) Ability to design and conduct experiments, as well as to analyze and interpret data			F/S	F/S	F/S			F	S	S	F	F
(c) Ability to design system, component or process to meet needs	F/S	F/S	F/S		F/S	F/S	F	F	S		F	F
(d) Ability to function on multi-disciplinary teams				F/S		F/S			S		F	F
(e) Ability to identify, formulate, and solve engineering problem	F/S		F/S	F/S	F/S	F/S	F	F	S	S	F	F
(f) Understanding of professional and ethical responsibility									S			F
(g) Ability to communicate effectively						F/S		F	S		F	F
(h) Broad education		F/S				F/S			S			F
(i) Recognition of need an ability to engage in life-long learning									S		F	F
(j) Knowledge of contemporary issues		F/S			F/S	F/S	F		S		F	F
(k) Ability to use techniques, skills, and tools in engineering practice		F/S	F/S	F/S	F/S		F	F	S	S	F	F

This mapping can be done using CLOs of the core courses by the ABET team in consultation with the main instructor(s) of the courses or by using the suggested performance indicators as illustrated in the appendix.

Roadmap for SO Measurements SC Program

Measurement of Student Outcomes				
Student Outcomes	**Embedded test questions, homework, lab assignments (D)**	**Senior project presentation evaluation by program faculty (D)**	**CO-OP Employer Survey (I)**	**Student Exit Survey (I)**
(a) an ability to apply knowledge of mathematics, science, and engineering	EECS 304, EECS 346		✓	✓
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	EECS 305	✓	✓	✓
(c) an ability to design a system, component, or process to meet desired needs within multiple realistic constraints and engineering standards	EECS305, EECS 313, EECS 398	✓	✓	✓
(d) an ability to function on multi-disciplinary teams	ENGL 398	✓	✓	✓
(e) an ability to identify, formulate, and solve engineering problems	EECS 346	✓	✓	✓
(f) an understanding of professional and ethical responsibility	ENGR 398	✓	✓	✓
(g) an ability to communicate effectively	EECS 346, ENGL 398	✓	✓	✓
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	ENGR 398	✓	✓	✓
(i) a recognition of the need for, and an ability to engage in life-long learning	ENGL 398		✓	✓
(j) a knowledge of contemporary issues	ENGR 398		✓	✓
(k) an ability to use the techniques, skills, and modern engineering tools	EECS 346 EECS 398	✓	✓	✓

Choosing Embedded Questions from CWRU SC Core Courses Selected for Each SO

StudentWork	Course	SO
Exam problem on applying stochastic simulation to logistic problems involving uncertainties	EECS 324	a
Exam problem adressing Laplace Transform properties	EECS 304	a
Exam problem on the aplication of Kuhn-Tucker conditions	EECS 346	a
Liquid Level Modeling Laboratory report	EECS 305	b
FIR filter Design Lab	EECS 313	c
System Design Component in the Final Report	EECS 398	c
PID Analog Controller Design Lab	EECS 305	c
Teaming Component in the Final Report	EECS 398	d
Technical Component in a Logistic Network Optimization Case Study	EECS 346	e
Written Ethics Assignment Report	EECS 398	f
Writing Component and the Oral Presentation Component in a Case Study	EECS 346	g
Writing Component and the Oral Presentation Component in the Final Report	EECS 398	g
Final Report	EECS 398	h
Final Report	EECS 398	i
Final Report	EECS 398	j
Final Report	EECS 398	k
Optimization Case Study	EECS 346	k

Examples Embedded Questions for Measuring SOs

Outcome a: Ability to apply mathematics, science and engineering principles

From EECS324:

1) There were questions in the mid-term, the final and the case studies on modeling of stochastic systems and dynamic systems using principles from engineering, science and mathematics. For example:
   - Modeling of snow plow/salt trucks operations (stochastic) in the mid-term
   - Modeling of "cat-and-mouse", "foxes-and-rabbits", and "water-in-the-gutter" (all dynamic systems) using engineering principles in the final.
   - Modeling of a Surge Tank in a hydro-electricity generation system (dynamic system) using science and engineering principles in the second case study
2. In questions on simulation of stochastic systems in the mid-term, abilities to use probability and statistics to generate random variates, model random input, and analyze random output were tested
3. In questions on simulation of dynamic systems in the final and the second case study, ability to select and use numerical integration was tested.

Data Collection Plan from 2016-2018

Frequency of SO Measurements	
Measurements	Frequency
Student Exit Survey	Every spring
CO-OP Supervisor Survey	Roughly every January
Senior project presentations (EECS 398)	Every semester
EECS 304/305	Every spring semester 20
EECS 313	Every spring semester
EECS 324	Every fall semester
EECS 346	Every fall semester
ENGL 398	Every semester

Another Example: Instruments used by CWRU EE

Measurement of Student Outcomes				
Student Outcomes	**Embedded test questions, homework, lab assignments (D)**	**Senior project presentation evaluation by program faculty (D)**	**CO-OP Employer Survey (I)**	**Student Exit Survey (I)**
(a) an ability to apply knowledge of mathematics, science, and engineering	EECS 246 EECS 321		√	√
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	EECS 281 EECS 245	√	√	√
(c) an ability to design a system, component, or process to meet desired needs within multiple realistic constraints and engineering standards		√	√	√
(d) an ability to function on multi-disciplinary teams	ENGL 398	√	√	√
(e) an ability to identify, formulate, and solve engineering problems	EECS 246	√	√	√
(f) an understanding of professional and ethical responsibility	ENGR 398	√	√	√
(g) an ability to communicate effectively	ENGL 398	√	√	√
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	ENGR 398	√	√	√
(i) a recognition of the need for, and an ability to engage in life-long learning	ENGL 398		√	√
(j) a knowledge of contemporary issues	ENGR 398		√	√
(k) an ability to use the techniques, skills, and modern engineering tools	EECS 309 EECS 321	√	√	√

Example of SO Assessment

Data Collection Schedule from (2009-2015)

Frequency of SO Measurements (2009-2015)	
Measurements	Frequency
Student Exit Survey	Every spring
CO-OP Supervisor Survey	Roughly every January
Senior project presentations (EECS 398)	Every semester
EECS 246	Every fall semester
EECS 309	Every spring semester
EECS 321	Every spring semester
EECS 245	Every spring semester
EECS 281	Every semester

The following slides demonstrate one way of using data collected to perform assessment and evaluation of each SO.

(a) An ability to apply knowledge of mathematics, science and engineering

EECS 246 Question #4 from final exam (Direct)

The following differential equation defines a causal continuous-time system

$$\frac{d^2y(t)}{dt^2}+2\frac{dy(t)}{dt}+5y(t)=f(t)$$

Calculate the impulse response of this system.

- Fall 2015 11.7/15 = 78% n=28, five students with a score of 15
- Fall 2014 9.4/15 = 63% n=23, one student with a score of 15
- Fall 2013 10.8/15 = 72% n=19, three students with a score of 15
- Fall 2012 9.8/15 = 65% n=29, five students with a score of 15
- Fall 2011 12.0/15 = 80% n=25, nine students with a score of 15

Average score:
[(28)78% + (23)63% + (19)72% + (29)65% + (25)80%]/124
= **72%**

EECS 321 homework problem (Direct)

An electron is described by a plane-wave wave function $\psi(x,t)=Ae^{j10x+3y-4t}$. Calculate the expectation value of a function defined as $\{4p_x^2+2p_z^3+7E/m\}$, where m is the mass of the electron, p_x and p_z are the x and z components of momentum, and E is energy. Please give values in terms of the Planck constant.

- Spring 2013 37.7/40 n=43, 24 students with a score of 40

Average score:
= **94%**

WE NEED SPRING 2014, SPRING 2015, SPRING 2016 DATA

(a) An ability to apply knowledge of mathematics, science and engineering

CO-OP Employer Survey (Indirect).

- Fall 2014 4.00/5, n=6
- Fall 2013 No surveys returned.
- Fall 2012 4.17/5, n=6 with data taken in spring 2013
- 2011 4.67/5
- 2010 4.50/5
- 2009 4.43/5

Average score: Assume 6 returns in 2011, 2010, and 2009
(80% + 83.4% + 93.4% + 90% + 88.6%)/5 = **87%**

Senior Survey (Indirect).

- 2015 (S) 2.67/5, n=2
- 2014 2.75/5, n=17
- 2013 3.2/5, n=5
- 2012 4.20/5 n=5
- 2011 4.00/5, n=8
- 2010 4.45/5, n=11
- 2009 4.20/5, n=9

Average score:
[(2)53.4% + (17)55% + (5)64% + (5)84% + (8)80% + (11)89% + (9)84%]/62
= **67%**

Final Evaluation of SO (a) and CQI

Faculty-established rules:

- Direct instruments are deemed more accurate than indirect: So the total weights for direct instruments will be 70% as opposed to 30% for "indirect"
- Of the two direct instruments, EECS 246 has 5 sample points as opposed to 1 for EECS 321. So the weight of 50% will be assigned to EECS 246 and 20% to EECS 321
- Equal weight of 15% will be assigned to each of the two indirect instruments.
- A threshold of 70% will be used to judge whether the SO is achieved

Instrument	Score	Weight
EECS 246 (D)	72%	0.50
EECS 321 (D)	94%	0.20
Co-op Empl_ers (I)	87%	0.15
Snr Exit surveys (I)	67%	0.15

Weighted Average Total Score: **78%**

The final verdict:

The average total score of 78% MARGINALLY surpasses the faculty-established threshold of 70% indicating that the curriculum has achieved Student Outcome (a), but only marginally. There are obviously rooms for improvement.

Continuous Improvement:

A quick glance at the scores of individual instruments reveals that Senior exit survey (I) and EECS 246 (D) attained the two lowest scores which adversely impact the average total score. This indicates that most students in those graduating classes did not have confidence in applying mathematics and science to solve engineering problems. A closer examination of the individual raw scores in those EECS 246 classes confirms the above finding—many students have difficulty understanding the abstract concepts characterizing the behaviors of dynamic systems represented by a set of ODEs.

The program faculty proposes the following actions as possible remedies:

1) Reshape the course to be experiential problem-centric instead of concepts-centric;
2) Introduce much more MATLAB-based assignments and projects to help students "see" abstract concepts and to have hands-on experience how such concepts play out in the real world
3) Conduct special recitation sessions on differential equations and linear algebra

(b) An ability to design and conduct experiments, as well as analyze and interpret data

EECS 245 Lab #5: BJT transistor and amplifier characteristics (D)

Students must measure the DC characteristics of a BJT and then design and characterize the DC and AC characteristics of a single transistor amplifier using this BJT . Students measure I_C vs. I_B, V_{CE} vs. I_B for the transistor and DC and AC gain for the amplifier. The measured performance is compared to the calculated performance.

- Spring 2015 44.5/50 = 89% (n=24, individual program assessment)
- Spring 2014 42.5/50 = 85% (n=18, individual program assessment)
- Spring 2013 41.7/50 = 83.4% (n=26, individual program assessment)
- Spring 2007 43.0/50 = 86% (n=37, individual program assessment)

Average score:
[(24)89% + (18)85% + (26)83.4% + (37)86% = **86%**

(b) An ability to design and conduct experiments, as well as analyze and interpret data

EECS 398 Evaluated during final presentation using rubric (a) (D)

- Fall 2015 4.29/5 (n=28, individual program assessment
- Fall 2014 3.93/5 (n=18, individual program assessment)
- Spring 2014 4.78/5 (n=7, individual program assessment)
- Fall 2013 4.08/5 (n=28, individual program assessment)
- Spring 2013 4.33/5 (n=4, individual program assessment)
- Fall 2012 3.64/5 (n = 21, individual program assessment)
- Fall 2011 4.67/5 (n = 25, individual program assessment)
- 2010 = (was not evaluated in 2010)
- Fall 2009 4.40/5 (n = 24, individual program assessment)

Average score:
[(28)86%+(18)79%+(7)96%+(28)82%+(4)87%+(21)73%+(25)93.4%+(24)88%]/155
= **85%**

EECS 281 homework problem (D)

Design a state machine to implement the guessing game [See Section 7.7.1 of Wakerly, *Digital Design*, 4th Edition].

Spring 2015	60.8/100	n=21, five students with a score of 100
Fall 2014	56.9/100	n=8, no students with perfect score
Spring 2014	60.8/100	n=7, two students with a score of 100
Fall 2013	88/100	n=5, four students with a score of 100
Spring 2013	79.3/100	n=3, no students with perfect score
Spring 2012	88/100	n=9, three students with a score of 100

Average score:
[(21)61% + (8)87% + (7)61% + (5)88% + (3)79% + 9(88%)]/53
= **73%**

(b) An ability to design and conduct experiments, as well as analyze and interpret data

CO-OP Employer Survey (I)

- Fall 2014 3.667/5, n=6
- Fall 2013 No surveys returned.
- Fall 2012 4.33/5, n=6
- 2011 4.33/5
- 2010 4.67/5
- 2009 4.57/5

Average score: Assume 6 returns in 2011, 2010, and 2009
(73.4% + 86.6% + 86.6% + 93.4% + 91.4%)/5 = **86%**

Senior Survey (I)

2015 (S)	3.00/5, n=2
2014	3.00/5, n=17
2013	3.40/5, n=5
2012	4.40/5, n=5
2011	3.43/5, n=8
2010	3.45/5, n=11
2009	3.78/5, n=9

Average score:
[(2)60% + (17)60% + (5)68% + (5)88% + (8)67% + (11)69% + (9)75%]/62
= **63%**

Final Evaluation of SO (b) and CQI

Faculty-established rules:

- Direct instruments are deemed more accurate than indirect: So the total weights for direct instruments will be 75% as opposed to 25% for “indirect”
- Each of the three direct instruments will be assigned the same weight of 25%
- Each of the two indirect instruments will be assigned the same weight of 12.5%
- A threshold of 70% will be used to judge whether the SO is achieved

Instrument	Score	Weight
EECS 245 (D)	86%	0.25
EECS 281 (D)	73%	0.25
EECS 398 (D)	85%	0.25
Co-op Empl_ers (I)	86%	0.125
Snr Exit surveys (I)	63%	0.125

Weighted Average Total Score: **79.6%**

The final verdict:

Again the average total score of 79.6% MODERATELY surpasses the faculty-established threshold of 70% indicating that the curriculum has moderately achieved Student Outcome (b). There are obviously rooms for improvement.

Continuous Improvement:

A quick glance at the scores of individual instruments reveals that Senior exit survey (I) and EECS 281 (D) attained the two lowest scores which pull down the average total score. This indicates that most students in those graduating classes did not have confidence in designing and conducting scientific experiments (and analyze experimental results). A closer examination of the individual raw scores in the classes of EECS 281 confirms that students have difficulty understanding and applying (i) the concepts and techniques that underpin Digital Logic Circuits, and (ii) statistical concepts required to analyze experimental data.

As a possible remedies, the program faculty proposes that:

1) The instructor makes every efforts to supplement pedagogical approach with more experiential and hands-on projects, particularly on digital logic design.
2) Conduct special recitation sessions on statistical analysis of data and design of experiments,

An alternative way to assess student outcomes

CE and ME Examples

ABET Student Outcomes

1. Ability to solve complex engineering problems by *applying principles of Mathematics and Science* (Chemistry, Physics, and Biology)
2. Ability to *design engineering systems*, products, or processes
3. Ability to *develop and conduct experiments* in support of engineering tasks
4. Ability to *communicate effectively* to a wide audiences on engineering problems and solutions
5. Ability to *practice engineering ethically* and professionally
6. Ability to *work collaboratively with others*, both as team leader and/or team member
7. Ability to self seeking additional knowledge and information for engineering practice in this fast technological changing environment (*Lifelong Learning*)

Assessment Tools

- Direct Instrument (Assessment from courses, such as exams)
- Indirect Instrument (Assessment from Questionnaires and Surveys)

- Need a combination of Instruments (A Mix of Direct and Indirect Instruments)……Why…..
  - 2 Direct Instrument (Two courses) and 1 Indirect Instrument (One survey)……..(prefer), or
  - 1 Direct Instrument (One course) and 2 Indirect Instrument (Two surveys)

Questionnaires or Surveys are indirect instruments

- Students’ Exit Survey
- Alumni ’s Survey
- Employers’ Survey

Example of Students' Exit Survey

Student Outcomes	Your level of confidence in performing each expected task				
	No Confidence	………………………………………………			Highly Confidence
1 Apply Math/Sci.	1	2	3	4	5
2 Design Systems/Products	1	2	3	4	5
3 Conduct Experiment	1	2	3	4	5
4 Communicate Effectively	1	2	3	4	5
5 Practice Ethically	1	2	3	4	5
6 Work with others (team)	1	2	3	4	5
7 Life-long Learning	1	2	3	4	5

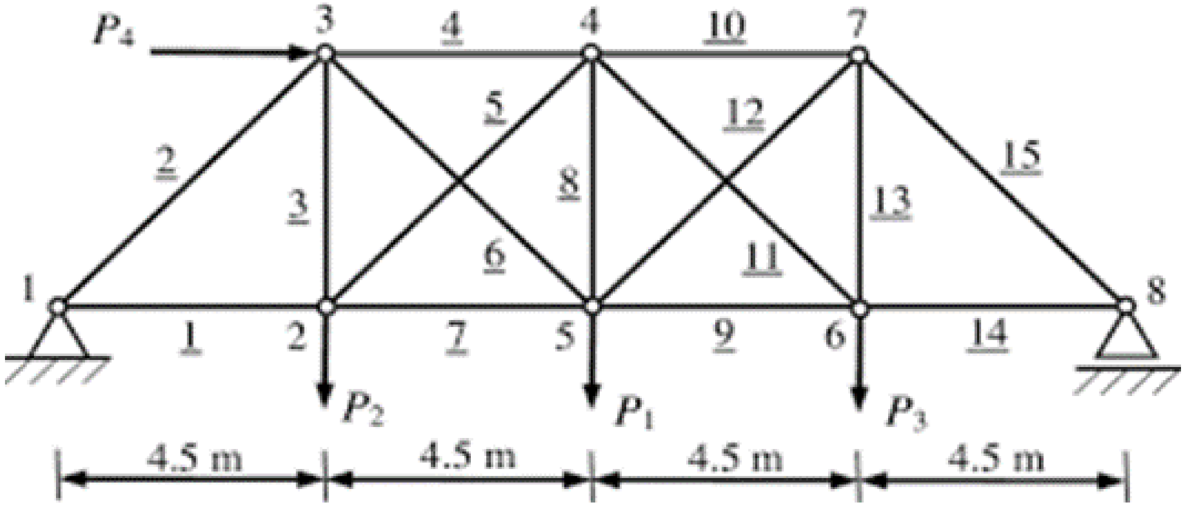
Average scores from Exit Survey (Indirect Instrument)

Student Outcomes	Average Score from Survey (x/5)	Percentage of Confidence (%)
SO1	3.5	70
SO2	4.0	80
SO3	4.5	90
SO4	3.0	60
SO5	2.5	50
SO6	4.0	80
SO7	2.0	40

Engineering Statics
SO1 -Apply math./sci. to solve engineering problems

Problem: Truss

- Solution:
  - Engineering Principle:
  - $\Sigma F = 0 \quad \Sigma M = 0$
  - Free Body Diagram
  - Leading to
    - Two equations with two unknowns
  - Apply Math:
    - Solve two equations two unknowns



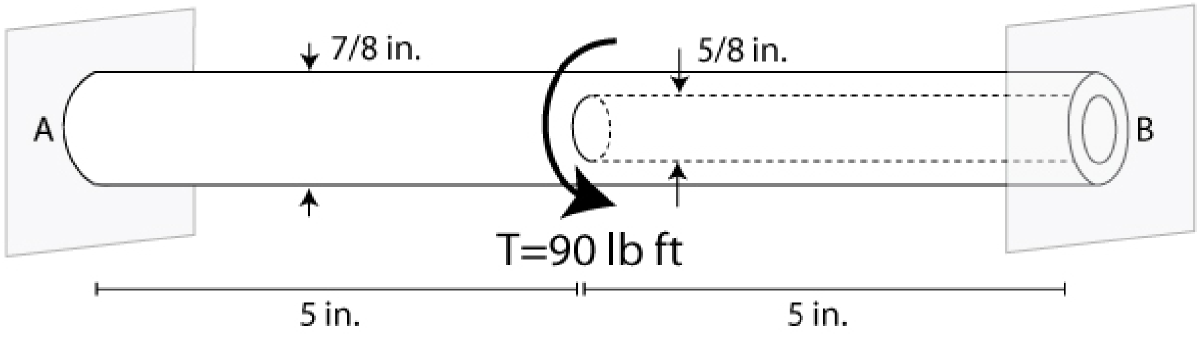
SO1 Direct assessment from Statics Problem: TRUSS

Name (Student)	Engineering	Apply Mathematics
Student 1	Yes (can set up equations)	Yes (can solve equations)
Student 2	Yes	Yes
Student 3	No (cannot set up equations)	No (cannot solve equations)
Student 4	Yes	No
Student 5	No	No
Student 6	No	Yes
Student 7	Yes	No
Student 8	No	Yes
Student 9	Yes	Yes
Student 10	Yes	No
Students' Performance	6/10	5/10
Percent Attained SO1	60%	50%

Strength of Materials
SO1 -Apply math./sci. to solve engineering problems

Problem: TORSION

- Solution:
  - Engineering Principle:
  - $\Sigma M = 0$ and Compatibility Eq.
  - Leading to
    - Two equations with two unknowns
  - Apply Math:
    - Solve two equations two unknowns



$$M_A + M_B = T$$
$$\phi_{AC} + \phi_{CB} = 0$$

SO1 Direct assessment (Strength of Materials) Problem: TORSION

Name (Student)	Engineering	Apply Mathematics
Student 1	Yes (can set up equations)	Yes (can solve equations)
Student 2	Yes	Yes
Student 3	Yes	Yes
Student 4	Yes	No (cannot solve equations)
Student 5	No (cannot set up equations)	No
Student 6	No	No
Student 7	No	No
Student 8	No	No
Student 9	No	Yes
Student 10	Yes	Yes
Course Performance	5/10	5/10
Percent Attained SO1	50%	50%

Summarizing SO1 Assessment
SO1 -Apply Math. and Sci. to Solve Engineering Problems

The Assessment Needs 2 Direct Instruments (courses) and 1 Indirect Instrument (survey)		
Course or Survey		% Attainable
Course 1 (Statics)	Direct Instrument 1	50%
Course 2 (Strength of Materials)	Direct Instrument 2	50%
Exit Survey	Indirect Instrument	70%
Weight: 40% from each course (direct) and 20% from survey (indirect)		
SO1 Assessment = 0.4(50%) + 0.4(50%) + 0.2(70%) = 54%		
If set passing threshold is 70% (set your own passing percentage); SO1 is unattainable		
Need to find/identify course weaknesses and take remedial action		

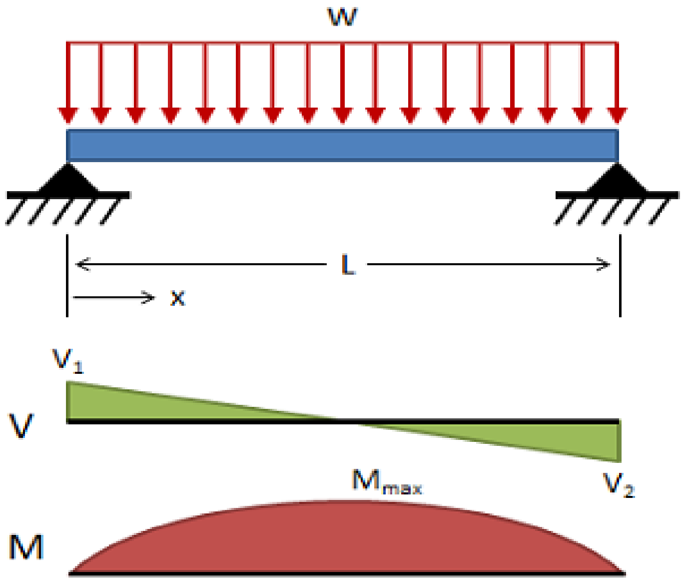
Problems and Continuous Improvement for SO1

COURSE	PROBLEMS	REMEDIAL ACTION FOR SO1
STATICS	1. 40% of students could not formulate equations from engineering principles	
	2. 50% of students has trouble with Linear Algebra (could not solve two equations two unknowns)	Instructors review Linear Algebra and give additional practice problems for those who failed to solve systems of linear equations
STRENGTH OF MATERIALS	1. 50% of students could not formulate equations from engineering principles	
	2. 50% of students has trouble with Linear Algebra (could not solve two equations two unknowns)	Instructors review Linear Algebra and give additional practice problems for those who failed to solve systems of linear equations

Engineering Statics
SO1 -Apply math./sci. to solve engineering problems

Problem: Deflection of a Simply Supported Beam

- Solution:
  - Structural Analysis:
  - ΣF = 0   ΣM = 0
  - Free Body Diagram, and
  - Leading to →
  - Apply Math:
    - Carry out ***Double Integration***



$$M(x) = \frac{\omega x}{2}(L - x)$$

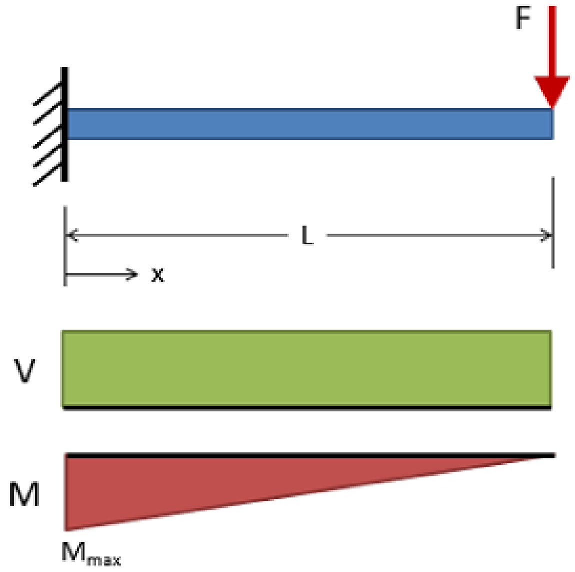
$$\frac{d^2 y}{dx^2} = -\frac{M(x)}{EI} = -\frac{\frac{\omega x}{2}(L - x)}{EI}$$

Structural Analysis
SO1 -Apply math./sci. to solve engineering problems

Problem:

Deflection of a Cantilever Beam

- Solution:
  - Structural Analysis:
  - $\Sigma F = 0 \quad \Sigma M = 0$
  - Free Body Diagram, and
  - **Leading to**
  - Apply Math:
    - Carry out ***Double Integration***



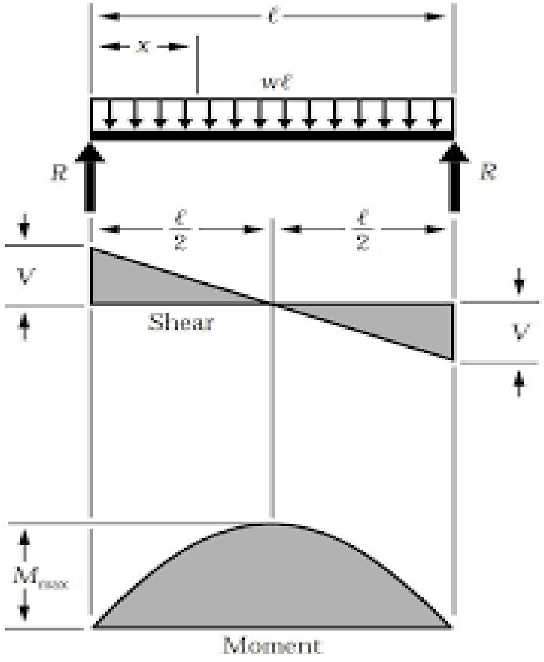
$$M(x) = Px$$

$$\frac{d^2y}{dx^2} = -\frac{M(x)}{EI} = -\frac{Px}{EI}$$

Structural Steel Design
SO2 –Design engineering systems and products

Problem: Design a Steel Beam

- Solution:
  - Find the maximum applied moment M_{max} for the beam and from the applied load (from pre-requisite courses)
  - From Steel Design course
    - Design a steel beam
    - Section **W12x65**



$$C_b = 1.14$$

$$\frac{M_{\max}}{C_b}; L_b = 20ft$$

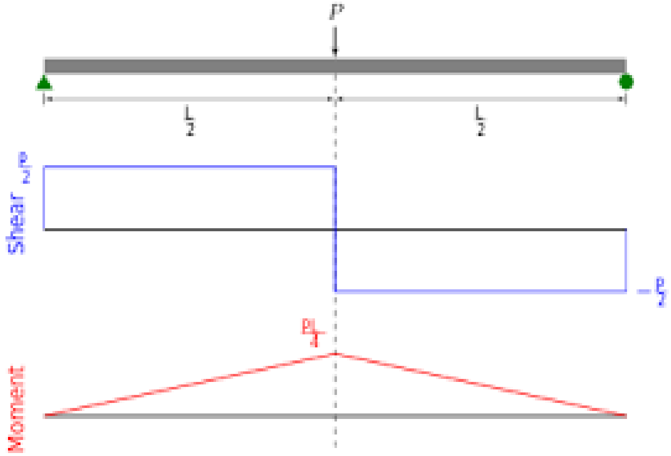
SO2 Direct assessment from Steel Design Problem: Beam Design

Name (Student)	Find Maximum Applied Moment	Design the Steel Beam
Student 1	Yes (can find maximum moment)	Yes (can design steel beeam)
Student 2	Yes	Yes
Student 3	No (cannot find maximum moment)	No (cannot design)
Student 4	No	Yes
Student 5	No	Yes
Student 6	No	No
Student 7	Yes	No
Student 8	Yes	No
Student 9	Yes	Yes
Student 10	Yes	Yes
Students' Performance	6/10	6/10
Percent Attained SO2	60%	60%

Structural Reinforced Concrete Design
SO2 –Design engineering systems and products

Problem: Design a Concrete Beam

- Solution:
  - Find the maximum applied moment M_{max} for the beam and from the applied load (from pre-requisite courses)
  - From Concrete Design course
    - Design a reinforced concrete beam
    - Get ***b***, ***d***, and ***As***



$$\frac{M_{\max}}{\varphi f'_c b d^2} = \omega(1 - 0.59\omega)$$

$$\frac{d}{b} = 3; \rho = 1.5\%$$

SO2 Direct assessment from Concrete Design Problem: Beam Design

Name (Student)	Find Maximum Applied Moment	Design the Conncrete Beam
Student 1	Yes (can find maximum moment)	No (cannot design)
Student 2	Yes	No
Student 3	Yes	Yes (can design steel beeam)
Student 4	Yes	Yes
Student 5	No (cannot find maximum moment)	Yes
Student 6	No	Yes
Student 7	No	No
Student 8	Yes	No
Student 9	Yes	Yes
Student 10	Yes	Yes
Students' Performance	7/10	6/10
Percent Attained SO2	70%	60%

Summarizing SO2 Assessment
SO2 –Ability to Design System, Product, and Process

The Assessment Needs 2 Direct Instruments (courses) and 1 Indirect Instrument (survey)		
Course or Survey		% Attainable
Course 1 (Steel Design)	Direct Instrument 1	60%
Course 2 (Concrete Design)	Direct Instrument 2	60%
Exit Survey	Indirect Instrument	80%
Weight: 40% from each course (direct) and 20% from survey (indirect)		
SO2 Assessment = 0.4(60%) + 0.4(60%) + 0.2(80%) = 64%		
If set passing threshold is 70% (set your own passing percentage); SO2 is unattainable		
Need to find/identify course weaknesses and take remedial action		

Problems and Continuous Improvement for SO2

COURSE	PROBLEMS	REMEDIAL ACTION FOR SO2
STEEL DESIGN	1. 40% of students has problems finding maximum applied moment	Instructors review Structural Analysis and show students how to find maximum moment
	2. 40% of students does not know how to design a steel beam from the applied maximum moment	Instructors review steel design concept/procedure and give additional practice problems for those who failed design steel beam
REINFORCED CONCRETE DESIGN	1. 30% of students has problems finding maximum applied moment	Instructors review Structural Analysis and show students how to find maximum moment
	2. 40% of students does not know how to design a concrete beam from the applied maximum moment	Instructors review reinforced concrete design concept/procedure and give additional practice problems for those who failed design concrete beam

Appendix

Performance Indicators:

Handy Aid for Selecting Core courses as Direct Instruments

- A Performance Indicator is a measurable metric that serves as a good indicator of the attainment of an outcome
- Attainment of an SO can be measured by a suite (or single) of performance indicators.

Suggested Performance Indicators:

Student Outcome	Performance Indicators
a) An ability to apply knowledge of mathematics, science, and engineering	• Chooses a mathematical model of a system or process appropriate for required accuracy • Applies mathematical principles to achieve analytical or numerical solution to model equations • Examines approaches to solving an engineering problem in order to choose the more effective approach
b) An ability to design and conduct experiments, as well as to analyze and interpret data	• Observes good lab practice and operates instrumentation with ease • Determines data that are appropriate to collect and selects appropriate equipment, protocols, etc. for measuring the appropriate variables to get required data • Uses appropriate tools to analyze data and verifies and validates experimental results including the use of statistics to account for possible experimental error
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	• Produces a clear and unambiguous needs statement in a design project • Identifies constraints on the design problem, and establishes criteria for acceptability and desirability of solutions • Carries solution through to the most economic/desirable solution and justifies the approach
d) An ability to function on multi-disciplinary teams	• Recognizes participant roles in a team setting and fulfills appropriate roles to assure team success

Suggested Performance Indicators:

Student Outcome	Performance Indicators
e) An ability to identify, formulate, and solve engineering problems	• Problem statement shows understanding of the problem • Solution procedure and methods are defined. • Problem solution is appropriate and within reasonable constraints
f) An understanding of professional and ethical responsibility	• Knows code of ethics for the discipline • Able to evaluate the ethical dimensions of a problem in the discipline
g) An ability to communicate effectively, both orally and in writing	• Writing conforms to appropriate technical style format appropriate to the audience • Appropriate use of graphics • Mechanics and grammar are appropriate • Oral: Body language and clarity of speech enhances communication
h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	• Evaluates conflicting/competing social values in order to make informed decisions about an engineering solution. • Evaluates and analyzes the economics of an engineering problem solution • Identifies the environmental and social issues involved in an engineering solution and incorporates that sensitivity into the design process

Suggested Performance Indicators:

Student Outcome	Performance Indicators
i) A recognition of the need for, and an ability to engage in life-long learning	• Expresses an awareness that education is continuous after graduation • Able to find information relevant to problem solution without guidance
j) A knowledge of contemporary issues	• Identifies the current critical issues confronting the discipline • Evaluates alternative engineering solutions or scenarios taking into consideration current issues
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	• Selects appropriate techniques and tools for a specific engineering task and compares results with results from alternative tools or techniques • Uses computer-based and other resources effectively in assignments and projects

Mapping of Core Courses to Performance Indicators of

1) An ability to identify, formulate and solve complex engineering problems by applying principles in math, science and engineering

Performance Indicators	ENG R131	ENG R145	ENG R200	ENG R210	ENG R225	ENGR/ ENGL 398	EEC S246	EEC S281	EEC S304 / 305	EEC S313	EEC S324	EEC S342
• Problem statement shows understanding of the problem						✓			✓		✓	✓
• Solution procedure and methods are defined.	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
• Problem solution is appropriate and within reasonable constraints	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓

Example Rubrics for Measuring SOs

(when quantitative data is not available)

a. An ability to apply knowledge of mathematics, science, and engineering		
Level 5	Level 3	Level 1
Combines mathematical and/or scientific principles to formulate models of chemical, physical and/or biological processes and systems	Chooses a mathematical model or scientific principle that applies to an engineering problem, but has trouble in model development	Does not understand the connection between mathematical models and chemical, physical, and/or biological processes and systems
Applies concepts of integral and differential calculus and/or linear algebra to solve systems and control engineering problems	Shows nearly complete understanding of applications of calculus and/or linear algebra in problem-solving	Does not understand the application of calculus and linear algebra in solving systems and control engineering problems
Shows appropriate engineering interpretation of mathematical and scientific terms	Most mathematical terms are interpreted correctly	Mathematical terms are interpreted incorrectly or not at all
Translates academic theory into engineering applications and accepts limitations of mathematical models of physical reality	Some gaps in understanding the application of theory to the problem and expects theory to predict reality	Does not appear to grasp the connection between theory and the problem

f. An understanding of professional and ethical responsibility		
Level 5	Level 3	Level 1
Student understands and abides by the IEEE Code of Ethics and the EECS Statement of Academic Integrity	Student is aware of the existence of the IEEE Code of Ethics and other bases for ethical behavior	Student is not aware of any codes for ethical behavior
Evaluates and judges a situation in practice or as a case study, using facts and a professional code of ethics	Evaluates and judges a situation in practice or as a case study using personal understanding of the situation, possibly applying a personal value system	Evaluates and judges a situation in practice or as a case study using a biased perspective without objectivity
Evaluates and judges a situation in practice or as a case study, using facts and a professional code of ethics	Evaluates and judges a situation in practice or as a case study using personal understanding of the situation, possibly applying a personal value system	Evaluates and judges a situation in practice or as a case study using a biased perspective without objectivity
Participates in class discussions and exercises on ethics and professionalism	Does not take the discussion of ethics seriously but is willing to accept its existence	Does not participate in or contribute to discussions of ethics; does not accept the need for professional ethics
Is punctual, professional, and collegial; attends classes regularly	Sometimes exhibits unprofessional behavior; is sometimes absent from class without reason	Is frequently absent from class and is generally not collegial to fellow students, staff, and faculty