

# Defining and Measuring Outcome Skills for a Large Mechanical Engineering Program

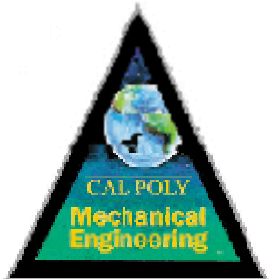
Christopher C. Pascual

Professor, Mechanical Engineering

Fred DePiero

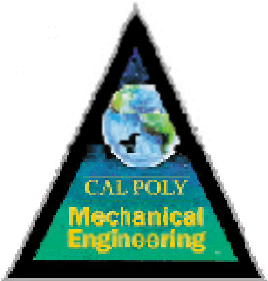
Associate Dean & EE Professor

California Polytechnic State University, San Luis Obispo, CA



# Overview

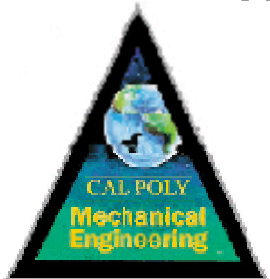
- Background
- Development of Criterion 3 Outcome Skills
- Assessment Tools
- Review of Assessment Data
- Criterion 4: Continuous Improvement
- Sustainable Process



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, [cpascual@calpoly.edu](mailto:cpascual@calpoly.edu)

# Background

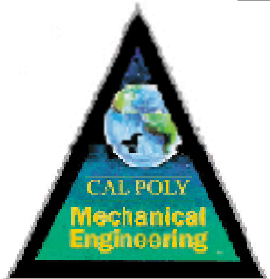
- University
  - Primarily undergraduate
  - 19,000 students
  - 56% men and 44% women
  - Part of 23 campus California State University System
- Student Body Size
  - College of Engineering: 5000 students
  - Mechanical Engineering: 1000 students



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Background

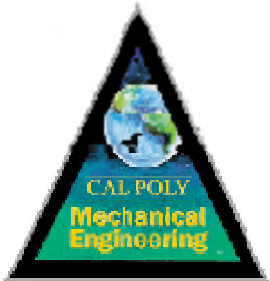
- Other Engineering Programs
  - College of Engineering: 13 total programs
  - 2 engineering programs outside CENG
- Mechanical Engineering
  - 200 ME students graduate per year
  - Approximately 5 years to complete program requirements
  - 199 quarter units (~133 semester units)
  - 27 tenure/tenure-track faculty, 15 lecturers



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Development of Criterion 3 Outcome Skills

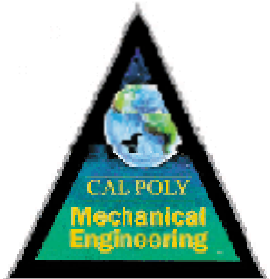
- Process for Development
  - Developed by small group of faculty (3)
  - Presented to the entire faculty for review
  - Debated, revised, and approved by the faculty



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, [cpascual@calpoly.edu](mailto:cpascual@calpoly.edu)

# Development of Criterion 3 Outcome Skills

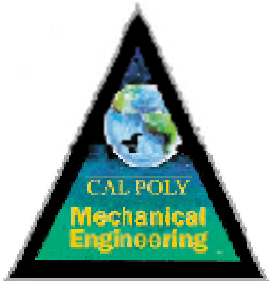
- List of Skills (separate handout)
  - Students are expected to obtain these skills by graduation
  - If students demonstrate acceptable performance on these skills, they satisfy the Program Outcomes which will foster attainment of the Program Educational Objectives



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Development of Criterion 3 Outcome Skills

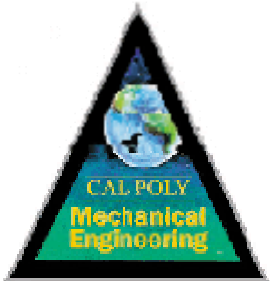
- Process to review skills
  - The ME Curriculum Committee is charged with periodically reviewing these skills and making recommendations to the faculty about changes.



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, [cpascual@calpoly.edu](mailto:cpascual@calpoly.edu)

# Assessment Tools

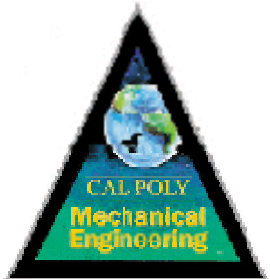
- Decentralized to Centralized
  - Through 2002, a decentralized method of indirect measures were used as assessment tools.
  - In general these were surveys given to graduating seniors, faculty, alumni, and employers.



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

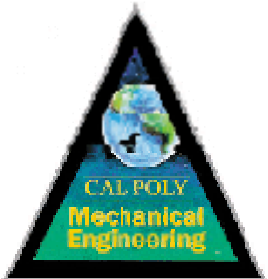
- Decentralized to Centralized
  - As a result of a concern on the 2002 ABET visit, direct measures were introduced as new assessment tools
  - At first this was handled in a decentralized manner with individual faculty members evaluating the skills of the students in their particular class



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

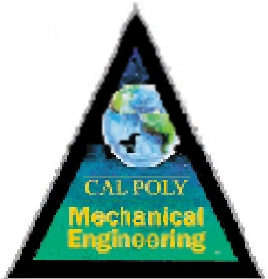
- Decentralized to Centralized
  - This approach had many shortcomings including:
    - Difficult to get significant involvement from faculty
    - Faculty tended to measure the same skills as other faculty members
    - Many skills were not measured
    - Difficult to manage process and disseminate results



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

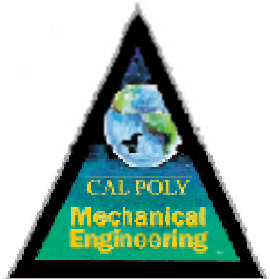
- Decentralized to Centralized
  - Centralized method developed with an ABET coordinator using direct measures.
  - Coordinator managed process, but faculty performed assessment



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

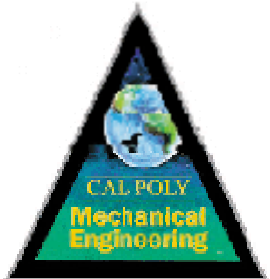
- Direct Measures-Senior Exam
  - 3-hour exam given to students in the senior project class
  - Only reference material is the FE Supplied Reference Handbook
  - Students are encouraged to review the contents of the Handbook prior to the exam-only review for exam



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

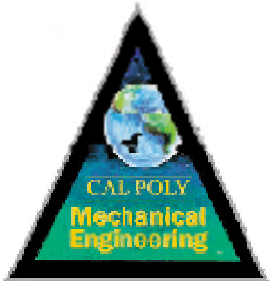
- Direct Measures-Senior Exam
  - Students are told that the exam is a comprehensive assessment of their Cal Poly education
  - Exam is worth 10-15% of the students' final grade
  - Course is taken in either of the students' last two quarters



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

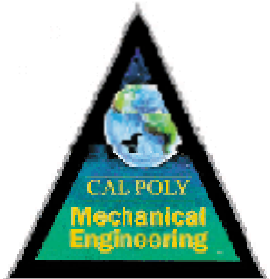
- Direct Measures- Senior Exam
  - The 23-question exam measures 27 Criterion 3 outcome skills
  - 55% approved as the minimal acceptable performance level on each individual skill
  - Exam developed by the entire faculty. A sizeable test bank is now available



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

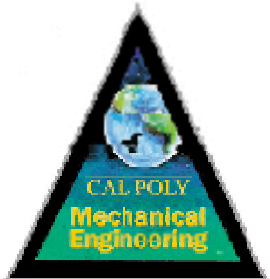
- Direct Measures- Senior Exam
  - Multiple faculty members grade the exam
  - Faculty members rotate on grading the exam
  - Each faculty member will only need to grade a portion of an exam every three years
  - Approximately 200 students per year take the exam



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

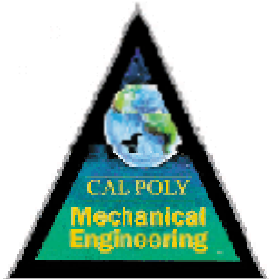
- Direct Measures- Senior Exam
  - Managed by the ABET coordinator
  - Handout of typical questions
  - Results from 2007 and 2008



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, [cpascual@calpoly.edu](mailto:cpascual@calpoly.edu)

# Assessment Tools

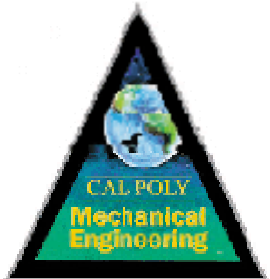
- Direct Measures- Senior Project Class
  - Used to measure 10 skills:
    - Design (3c)
    - Multidisciplinary (3d)
    - Communication (oral and written) (3g)
    - Life long learning (technical resources) (3i)



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

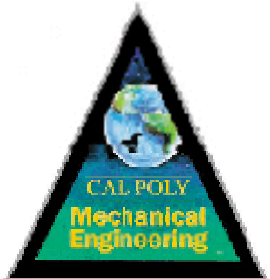
- Direct Measures- Senior Project Class
  - 3-quarter long senior project:
    - Development of design specifications
    - Design solutions
    - Analysis to refine the design
    - Build a functional prototype
    - Test if it meets performance specifications



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

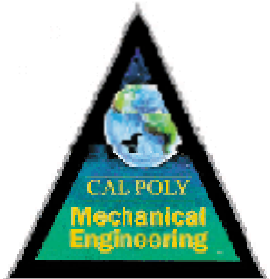
- Direct Measures- Senior Project Class
  - Senior project reports are reviewed by faculty members using a grading rubric to assess these skills



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

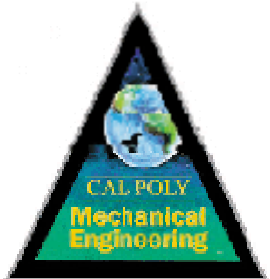
- Direct Measures- FE Exam
  - External nationally normed direct measure of some criterion 3 skills like 3a, 3f, and 3h
  - Currently students self-select on taking the exam with 50% opting to take the exam
  - Since these are not random students, the data are used to support other direct measures



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

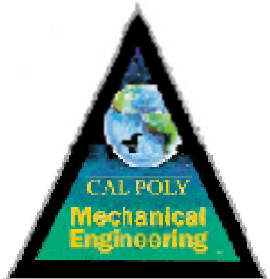
- Direct Measures-Writing Proficiency Exam
  - Students must demonstrate writing proficiency as a requirement for graduation (Graduate Writing Requirement- GWR)
  - Accomplished by either taking an approved course or by passing the Writing Proficiency Exam (WPE)
  - Approximately 50% of ME students take WPE



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

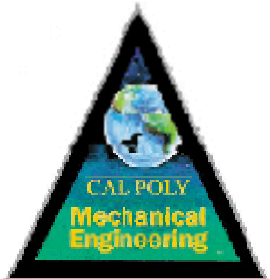
- Direct Measures-Writing Proficiency Exam
  - WPE is a two-hour expository essay:
    - Organization
    - Idea Development
    - Make and support generalizations
    - Use language at the level expected of and appropriate for a college graduate



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

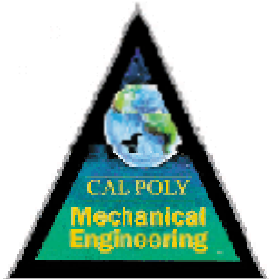
- Direct Measures-Writing Proficiency Exam
  - Essay graded by two evaluators each using a grading rubric on a scale from 0 to 6
  - Evaluators are from across the university
  - Scores of two evaluators are combined together to give the final score.
    - Maximum score is 12
    - Minimum passing score is 8.



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

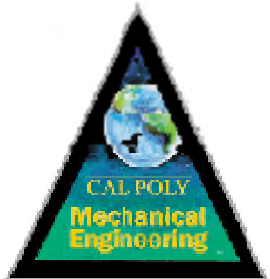
- Direct Measures- Modern Tools (3k)
  - Skill 1: Computer-based simulation/analysis
    - Embedded exam question used in controls lab (ME 422)
    - As part of lab final, students use Matlab to design a proportional controller and to simulate the closed-loop system.



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

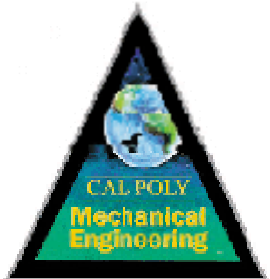
- Direct Measures- Modern Tools (3k)
  - Skill 2: Parametric Studies
    - Individual graded assignment in thermal system design class (ME 440)
    - Parametric study of a proposed thermal system
    - Use of software like EES
    - Examples:
      - Pipe/Pumping Systems
      - Effect of ambient temperature on chiller/cooling tower



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

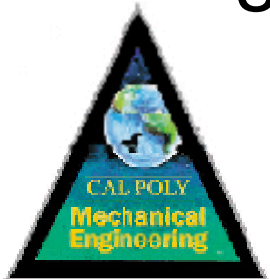
- Direct Measures- Modern Tools (3k)
  - Skill 3: Develop a Computer Algorithm
    - Embedded exam question in vibrations lab (ME 318)
    - As part of lab final, students program using Matlab the solution to second order differential equation for a damped oscillator.



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

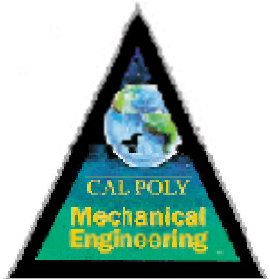
- Direct Measures-Other Direct Measures
  - Code of Ethics Graded Assignment
  - Graded ethical case studies
  - Embedded exam and homework questions in various 200 and 300 level classes
  - Diagnostic tests in fluid mechanics
  - Industrial Advisory Board (IAB) review of senior project reports



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

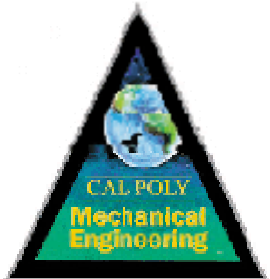
- Indirect Measures
  - Senior Surveys
    - Required survey in senior project class
    - On-line using Survey Monkey
    - Asks students to rate their abilities with respect to Criterion 3 skills
    - Criterion 4 improvements
    - Short answer responses about likes and dislikes of the program



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

- Indirect Measures
  - Alumni Surveys
    - Sent to alumni who graduated three to five years ago.
    - Primarily used to assess achievement of Program Educational Objectives
    - Deficiencies noted on alumni surveys also noticed in other assessment tools



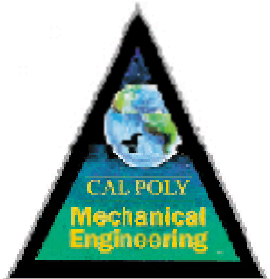
California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

- Indirect Measures

- Career Services

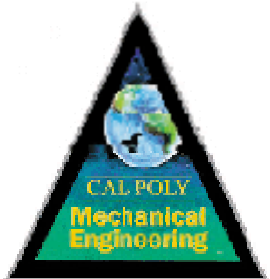
- Employer survey conducted by Career Services
    - In 2005, 107 surveys completed by 68 different mechanical engineering employers
    - Asked to rate Cal Poly graduates with respect to Criterion 3 skills
    - Also used to rate achievement of Program Educational Objectives



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Assessment Tools

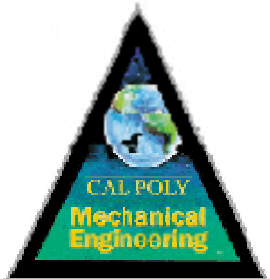
- Multiple Tools to Measure Each Outcome
  - Goal is to have multiple direct and indirect assessment tools to measure students' Criterion 3 skills
  - Therefore, improvement areas are not selected based on one survey result or one direct measure



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Review of Assessment Data

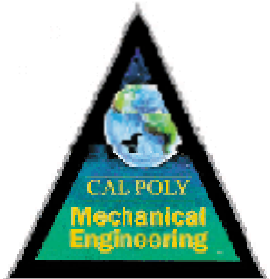
- Role of Curriculum Committee
  - Central clearing house for the assessment data
  - Primary organization tasked with making recommendations to the faculty
  - Reviews all direct and indirect measures associated with Criterion 3 and 9 skills
  - Ranks and strategizes the issues arising from the assessment data



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Review of Assessment Data

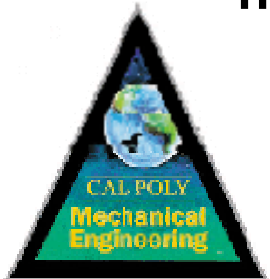
- Strategize Program Improvements
  - Curriculum Committee recommends program improvements to the entire faculty
  - Typically no more than 3 per year (or at a time)



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, [cpascual@calpoly.edu](mailto:cpascual@calpoly.edu)

# Review of Assessment Data

- Improvements Approved by Faculty
  - Faculty reviews recommendations from the Curriculum Committee
  - Discusses recommendations at fall retreat or faculty meeting
  - Entire faculty approves of improvement areas
  - Faculty member is put in charge of an improvement area

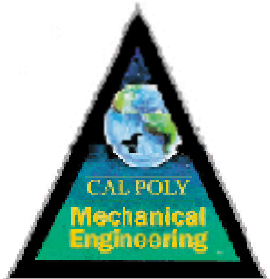


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - Senior Design/Senior Project Experience
    - Changed from individual senior project with an individual faculty member to industry-based team projects
    - Changed from two-quarter to three-quarter (or year-long) senior project
    - Change to industry-sponsored projects has resulted in improvements in the program (as measured by surveys and review of senior project reports)

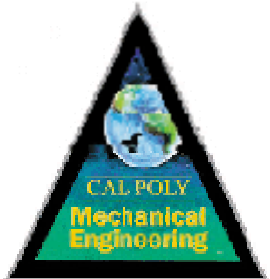


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - Design of Experiments (DOE)
    - Senior exam indentified weakness
    - Faculty concluded not enough practice in DOE
    - Implemented a DOE experience in fluid mechanics lab
    - Results are mixed
      - Students not comfortable with open-ended experiences
      - More practice needed in other labs (i.e. one experience will not fix weakness)
  - Improvements monitored with senior exam

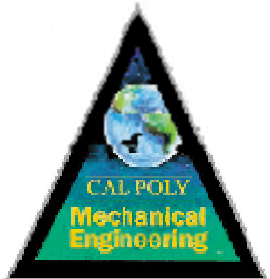


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - Standardized free body diagrams
    - Senior Exam identified weakness in ability to draw an appropriate free body diagram (FBD)
    - Faculty proposed using a standardized presentation of FBD starting in statics
    - FBD bookmark developed
    - Bookmark encouraged to be used by all faculty in various design classes throughout the curriculum
    - Improvement will be monitored on senior exam

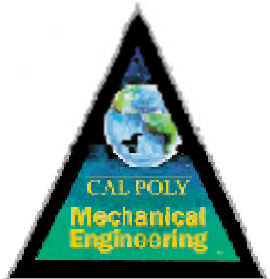


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - Calculus
    - Senior exam identified ability to solve ordinary differential equations as a weakness
    - Performance on FE exam is good
    - Faculty concluded more information is needed
      - This year simple calculus problems were used on the senior exam

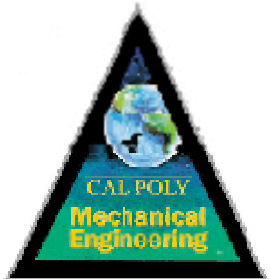


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - Written communication skills
    - WPE average score is below 8 (i.e. failing)
    - Alumni survey indicates this is a minor weakness
    - Pursued as an improvement area
    - Faculty reviewed where writing occurs in the program
    - Determined that after freshman English, very few individual writing experiences (1 or 2)
    - Methods being developed to help faculty assess student writing

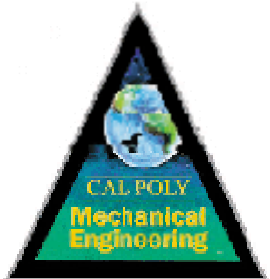


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

- Recent and Current Improvement Areas
  - FE exam as a requirement for graduation
    - 50% of students taking exam
    - Faculty consider the exam to be an important milestone in an engineer's professional development
    - Life-long learning
    - FE exam now required for graduation (taking the exam only)

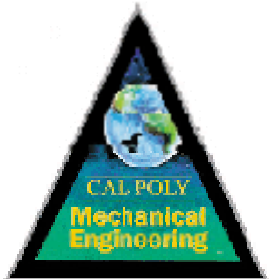


California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Criterion 4

## Continuous Improvement

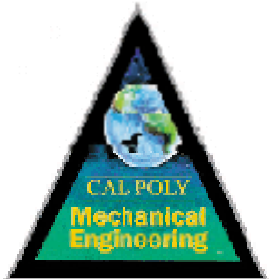
- Recent and Current Improvement Areas
  - Improve quality of faculty advising
    - Survey data indicate student dissatisfaction with quality of faculty advising
    - Faculty made aware of this student concern
- Generate improvement and monitor improvement
  - Senior Exam
  - Surveys



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Sustainable Process

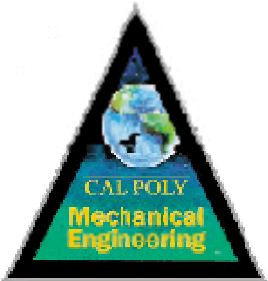
- Senior Exam
  - Administered twice a year
  - Use established question bank
  - Service load for ABET coordinator
- Faculty Involvement
  - More faculty involved in assessment process
  - Senior Exam grading
  - Reviewing the assessment data



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Sustainable Process

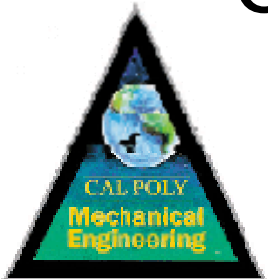
- Requires coordinator to manage process
  - Service load for individual faculty member
  - Must be enthusiastic about the process
  - Preferably a senior faculty member
  - Relief from teaching needed as ABET visit approaches



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Sustainable Process

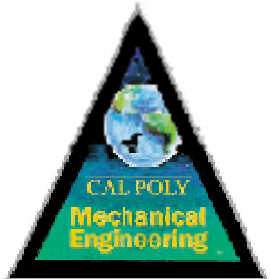
- Use Blackboard to disseminate results
  - All faculty are familiar with format
  - Web-based, so easy access
  - Maintains historical record
- College of Engineering manages centralized services
  - Surveys
  - Feedback on skills, outcomes, improvements
  - Consistency across programs



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Conclusion

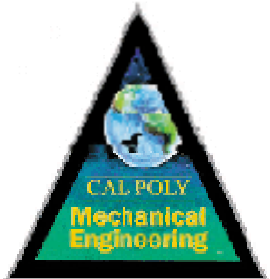
- Development of Criterion 3 skills
  - 3 or 4 skills per outcome
  - Start with small group of faculty
  - Need buy-in from entire faculty
  - Skills reviewed by curriculum committee



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Conclusion

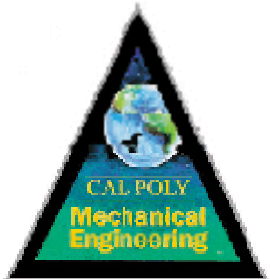
- Assessment Tools
  - Centralized measurement of skills easier to manage
  - Senior Exam
    - Measure most skills with single exam
    - Faculty set minimum acceptable performance level
    - More faculty involvement



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Conclusion

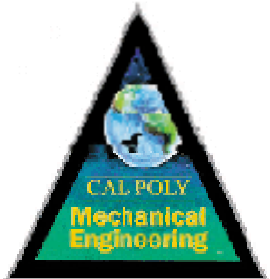
- Assessment Tools
  - Senior Project Class- measures 10 skills
  - FE Exam
  - Writing Proficiency Exam
  - Other Direct Measures
  - Indirect Measures



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Conclusion

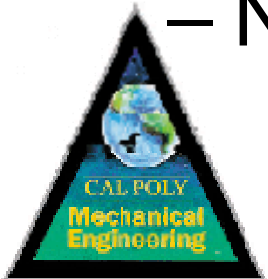
- Review of Assessment Data
  - Curriculum Committee
  - Strategize program improvements
  - Improvements pursued by faculty
    - Better to limit number of improvement areas



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu

# Conclusion

- Continuous Improvement
  - Senior exam and surveys used to monitor improvements
- Sustainable Process
  - With senior exam there is more buy-in from faculty
  - More faculty involved in process
  - Needs enthusiastic coordinator



California Polytechnic State University, San Luis Obispo, CA  
Christopher Pascual, cpascual@calpoly.edu