Conversion of Penn State's Chemical Engineering Program Assessment and Evaluation Process

An ABET system: 10 practical steps.

1. Simple and sustainable for you and your program
2. Effective in improving the educational experience

PennState College of Engineering | CHEMICAL ENGINEERING

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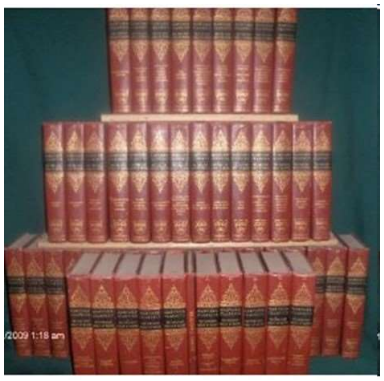
2015 November 10

ABET 2008: 0 problems, $\rightarrow \infty$ work, $O(\varepsilon)$ gain

Ron Danner



roughly 15 ft of notebooks

Gloria Rogers

2

ABET Workshop showed a sustainable process

3

Summary of the 10 steps

1. team. Build a commited A-Team.
2. PEOs (Criterion 2). Simple, clear, stable.
3. Outcomes (Criterion 3). Define grads by PIs.
4. Data. Collect PESTS data … in simple way.
5. e-folder. Maintain an e-folder of ABET info and discussions.
6. Semester review. Work a checklist.
7. Continuous Improvement (Criterion 4). Use trigger-action-result.
8. Self-study. Draft early and often.
9. PEV visit. Prepare for the Program Evaluator (PEV) and treat professionally.
10. Sand traps. Diligently identify and watch for potential challenges.

For a PDF of the slides, email Darrell at velegol@psu.edu, ABET in the Subject line.

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1. Team. Build a committed A-Team.

1. Head, Andrew Zydney
"improve the department"

2. ABET Review Committee.


head


coordinator


design


special

3. Staff, TAs, College


staff


COE lead (Criterion 1, Appendices)

5

Faculty. Not your core team, but essential to ABET success!

empathy

simplicity

awareness

6

Constituents. They provide critical input.

students
job surveys, senior survey

PENN STATE ALUMNI

alumni
IPAC, CH E 300, surveys

industry
IPAC, surveys

grad schools
anecdotal input

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2. PEOs (Criterion 2). Simple, clear, stable.

Program Educational Objectives

Broad statements that describe what graduates are expected to attain within a few years after graduation (definition 2011)

ABET Leadership and Quality Assurance in Applied Science, Computing, Engineering, and Technology Education

- **review frequently**. Discuss at each "Semester Review" (mentioned later).
- **PEOs ≠ a-k Outcomes**. Not … "Our graduates will know how to work in teams with other professionals." [Outcome d]

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Penn State Chemical Engineering PEOs

The undergraduate program in Chemical Engineering at Penn State has been designed so that students can identify and pursue their personal and professional goals while obtaining a strong foundation in the principles and practice of Chemical Engineering. The program aims to produce graduates who will attain one or more of the following:

1 Careers as practicing chemical engineers in traditional chemical and energy-related industries as well as in expanding areas of materials, environmental, pharmaceutical, and biotechnology industries

2 Advanced degrees in chemical engineering (or a related technical discipline), medicine, law, or business

3 Positions that enable the technical, educational, business, and / or political leadership needed in today's rapidly changing, increasingly technological, global society.

http://www.che.psu.edu/accreditation/index.htm

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Questions

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3. Outcomes (Criterion 3). Define grads by PIs.

Criterion 3. Student Outcomes
The program must have documented student outcomes that prepare graduates to attain the program educational objectives. Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary 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, economic, environmental, 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.

- Use a-k as outcomes …
- … but then how is PSU CH E different from UIUC EE?

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Performance Indicators (PIs) measure a-k.

Bloom's Taxonomy
- For YOUR field or program, choose PIs that are 1) important, 2) measurable.
- We use "Bloom taxonomy" verbs (know, comprehend, apply, analyze, synthesize, evaluate) or similar (e.g., design), with a skill or concept.
- Simplify, clarify, focus toward about 25 PIs.

For example …

a6. apply reaction engineering concepts to ChE problems. [430, 470 pre-test]

Standard Problem PIs
f1. know the AIChE Code of Ethics. [210 standard problem]
k3. know how to obtain relevant data from internet databases. [340 standard problem]

Pilot Performance Indicators (introducing variance into our process, in a controlled way)
j2. comprehend current events in terms of chemical process industries (e.g., Marcellus Shale, BP spill). [300, pilot 452] [2014]
??? d2. communicate with students in other disciplines (e.g., civil engineering, finance, accounting) to complete an assignment or project. [2015]
??? h1. analyze sustainability using a framework (e.g., PPPP = people, planet, prosperity, politics) to analyze impacts of a design or case. [2015]
??? How to use our new required Safety Course, online capability, coops / research / experiences. [Toward greatness!]

http://www.che.psu.edu/accreditation/studentOutcomes.htm

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Our a-k PIs.

List of 35 Performance Indicators (PIs). Our students will be able to …

(a) an ability to apply knowledge of mathematics, science, and engineering
a1. apply differential and integral calculus to chemical engineering problems. [210, 220]
a2. apply ordinary or partial differential equations to chemical engineering problems. [210, 220]
a3. apply chemical and biochemical concepts to ChE problems. [340, 470 pre-test]
a4. apply transport (fluid, heat, mass) concepts to ChE problems. [330, 350, 410, 470 pre-test]
a5. apply thermodynamics concepts to ChE problems. [220, 320, 470 pre-test]
a6. apply reaction engineering concepts to ChE problems. [430, 470 pre-test]

(b) an ability to design and conduct experiments, as well as to analyze and interpret data
b1. design and conduct experiments for unit operations, with safety in mind. [480]
b2. analyze experimental data using simple statistics. [480, pilot 297]
b3. evaluate experimental data in light of ChE theory and literature. [480]

(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
c1. design a single unit operation (e.g., separator, pump, heat exchanger, or reactor), recognizing heuristics for realistic opportunities and constraints. [320, 330, 350, 410, 430, 470 pre-test]
c2. design a process that includes multiple unit operations, recognizing heuristics for realistic opportunities and constraints. [470, 470 pre-test]
c3. analyze a process with systematic techniques (e.g., HAZOP, ROI). [470, pilot 452]

(d) an ability to function on multidisciplinary teams
d1. apply synergistical division of effort strategies for complex problems (e.g., section of design, or by specialty calcs, data collection, or writing). [470, 480]
d2. apply interdependent management strategies in teamwork (e.g., leading, scheduling, formatting). [470, 480]
databases. [340 standard problem]

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Our a-k PIs (continued).

List of 35 Performance Indicators (PIs). Our students will be able to …

(e) an ability to identify, formulate, and solve engineering problems
e1. identify and formulate basic ChE problems (e.g., sketch, or state variables and parameters). [210, 220]
e2. identify and formulate sophisticated ChE problems (e.g., combining rate expressions with balances). [410, 430, 470 pre-test]
e3. solve challenging technical problems that combine scales (molecular, continuum, or systems). [470]

(f) an understanding of professional and ethical responsibility
f1. know the AIChE Code of Ethics. [210 standard problem] [210, 300]
f2. comprehend multiple ethical issues in a model scenario. [300, pilot 452]
f3. recognize some conflict of interest situations. [300]

(g) an ability to communicate effectively
g1. write clear and concise emails, memos, or summaries. [470, 480]
g2. plot appropriate graphs. [470, 480]
g3. write clear, organized documents with appropriate conciseness. [470, 480]
g4. present clear presentations (often including slides) and answer follow-up questions. [470, 480]

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
h1. analyze the economics of an entire process. [470]
h2. know key advantages and challenges for global teams and workflow. [300]

(i) a recognition of the need for, and an ability to engage in life-long learning
i1. know about the FE and PE exams. [300]
i2. apply preparation strategies for a first job, a job transition, grad school, or similar (e.g., resume, cover letter, networking, interview questions). [210]

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Our a-k PIs (continued).

List of 35 Performance Indicators (PIs). Our students will be able to …

(j) a knowledge of contemporary issues [PSU CH E uses 20 years]
j1. know contemporary issues affecting the CPI (6 sigma, patent law). [300]
j2. comprehend current events in terms of chemical process industries (e.g., Marcellus Shale, BP spill). [300, pilot 452]

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
k1. apply spreadsheets to solve problems. [210]
k2. apply Hysys or similar process simulation software to analyze processes. [470]
k3. apply math software (e.g., Mathematica, MatLab, MathCad, COMSOL, or FORTRAN) to solve challenging problems. [360]
k4. apply a computer to collect data. [480]
k5. know how to obtain relevant data from internet databases. [340 standard problem]

Updated PIs online (Google Penn State Chemical Engineering ABET)
http://www.che.psu.edu/accreditation/studentOutcomes.htm

Proposed changes in a-k ...
1. An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs.
3. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
4. An ability to communicate effectively with a range of audiences.
5. 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.
6. An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.
7. An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

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4. Data. Collect PESTS data … in simple way.

☐ ***Problem statement.***
We need particular problem statements from exams, quizzes, homeworks, projects, reports, or in-class exercises. The problems should address a particular "Performance Indicator" (PI) on p 2 (e.g., c1 or f2), which are described on pp 3-4. The goal is to assess the Performance Indicator, and not to have an especially difficult or easy problem. The problem could be PDF, Word, or hard copy. A particular problem can sometimes cover more than one PI.

☐ ***Example work. 3 items.***
- ☐ excellent work (A-level)
- ☐ good work (B or C-level)
- ☐ poor work (D or F-level)

In order to "calibrate" the student work and its grading, we need examples of excellent work (typically "A" work), good work (B or C), and poor work (D or F). If all work is A-level for a given problem, that is OK – just give three examples of A work. PDF or hard copy are best.

DESIGN and LAB courses: Keep copies of excellent-good-poor projects.

☐ ***Scores***
- ☐ list of scores for the particular problem (0-100), not just for the entire exam.
- ☐ score for a "C" grade (e.g., 60% or 70%)

☐ ***Thoughts***
A few brief, written sentences about the problem, especially if the average was below "C", or more than 30% of the scores were below "C". Comments on why the scores were high or low on average? Comments on heterogeneity of the scores?

☐ ***Syllabus***
Provide a copy of the course syllabus.

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Output: PESTS in red-yellow-green page.

2013-2014 Academic Year

PI	Fall 2013	Spring 2014
a1		ChE 220, Exam 3, problem 2, 78 (17) OK
a2	ChE 360, Final Exam, Problem 3, 66.0 (47)	
a3	ChE 340, Midterm, problem 3, 63 (56)	
a4	ChE 330, Exam problem, 70.0 (26) ChE 330, Exam problem, 71.0 (41) ChE 330, Homework problem, 84.0 (12) OK ChE 350, Exam problem, 79.0 (20) ChE 410, Exam 1, problem 1, 79.0 (25.0), OK ChE 410, Exam 2, problem 3, 74.0 (43.0)	ChE 330, Midterm problem 3, 88 (11) OK ChE 330, Final exam problem 1, 77 (31) ChE 330, Exam 2 problem 1, 88 (23) OK ChE 470, Pre-test, HEx Problem, 46.0 (71) ChE 470, Pre-test, Pump Problem, 33.0 (76) ChE 410, Exam 2, problem 1, 88 (23) OK ChE 410, Final exam, problem 1, 77 (31)
a5	ChE 320, Exam 4, Problem 2, 66.0 (49)	ChE 470, Pre-test, Rx-Energy Problem, 51.0 (57) ChE 470, Pre-test, T-xy problem, 77.0 (17), OK ChE 470, Pre-test, PV=nRT problem, 60.0 (39) ChE 220, Exam 2, problem 2, 74 (23) OK
a6		ChE 470, Pre-test, Kinetics Problem, 69.0 (28) OK
b1	ChE 480, 88 (0) OK	ChE 480, HPLC experiment, 93 (0)
b2	ChE 480, 83 (10) OK ChE 297A, Problem set 2, 83 (27) OK	ChE 480, Ultrafiltration experiment, 77 (16)
b3		ChE 480, Experimental data vs. theory, 87 (11)
c1	ChE 320, Exam 2, Problem 2, 64.0 (49) ChE 330, Exam problem, 90.0 (8) OK ChE 350, Exam problem, 71.0 (28) ChE 410, Exam 2, problem 2, 77.0 (22.0) OK	ChE 470, Pre-test, HEx Problem, 46.0 (71) ChE 470, Pre-test, McCabe Problem, 79.0 (15) OK ChE 410, Course project, 82 (17) OK
c2		ChE 470, Pre-test, BFD Problem, 68.0 (22) OK ChE 470, Pre-test, MatBal Problem, 73.0 (28) OK ChE 470, Process with multiple unit operations, 86, [7] OK
c3	ChE 452, Homework 3, Problem 3, 63.0 (58) ChE 452, Test 3, 88.0 (31) OK	
d1		ChE 470, Group work, 87.0 (15) OK ChE 470, Teamwork evaluations, 88 (7) OK ChE 480, Teamwork, 87 (8) OK

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Collect data from CH E "core courses"

ChE 210. a1, e1, f1 (standard problem), i1 (standard problem)
ChE 220. a1, a4, e1
ChE 230. e2, k1
ChE 300. f1, f2, h1, h2, i2, j1
ChE 320. a4
ChE 330. a3, c1
ChE 340. a2, k3 (standard problema)
ChE 350. a3, c1
ChE 410. a3, c1, e1
ChE 430. a2, a5, c1, e1
ChE 452. c2, f2, j1, j2
ChE 470. c2, d1, e1, e2, g1, g2, h1, k2.
ChE 480. b1, b2, d1, g1, g2.
pre-test (ChE 470). a3, a4, a5, c1, c2

Make data collection simple!
- teaching assistants + staff
- faculty in their own courses

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(P) Choose an example problem (here PI a4).

ChE 320: Phase and Chemical Equilibria (Velegol), Exam 2 problem 1.

Changing temperatures [35].
Sulfur hexafluoride is used as a gaseous dielectric medium in the electric industry. We SF_6 have being heated from 100 C to 120 C in a continuous process. The flowrate is 11.3 kg/s (MW = 146.06, so 77.37 mol/s) at a pressure of 10 bar. The C_V = 88.7 J/mol-K, and an empirical expression for the residual enthalpy has been found in terms of its reduced temperature and pressure to be

$$H^R = -RT\left(0.536 + \frac{0.229}{T_r}\right)P_r$$

where the critical T_c = 318 K and the critical P_c = 37.6 bar. Calculate the heat required for the process.

Q _____ W

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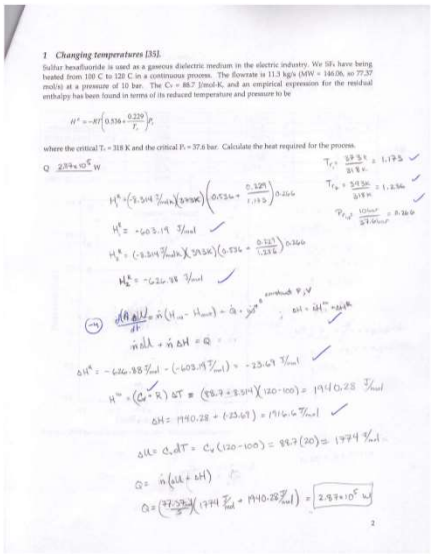
(E) Include high-middle-low for calibration



(S) Scores.
C = 70.0%
average = 82.9%
>C = 80.0% of students

(T) Thoughts.
The students did well as a class on this problem.

(S) Syllabus.
Attached

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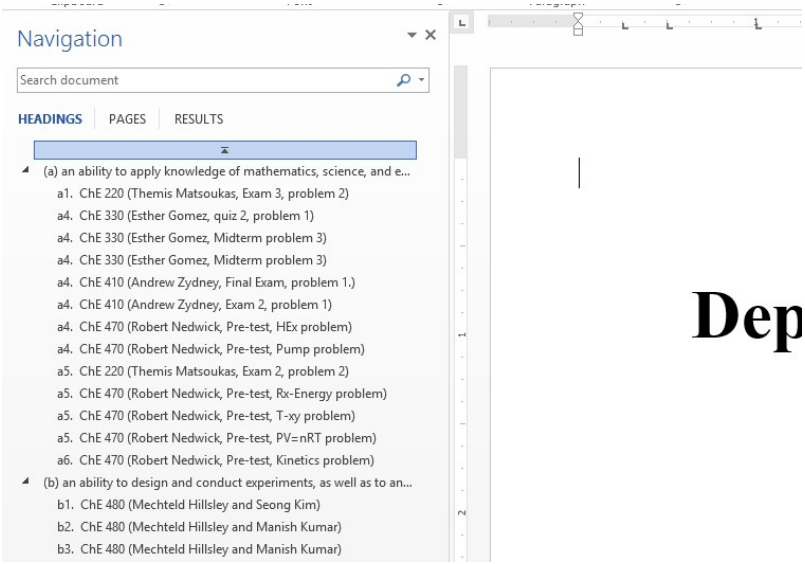
Store raw PESTS in e-doc (e.g., MS Word) by semesters



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Questions

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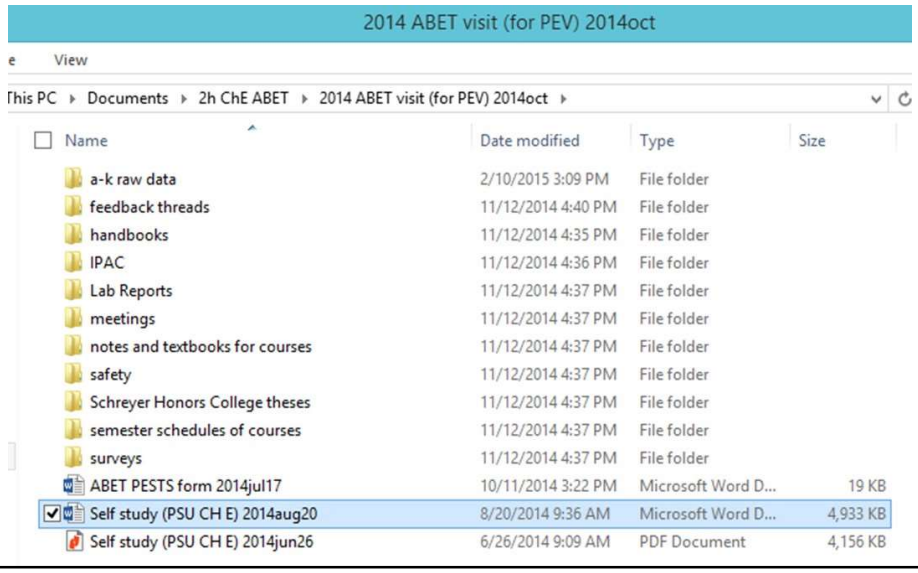
5. e-folder. Maintain an e-folder of ABET info and discussions.



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6. Semester review. Work a checklist.

Semester Reviews (Jan, Jun)
- ☐ date, time, present, absent.
- ☐ PEOs discussion. Infrequent updates.
- ☐ PESTS a-k Performance Indicators.
- ☐ Constituent input (students, alumni, industry, grad schools surveys, stories).
- ☐ Black swans (courses, facilities, other).
- ☐ Measurements of past changes.
- ☐ consistency of courses across faculty.
- ☐ campus-wide SWOT analysis (other departments and courses).
- ☐ facilities (unit ops, computers, building).
- ☐ new faculty-staff-TA ABET training.
- ☐ advising (first 2 years, last 2 years).
- ☐ special (Options, minors).
- ☐ ABET process review (PIs, other).
- ☐ Action (instructor, course, curriculum, standard problems, surveys, retreat, policies).

_____
_____
_____
_____
_____

ABET coordinator
- ☐ Monthly meeting with staff.
- ☐ Monthly faculty meeting update.
- ☐ Course objectives check (even years).

Staff
- ☐ Update PESTS Google doc.
- ☐ Email PESTS before semester.
- ☐ Collect PESTS data (with TAs).
- ☐ Organize raw PESTS data in Word.
- ☐ Organize red-yellow-green table.
- ☐ Organize email discussions.
- ☐ Update files (CVs, handbooks, syllabi)
- ☐ FAB monthly lunch meetings and report.
- ☐ Semester reviews prep (PESTS file, red-yellow-green table, Senior Exit survey, jobs survey, organized files).

TAs
- ☐ PESTS collection training (with staff).

IPAC (Mar)
- ☐ PEOs discussion and approval.
- ☐ ABET review results, PEV visits.

Design instructor
- ☐ pre-test data
- ☐ Design reports, High-Mid-Low/semester.
- ☐ senior jobs survey and figure

Lab instructor
- ☐ Lab reports, 2 High-Mid-Low/semester.
- ☐ safety report each semester.

Faculty
- ☐ PESTS data for course.
- ☐ PEOs discussion and approval.

Feature of ABET:
Think of changes as “process”, not personalities.

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7. Continuous Improvement (Criterion 4). Use trigger-action-result.

Table 4-1. Summary of evidence-guided improvements. These are some of the most important changes.

Semester	Trigger	Action	Result
2013 Spring	Written essays in CH E 300 Professional Development Seminar indicated a lack of awareness of (or at least reference to) AIChE Code of Ethics as a tool for dealing with ethical issues.	**CH E 210. AIChE code of ethics "standard problem".** Course Level. Recognizing the critical importance of ethics, and that we did not educate our students with any basis for their choices, we added a standard problem, usually given in homework, and sometimes also in exams. It covers PI f1 on ethics.	As the more recent data on PI f1 indicates, this important PI now scores strongly.
2013 Fall	Poor CH E 360 PI scores, poor Senior Exit Survey evaluations, consultation with industrial partners.	**CH E 360 moving to an elective course.** Curriculum Level. This has been a required course: Mathematical Modeling in Chemical Engineering. In its place we will be adding CH E 230 (see below).	Paperwork is in the Penn State system to have this change approved (requires approval by Faculty Senate).
2014 Spring	Numerous faculty requests for a description of ABET needs for each semester.	**PEST form for streamlining data collection.** ABET level. Problem / Examples / Scores / Thoughts for each PI measurement. Streamline	Data will come in future semesters, especially concerning the "Thoughts" category.

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Levels of change or "experiments"

Levels of "Continuous Improvement" change:

1. **instructor**. One instructor in a core course has challenges.
   - Sometimes due to circumstances (e.g., illness, a bad exam, new grant).
   - The remedy is usually straightforward.

2. **course**. Multiple instructors teaching the same course have challenges.
   - Consistency across courses requires clarifying some course outcomes.

3. **curriculum**. Students, faculty, alumni, and industry

4. **ABET process**. Sometimes it is the assessment process that must be fixed.
   - Unclear or overly-ambitious Performance Indicator (PI).
   - Too many PIs.

Sometimes the change will involve an "experiment" (e.g., a change in a course, a trial course) … which will then be examined by the same ABET process.

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Questions

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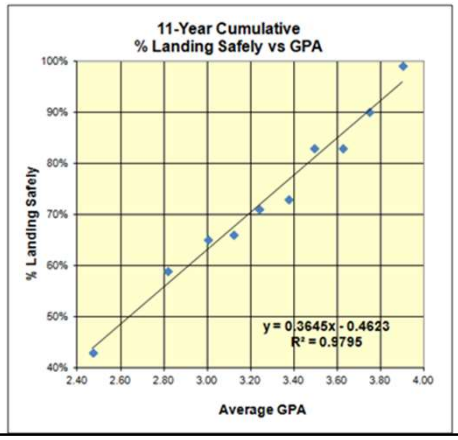
8. Self-study. Draft early and often.

- **self-study**. Draft now and update continuously to find “holes”.
- **Criterion 5: Curriculum**. Count the beans!
- **highlight special items**. E.g., CH E 452: Safety course, Senior Jobs survey, pre-test.
- **time**. 100-500 hours. Good info is a net “time saver”.



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9. PEV visit. Prepare for the Program Evaluator (PEV) and treat professionally.

- **transcripts**. 6 that start at a random letter.
- **people prep**. Respect, professionalism … not griping and "giving right answers".
- **safety**. Review your labs, perhaps working with other departments.
- **PEV space**. Computer, printer, design reports, lab reports, primary books, snacks.
- **professional**. PEVs are volunteers, doing their jobs. Not enemies, not buddies. Accept their report, and then respond professionally.

- **response**. Respond to all deficiencies, weaknesses, concerns, observations.
- **diligence**. Remain diligent with the process until final approval is secured.
- **timeline**. Our visit was Oct 2014, response by Feb 2015, follow up May 2015.

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10. Sand traps. Diligently identify and watch for potential challenges.

Point	Advice
start early	Start immediately. ABET is a continuous process.
Criterion 5: Curriculum	Count beans (e.g., engineering credits) conservatively.
self-study draft	Draft early and often, and have a full draft summer >1 year ahead.
building safety	Have other ABET departments visit and critique each other.
pre-requisites	Minimize pre-reqs, and enforce rigidly. Avoid using pre-reqs as "gates".

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Summary: 10 steps we used for Penn State Chemical Engineering ABET.

1. team. Build a commited A-Team.
2. PEOs (Criterion 2). Simple, clear, stable.
3. Outcomes (Criterion 3). Define grads by PIs.
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5. e-folder. Maintain an e-folder of ABET info and discussions.
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