Session 1302

Design and Implementation of a Mechanical and Aerospace Program Assessment Model

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Abstract
This paper describes both the process and the content we at the SJSU College of Engineering experienced in designing, implementing and testing a model assessment system for engineering programs. Described in the context of the Mechanical and Aerospace Engineering Programs, the paper's focus is on the assessment system design and development, together with a critique based on pilot testing. More than two year's development, initiated and coordinated at the college level, were involved in preparation for the SJSU Fall 1999 ABET general review. The assessment system involves three nested assessment and enhancement (A&E) feedback cycles: a course cycle supporting an outcomes cycle that in turn supports the overall degree program and department enhancement cycle. Documentation products and personnel links devised to provide connectivity and effectiveness required considerable evolution and clarification as the development took place; additional revision will occur as a result of the pilot testing used for the ABET review. Significant lessons were learned in terms of educating faculty concerning assessment and achieving faculty participation in, and contributions to, the assessment system. The system appears to work well with minor gaps and adjustments still needing to be addressed. Performance of this system shows it meets accreditation requirements as well as the requirement for a continuous program improvement system.

I. Introduction & Context

This paper reports the process and results by which the College of Engineering and the Mechanical and Aerospace Engineering Department at San Jose State University developed and implemented a model for engineering program assessment. The MAE model will be reported in generic terms since it is applicable to any engineering program. The COE and MAE development process has been going on for more than two years in preparation for college-wide evaluation visits by ABET in Fall 1999. Regardless of evaluation visit results, the educational experience for faculty and staff in going through the assessment model development process has already made the effort a success.

The SJSU College of Engineering was recently reorganized into five engineering departments hosting nine degree programs of which all but one has historically enjoyed continuous accreditation. Also, the SJSU Department of Aviation and the Division of Technology were recently transferred into the College. As technology programs, they are not involved in the accreditation process incumbent on the engineering programs.

Characteristics of the SJSU engineering student body are as follows. The College student population of 2935 majors is 17% women, 46% Asian, 18% White, 35% other minority. From 1990 to 1997, freshman composite SAT scores rose nearly monotonically from 887 to 1028 while enrollment increased from 258 to 466. The average student age is about 26. The average student load is just under 12 units, and a majority of the upper-division engineering students works part-time. Nearly all students enter from Bay area high schools / community colleges, and are commuting to the University. The average time to degree is about 4.8 years, primarily due to taking less than a full load while working part-time. And about half the incoming freshman class requires additional preparation before being ready to begin the engineering curriculum.

The SJSU Aerospace Engineering Program was established in 1987 and began as a stand-alone program and department. It reached a peak enrollment of 400 majors (mostly freshmen sophomores; all AE classes are upper division) and was accredited in 1991. Following the end of the cold war, it experienced the same disastrous 67% enrollment loss as the national average for other programs. As with some other programs, productivity factors resulted in a merger being negotiated with another department, in this case mechanical engineering. Initiated in Fall 1996, the merger appears to have succeeded well with continuation of separate degrees and both programs benefiting from the increased resource base, efficiency and synergism. The SJSU undergraduate AE Program has been known for its strong emphasis on laboratory education with advanced equipment, full and balanced aeronautics and astronautics curriculum, and emphasis on applications. The combined MAE faculty number 10 full-time, supplemented with approximately 12 part-time lecturers from industry.

A College Assessment Task Force (ATF) was formed in the Fall of 1997 to provide leadership and support to all engineering programs for developing and implementing program assessment plans. Faculty members attended national workshops and conferences on assessment and brought back ideas to work with their colleagues. The task force has developed a college schedule, a framework, templates for various instruments for gathering baseline data, and processes for assessment and continuing improvement. Task force members then take these back to share with their department chairs and faculty. Individual programs can use them directly or modify them to better suit their program objectives and performance criteria.

Department chairs and their ATF representatives worked with the department faculty and other constituencies to develop the following for programs within each department:

- Program educational objectives and performance criteria consistent with program-unique mission, the needs of various constituencies, and the ABET Engineering Criteria 2000's specifications;
- An assessment process that demonstrates educational objectives and their associated learning outcomes are being achieved;
- A system of evaluation that shows a commitment to and realization of continuous improvement.

The Dean meets with the Assessment Task Force and department chairs regularly to share information, monitor their progress, and provide support when needed.

II. Assessment Model Design

Evaluation of achievement of educational objectives requires both a process and data to be used in the process. We define the process as including *assessment* ("How well are the objectives being achieved?") and *evaluation* ("What changes need to be made to enhance achievement of the objectives?") to produce *enhancement* (carrying out the requisite changes leads to increased achievement of the objectives). The MAE Department's process addresses achievement of educational objectives through addressing the Program outcomes that support the objectives. Table 1 shows the 6 Educational Objectives and the 11 Program Outcomes that support them for the ME and AE degree programs.

The ME/AE Programs assessment, evaluation and enhancement (A&E) process is visually depicted in Figure 1. It consists of three nested A&E loops. The overall loop is both for continuous enhancement of the achievement of Program educational objectives and for continuous review of the objectives themselves. Assessing and enhancing achievement of the objectives is enabled by the Outcomes A&E loop. Outcomes assessment and enhancement in turn depends primarily (but not exclusively) on assessment and enhancement of individual course learning objectives. However, the Outcomes A&E loop is the key element, because it institutionalizes the process for holding individual courses, their sequencing and their "vertical integration" through the curriculum accountable to achieving the program educational objectives (through the Outcomes). Briefly stated, achievement of Program educational objectives is evaluated in terms of achievement of the supporting Outcomes, which involves the degree to which students meet specified Outcomes performance criteria. Outcomes achievement occurs through accumulation and integration of achievement of individual course learning objectives.

Stated bottom up, the course A&E loop is to be performed for all courses and has two purposes: 1) to support the achievement of program outcomes that support program educational objectives; and 2) to provide a reliable, objective and consistent basis for continuous course improvement. The Program A&E loop integrates the contributions of all courses supporting each outcome, assesses actual achievement of the outcome and provides the system mechanics for identifying shortfalls and determining how outcome achievement may be improved (e.g., specific course changes).

Some, but not all, of the interior processes and products (or documentation) in this system are common to most systems, and have been addressed by many universities in their development of assessment processes. Others will be new to the reader. The components will be presented briefly here for completeness and to provide an example of the concept for readers new to the process. The common processes / products include (listed in top-down order):

- Identifying a variety of candidate instruments for evaluating achievement of educational objectives (example instruments are noted in Figure 1 and various tables);
- Specifying performance criteria and metrics for each outcome (Table 2, which lacks metrics);
- Identifying which courses (freshman through senior level) are the primary ones for supporting achievement of each outcome (Table 3);

The following processes/products that are key to our assessment model are not necessarily common to other models:

- An Outcome Flowchart showing the intended vertical integration of the outcome skill as the student experiences it (see example in Table 4)
- An Outcome Notebook for each Program Outcome (sample table of contents shown in Table 5);
- A Course Journal for each course (sample table of contents shown in Table 6);
- Course Assessment Matrix (CAM) and Program Assessment Matrix (PAM) for each course (Tables 7,8).

The reader somewhat familiar with an assessment process need only scan Tables 2-4 as illustrations, but Tables 4-8 deserve some study. One must realize that in the "shakedown" initial development process as well as in an up and running system, all these processes/products are dynamic and changing with periodic review.

The "bottoms-up" data flow (tables above in reverse order) by which the system operates is as follows. Each course Instructor (Coordinator in the case of multiple sections) develops and maintains the course CAM, PAM and Course Journal. The CAM organizes course topics, assessable components and assessment methods. The PAM indicates the contributions the course makes (through its Learning Objectives) to achieving and assessing the appropriate Program Outcomes. The Course Journal is more restrictive than the "course notebooks" used in accreditation reviews under older ABET criteria in that it is not intended to contain student work. This is because under older criteria, the courses were being ABET-evaluated (topics), whereas under the new criteria, Program Outcomes (Outcome Notebooks) are being evaluated. The course Instructor/Coordinator also is responsible developing and maintaining the Course Expanded Green Sheet and ABET Course Syllabus, which list student learning objectives and course relationship to Program Outcomes and Educational Objectives. These are key components in the process and in the Course Journal.

Each Program Outcome has a Champion (faculty member or team) who develops and maintains the Outcome Notebook that is the new innovation and the key instrument for assessing Outcome achievement. The Champion compares the "promises" each course makes in terms of expected contributions to the Outcome to evidence of Outcome achievement (student work sampled from the various supporting courses, surveys, and the other Outcomes assessment methods). In essence, the Champion's results and recommendations are reported "up the line", i.e., to the whole faculty, for discussion and decisions for enhancement, and "down the line", i.e., to the Course Instructors for required changes and enhancements.

The whole process involves all Program faculty, with each individual contributing in more than one role. It also requires a plan and schedule for periodic cycles of assessment and enhancement at all three levels (Course, Outcome, and Program) – see Table 9. And an overall factor of central importance is the choice, development and administering of a wide variety of assessment methods for the Educational Objectives (top level), involving different constituents for the Program. This is not a simple or trivial matter; it also is dynamic process, requiring evolution and revision.

III. Model Implementation

We describe here our experience with implementing this model, for which we must say that it is not just "the devil is in the details." The primary implementation challenges are:

- faculty culture;
- system completeness and complexity;
- issues of parallel versus sequential development;
- the dynamic nature of every component;
- resources and timeline;
- decision and participation process

The following is a brief discussion of each of these in terms of the generic issue as well as our experience and solutions.

We all know the challenge of faculty culture. The fundamental change mandated by ABET Crtieria 2000 is two-fold: 1) a shift to degree Outcomes-based achievement evaluation (as opposed to topics and units) in which the outcomes to a significant extent are determined by constituents other than the faculty; and 2) use of an ongoing assessment process for continuous program improvement. The shift to Outcomes can be a problem for faculty in two ways: 1) faculty may not be whole-heartedly behind some of the Outcomes (possibly some of the 11 ABET mandated Outcomes); and/or 2) faculty may wish they could continue to evaluate topics and units rather than vertical integration of skills over four years. We are fortunate in our department. Our Program Outcomes consist of only the 11 ABET mandated ones and our faculty support all of them. In addition, as educators our faculty indeed wants to evaluate and enhance Program quality based on Outcome skills as the student's skills mature in progressing to the degree. The ongoing assessment process can be onerous for the faculty because of the work and effort (usually unrewarded) required (resources). Our faculty carry very high class work loads, and we were not able to compensate them in general. The smaller the department, the more difficult is the resource challenge. However, all our faculty did join in as a team, and we all were encouraged by the teamwork and by seeing some early results of establishing and using the assessment system. But larger than the resource problem is the problem is that some faculty do not philosophically accept the requirement to recognize "customers" and "constituents" being involved in setting degree Outcomes with resulting impacts right down to the individual courses! Frankly, we won't be able to say we have passed this test of faculty culture until we have seen some of the dynamics of "externally" mandated changes right down to the course level ("external" could even be another faculty member!). This is perhaps the first time for some faculty that other people (even other faculty) are authorized to mandate changes in content or assessment methods or presentation in their course!

On the one hand, the challenge of system completeness and complexity is that when the system is implemented one discovers gaps and awkward connections / processes. On the other hand, good engineers can design wonderful systems, but the systems (like this one) can become very complicated and confusing; streamlining may be required, but where? While we haven't addressed the streamlining issue yet (we are about to), we have found gaps and awkward processes in our system that we need to improve. At the top level, it is awkward to have to map Outcomes into Educational Objectives, and it can be confusing to talk in terms of achieving

Outcomes versus Objectives (confusing even down to the course syllabi level). Yet the Program Objectives and Outcomes are very different from each other and mapping one into the other seems to be here to stay. Another awkward feature is the need for having different components or elements on different cycles and periods. Good visualizations, definitions, and documentation (instructions) together with clear assignment of responsibilities can overcome this challenge. A third issue is proper time-interleaving/shifting and analysis of data such as survey data. With so many system components and interior cycles, the faculty must be well organized on master charts and schedules. A very awkward component is the element of student course work - how much should be collected, how sampled, and where should it be kept for review each cycle by multiple Outcome Champions? Should some or all of it go into Course Journal or Outcome Notebooks (duplicate copies)? Also, the overall cross-mapping of courses with Outcomes and multiple roles played by each faculty member poses a real challenge in communication and system management. And the CAM and PAM instruments for each course may need significant revision, perhaps even replacement.

How did we go about the system development and implementation process in “sequential” or “parallel” mode? In the “sequential” mode, one designs the whole system top-down in detail, then implements and tests it. Like any true system, this assessment model cannot be developed this way. The very process of implementing a partial system along the way results in identifying additional mechanisms and connectivities, etc, that must be designed into the system. In addition,the faculty must see some tangible products and results along the way so that the concepts become real and are clarified, and they are motivated to continue. In truth, one starts with an overall system concept and then develops both each of the various components in parallel, both in terms of concept and its realization. Indeed all the parts are interconnected and as revisions are made in any component, they affect all the others (parallel engineering).

It should be obvious that every component in this system is dynamic, i.e., changes content if not form over time. In order of increasing time scale, CAMs, PAMs, Expanded Green Sheets and Syllabi, Course Journals, Outcome Notebooks, Outcome Performance Criteria and Metrics, the Outcomes themselves and Program Educational Objectives will be periodically reviewed and revised. The subsequent revision cycles should become more and more “fine-tuning” after the full system is installed, “debugged”, pilot tested and brought into maintenance mode.

The resources and timeline required for establishing and maintaining such an assessment model is best indicated by experience. Our college required more than two years to establish a formative model in each department, with College level support being one-course faculty release time for a single department coordinator in each department. Of this, we estimate more than a year was required to understand some of the concepts and terminology in assessment. We still argue and have differences over the definition of goals versus objectives, and distinctions among outcomes, performance criteria and metrics! Other than the department coordinator, department faculty were not compensated for the development effort – it was an extra duty above all their other duties. In the last year of preparation, we meet monthly and then biweekly as a faculty in discussing and determining many of the issues involved in the assessment system.

What were the dynamics in the MAE department for faculty participation and decision processes? The Department ABET coordinator (the author) worked closely with the Chair especially during the second year, and together they provided the required leadership. The Coordinator primarily drafted the overall system and created flow charts for it, proposed example components, created status tables and planning charts as well as delegation and encouragement memos, and generally strategized with the Chair how to motivate the faculty and get them invested in the process. Earlier on, decisions such as the Program Outcomes and Education Objectives, the courses to be used to support outcomes, the assignment of Outcome Champions, the procedures to be for collecting and using student work, etc were discussed by the whole faculty and decided by consensus. But the most difficult challenges were: 1) the protracted time required to educate faculty to a common definition of learning objectives, goals, and concepts in assessment; and 2) reaching consensus on reasonable course learning objectives and especially a common Expanded Green Sheet/Syllabus Form (the most contentious issue of all!). And we have yet to experience the collegial process of determining changes that need to be made to curriculum and individual courses for program enhancement! A rushed pilot test of the system performed just before the ABET Fall 1999 visit did indeed manage to capture efforts of all the faculty and provided a first indication that the essential system design works well.

Overall, the basic system design works well and we have some initial assessment results that show unexpected areas of curriculum weakness. The faculty have taken ownership and work as a team in the process, although the maintenance level-of-effort poses a real problem. We are not quite to a maintenance mode, since we have more pilot testing to do. We need to develop metrics for measuring against Outcome performance criteria. And we need determine a plan for periodic and interleaving assessment, evaluation and enhancement cycles and tasks.

IV. Summary and Conclusions: Lessons Learned

The assessment model presented here works very well in providing the mechanism for consistency and integration of the curriculum as well as a complete process for assessment and enhancement of the degree program. It specifically enables efficient integration of accumulating Outcomes skills and the methods for identifying shortcomings and weaknesses to facilitate changes for increased achievement. This model necessarily introduces several mechanics and products beyond the weighty course notebooks and “unit counting” processes under the old ABETcriteria. These additional activities and products will require more time and effort on a maintenance level than the old procedures.

More far-reaching than the assessment and enhancement facility itself, this system draws all the faculty into active (and in our case, enthusiastic) participation in a team dedicated to continuous improvement of the educational program and student learning. It is a system design that engineering educators can appreciate and by which they can be motivated and empowered as educators. This is the real and long-term reward for the extra effort in development and establishment of the process.

For lessons learned, we offer the following in the form of advice:

- Provide at least 2 years to design, develop and install your assessment model (another 2-3 years will be required for it to become established).
- Create a forum from the beginning for representatives all engineering departments in the college to continuously share practice and encourage and track one another.

- Have a leader in the department coordinate, provoke and lead, but do everything possible to make important decisions consensual and to get all faculty to sincerely involved (build a team!).
- Have fun designing the model but recognize that faculty must “jump into it” in detail and implement it early on in order to understand it and finish the design (and become motivated)!
- Engineers love to overkill in a design – expect to have to find ways to streamline it once it is established (beware of maintenance effort levels).
- Recognize that definition of Outcomes, performance criteria and especially metrics take is the single most difficult process and are the heart of the process.
- Do not underestimate the time needed to assimilate what “goals”, “objectives”, etc, mean but also realize faculty could debate forever on these without reaching unanimity.
- Recognize that beyond sincere participation, faculty are most sensitive (potentially defensive) to the core of the process – educational goals set by others and mandated changes in “my” course.

Figure 1 BS Engineering Program Assessment & Enhancement (A & E) Process

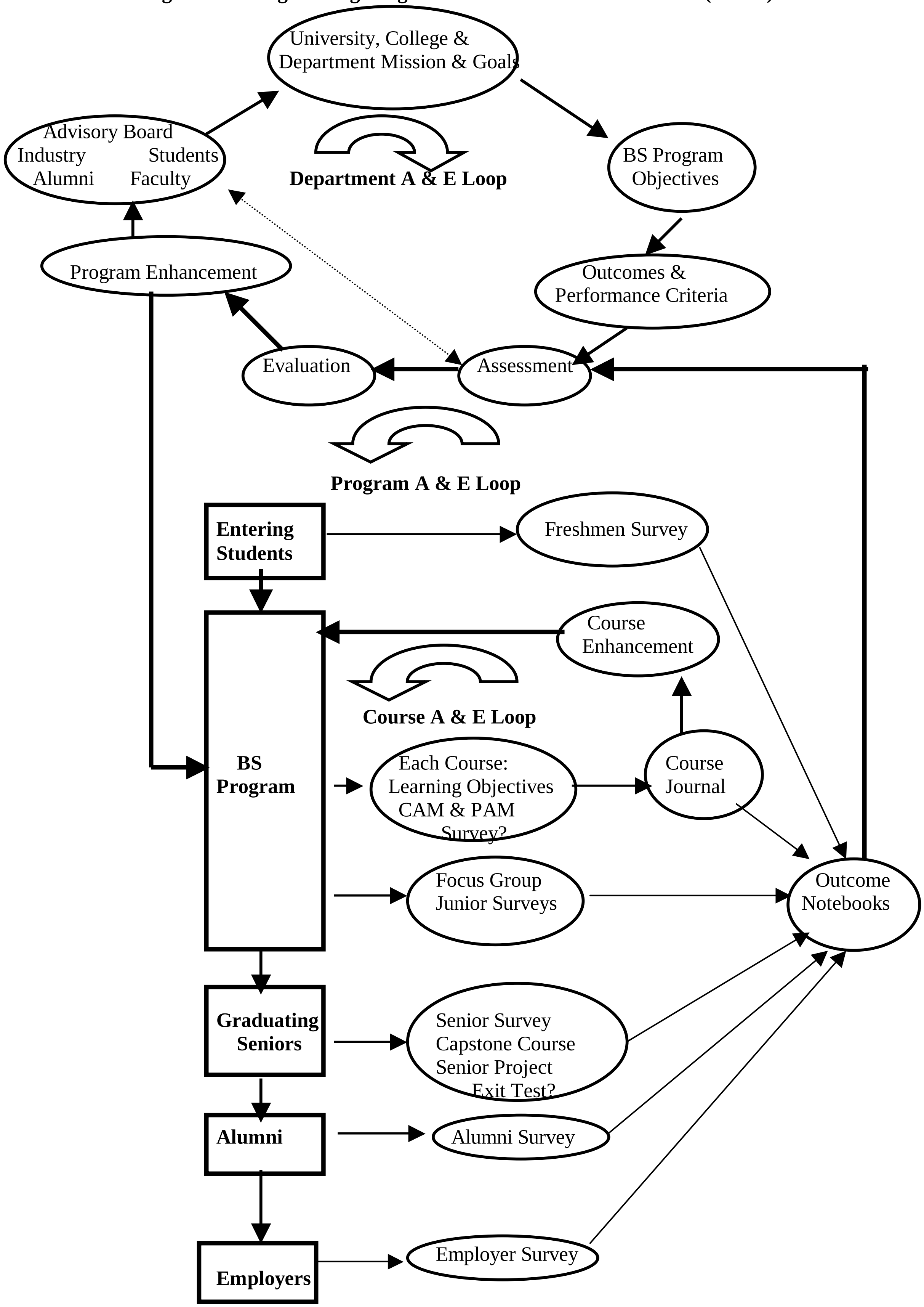

Table 1 Relationship Between Educational Objectives and Outcomes

Program Educational Objectives	Program (and Criterion 3) Outcomes
1. To a offer broadly based curriculum to our students that consists of two components: courses in engineering fundamentals that provide a basis for professional competence and life-long learning; and courses that provide contemporary professional skills required by industry.	Outcome 1: Have an ability to apply knowledge of **mathematics, science and engineering**. Outcome 3: Have an ability to **design** a system, component or process to meet desired needs. Outcome 5: Have an ability to identify, formulate and **solve** engineering **problems**. Outcome 11: Have an ability to use the techniques, skills, and **modern engineering tools** necessary for engineering practice.
2. To provide students with a strong foundation for graduate studies in AE/ME and related fields.	Outcome 9: Have a recognition of the need for, and an ability to engage in, **life-long learning**.
3. To provide students with experience in using computers and information technology in problem solving and learning.	Outcome 5: Have an ability to identify, formulate and **solve** engineering **problems**. Outcome 11: Have an ability to use the techniques, skills, and **modern engineering tools** necessary for engineering practice.
4. To provide students with hands-on experience through laboratory courses.	Outcome 2: Have an ability to design and conduct **experiments**, as well as to analyze and interpret data.
5. To develop students' ability to communicate and work effectively in teams.	Outcome 4: Have an ability to function on **multi-disciplinary teams**. Outcome 7: Have an ability to **communicate** effectively.
6. To develop students' understanding of multicultural and global perspectives, as well as ethical choices inherent in the engineering profession.	Outcome 6: Have an understanding of **professional** and **ethical** responsibility. Outcome 8: Have the broad education necessary to understand the impact of engineering solutions in a **global/societal** context. Outcome 10: Have a knowledge of **contemporary issues**.

Table 2 AE / ME Engineering Program Outcomes and Performance Criteria

Outcome 1: Graduates will have proficiency in and an ability to apply knowledge of engineering, chemistry and calculus-based physics, and advanced mathematics including multivariate calculus, differential equations, and familiarity with statistics and linear algebra

Ability to use knowledge of mathematics to solve engineering problems

1. The student can use differential and integral calculus to solve equations in engineering.
2. The student can solve ordinary differential equations commonly used in engineering.

Ability to use knowledge of physics and chemistry to solve engineering problems

3. The student can use concepts in chemistry to solve engineering problems.
4. The student can use concepts in physics to solve engineering problems.
5. The student can formulate governing differential equations using fundamental laws of physics.

Ability to use fundamental engineering principles to design and analyze components and systems

6. The student can analyze components and systems using fundamental engineering principles.
7. The student can design components and systems using fundamental engineering principles.

Outcome 2: Graduates will have an ability to design and conduct experiments, as well as to analyze and interpret data.

Ability to conduct an experiment

1. The student can conduct a simple engineering experiment accurately and collect data that represents actual aerospace engineering phenomena.
2. The student can operate appropriate testing equipment.

Ability to design an experiment

3. The student can determine the range of values of the parameters to be monitored as control variables for an experiment.
4. The student can determine the data to be collected during an experiment..
5. The student can use confidence intervals and statistical analysis to design a hypothetical experiment..

Ability to analyze and interpret data

6. The student can prepare graphs, tables and reports presenting data from an experiment..
7. Considering the data presented, the student can interpret the experiment and make conclusions and recommendations about the phenomena tested.
8. Student can to compare experimental results theoretical predictions

Outcome 3: Graduates will have an ability to design a system, component, or process to meet desired needs.

1. Demonstrate an ability to design a component to meet functional specifications and constraints.
2. Demonstrate an ability to design a system to meet functional specifications and constraints.
3. Demonstrate an ability to produce effective documentation of the design of a component or system.

Outcome 4: Graduates will have an ability to function on multi-disciplinary teams.

1. Demonstrate an ability to function on a team in engineering laboratory and/or lecture courses, including participation both as a team member and as a team leader.
2. Demonstrate an ability to function on a team in a team-based senior project course, including participation as member and team leader in problem-solving and decision-making activities, and in developing team strategies, plans, and schedules.
3. Demonstrate an ability to function on a team for team-based presentation and reporting activities.
4. Demonstration of effective participation in a collaborative industry/student design team.

Outcome 5: Graduates will have an ability to identify, formulate, and solve engineering problems.

Ability to Identify Engineering Problems

1. Demonstrate an ability of understanding and identifying the principles and theories on which the given problem is based.
2. Demonstrate an ability to understand the scope and complexity of the problem
3. Demonstrate an ability to clearly understand what is ‘given’ and ‘required in a given problem.
4. Ability to Formulate Engineering Problems
5. Show an ability draw the free-body-diagrams, sketches, flow-charts, figures, etc. prior to the solution.
6. Show an ability to begin a solution by first presenting the applicable theories and equations.

Ability to Solve Engineering Problems

7. Show an ability to solve several different problems based on a single principle or theory.
8. Show an ability to solve problems where a combination of engineering principles is applicable.
9. Ability to work on open-ended problems.

Outcome 6: Graduates will have an understanding of professional and ethical responsibility. 1. Demonstrated ability to analyze and evaluate a scenario, real or hypothetical, in which personal and/or professional ethics are involved. The student's resolution should conform to a reasonable standard of contemporary ethical standards. 2. Demonstrated knowledge of safety factors in the design process. 3. Demonstrated knowledge of the impact of the products on society that the student designs, including the production of and use of those products. 4. Demonstrated understanding of the impact of decisions made by engineers on society as a whole.
Outcome 7: Graduates will have an ability to communicate effectively. 1. Demonstrate an ability to develop and give an oral individual or group presentation that is organized and uses effective visuals. 2. Demonstrate an ability to write documents that have correct grammar, are well organized, properly formatted, and convey a specific concept. 3. Demonstrate an ability to convey technical information through the use of data plots, graphs, calculations, drawings and equations.
Outcome 8: Graduates will have the broad education necessary to understand the impact of engineering solutions in a global/societal context.
Outcome 9: Graduates will have a recognition of the need for, and an ability to engage in life-long learning. 1. Demonstrated ability to research, gather, and assess information using external sources specific to a given engineering issue. 2. Demonstrated ability to learn certain things on their own. 3. Demonstrated recognition of the need for professional licensing. 4. Demonstrated participation in professional societies and meetings.
Outcome 10: Graduates will have a knowledge of contemporary issues. 1. Demonstrated ability to synthesize and analyze information related to contemporary issues. 2. Demonstrated ability to work on projects that address contemporary issues such as legal issues, current codes, new technology, the environment, traffic, and other social issues.
Outcome 11: Graduates will have an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. 1. Demonstrate an ability to use Internet to locate pertinent information. 2. Demonstrate and ability to use computer programs and computer skills to organize and present information, to analyze problems, and to design components and systems. 3. Demonstrate an ability, to use other modern tools and instruments for engineering applications.

Table 3 MAE Outcome Supporting Courses

Outcome	**BSME**	**BSAE**
1. Math & Science Engr. (Maddren)	CE 99; MatE 25; ME 101, 106, ME 111, 113, 114, 130, 147, 154	CE 99, MatE 25; ME 101, 111, ME 113 ME 130
2. Experiments/Data (Lambert)	MatE 25; ME 106, 114, 120; CE 113	MatE 25; AE 162; ME 120
3. Design (Furman)	Eng. 10, ME 154; ME 195A, B	Eng 10; AE 162, 165, 170A, 170B
4. Multidisciplinary Teams (Wang)	Eng. 10, ME 106, 120, 195A,B	Eng. 10; ME 120; AE 170A, 170B
5. Engr. Problem solving (Agarwal)	Eng 10; ME 101, 111, 113; 114, 147, 154; CE 112	Eng 10; ME 101, 111, 113; CE112 AE 162, 165
6. Professional & Ethics (Pernicka)	Eng 10, 100W; ME 195A, 195B	Eng. 10, 100W: AE 170A, 170B
7. Effective Communication (Desautel)	Eng. 10,100W; ME 106, 114, 120; ME 154, 195A, 195B	Eng 10, 100W; ME 120; AE 170 A, 170B

8. Global & Societal (Lambert)	Eng 10, 100W; ME 113, 114	Eng 10, 100W; ME 113; AE 170A, 170B
9. Life-long Learning (Mourtos)	Eng 10, 100W; ME 111 ME 195A, 195B	Eng 10, 100W; ME 111 AE 170A, 170B
10. Contemporary Issues (Barez)	Eng. 100W; ME 113 ME 195A, 195B	Eng. 100W; ME 113 AE 165, 170 A, 170B
11. Modern Tools (Hsu)	Eng. 20, Eng. 30, ME 195A, B (ME 160, ME 165), ME 106	Eng. 20, Eng. 30, AE 114, AE 162, AE 167, AE 170A, B

Table 4 Example of an Outcome Flowchart

Outcome #3: Graduates Must Have an Ability to Design a System, Component, or Process to Meet Desired Needs

Semester	Courses	Assessable Components	Level	Assessment Methods
Freshman Fall	E 10	Understanding of the design process Application of the design process	Introductory	lab project, HW, and exam lab exercises, written and oral report
Freshman Spring				
Sophomore Fall				
Sophomore Spring	ME 106	Design of signal conditioning, analog and digital interfaces to electromechanical systems. Design of a mechatronic device	Applied	HW, exams Demonstration of prototype hardware, presentation, project report
Junior Fall				
Junior Spring	ME 154	Mechanism synthesis, component stress and fatigue analysis Design of a mechanical device to solve a problem	Applied	HW, exam Demonstration of prototype hardware, project report
Senior Fall	ME 195A	Definition of a design problem State-of-the-art review Development of design specifications Solution concept generation Detail design		Presentations, written report
Senior Spring	ME 195B	Rapid prototyping Testing and design refinement		Hardware models, presentations, written report

Table 5 Example Outcome Notebook Table of Contents

Tab 1: Assessment Summary
- Outcome Flow Chart
- Overall Assessment Results
- Evaluation Results
- Enhancement Plan and Implementation

Tab 2: Outcome Performance Criteria

Tab 3: Support Course Descriptions
- CAMS / PAMs
- Expanded Green Sheets with Course Goals & Student Learning Objectives

Tab 4: Support Course Assessment Results
- Selections of student work at A, B, C levels

Tab 5: Assessment of Culminating Indicators
- Capstone Course
- Senior Project
- Exit Test

Tab 6: Survey Assessment Results

Entering Students	Focus Group
Junior Students	Alumni
Graduating Seniors	Employer

Appendix:
- Program Assessment & Enhancement Process Diagram
- Program Assessment & Enhancement Calendar Cycles

Table 6 Example Course Journal Table of Contents

Tab 1: CAM / PAM

Tab 2: Goals & Objectives
- Expanded green sheet including:
  - Course Goals
  - Student Learning Objectives

Tab 3: Homework & Exams
- List/Description of Homework Assignments
- Exams with grading statistics
- Quizzes

Tab 4: Labs & Projects
- Description & Assignment:
  - Computer Laboratory Assignments
  - Physical Laboratory Experiments

Tab 5: Significant Handouts

Tab 6: Course Assessment
- Student statistics
- Surveys
- Grade distribution

Table 7 Course Assessment Matrix

Course Number: ME 111
Course Name: FLUID MECHANICS
Evaluator: NIKOS J. MOURTOS
Date of Evaluation: 13-Dec-97

TABLE 1 - Course Specific Topics Summary
(See notes at end of table to explain abbreviations)

MAJOR TECHNICAL TOPICS (No more than 15 total)	TOPIC KEYWORDS (1 to 3)			EXPECTED LEVEL AT COURSE END (I, A or D)	ASSESSMENT METHOD(s) (EXAM, HW, EXP, IP, GP, NA, OTHER) (1 TO 3)			PREREQUISITES COURSE(s) (0 to 3)			
TOPIC	KEYWORD 1	KEYWORD 2	KEYWORD 3	LEVEL	METHOD 1	METHOD 2	METHOD 3	PRECORS 1	PRECORS 2	PRECORS 3	PRETOPIC 1
Definition of a Fluid	Solids	Liquids	Gases	I	HW	EXAM			PHYS 61		Fluids
Fluid Properties	Density	Viscosity	Surf. Tension	I-D-I	HW	EXAM			PHYS 61	MATH 30	Newton's Laws
Fluid Satics	Pressure	Hydrostatic Eq.	Manometry	D	HW	EXAM		CE 99		MATH 30	Force Balance
Hydrostatic Forces	on Plane Surf.	on Curved Surf.	Buoyancy	D	HW	EXAM		CE 99		MATH 30	Force Balance
Fluids in Motion	Velocity	Flowrate	Flow Visualiz.	I	HW	EXAM				MATH 30	
Continuity	Steady	Unsteady		D	HW	EXAM				MATH 30	
Bernoulli's Equation	Pitot-Tube	Cavitation		D	HW	EXAM			PHYS 61	MATH 30	Newton's Laws
Momentum Principle	Jets	Pipe-Bends	Propulsion	D	HW	EXAM		CE 99		MATH 30	
Energy Principle	Heat Transfer	Shaft Work	Grade Lines	D	HW	EXAM			PHYS 61	MATH 30	Energy book.
Dimensional Analysis	Reynolds No.	Mach No.	Froude No.	I	HW	EXAM			PHYS 61	MATH 30	Units/Dimens.
Similitude	Geometric	Dynamic	Pressure Coeff.	I	HW	EXAM			PHYS 61		Various Forces
Boundary Layer on a Flat Plate	Laminar	Turbulent	Skin Friction	D	HW	EXAM				MATH 30	Newton's Laws
Pipe Flow	Laminar/Turb.	Moody diagram	Minor Losses	D	HW	EXAM				MATH 30	Newton's Laws

NOTES FOR TABLE 1 :	
Expected Level of Student Capability at End of Course	I = Introduction to Topic or Concept. A = Advanced Theoretical Development. General models but not used for Design. D = Design or Application Level. Used for Design of Component, System or Process.
Assessment Method(s) Used to Evaluate Level of Student Capability. In Priority Order	HW - Graded Homework Problems EXP = Experiment IP - Individual Project./Report GP = Group Project NA- Not Assessed Other = Any other method that is applied

Table 8 Program Assessment Matrix

Course Number: ME 111 Course Name: FLUID MECHANICS

Evaluator: NIKOS J. MOURTOS Date of Evaluation: 13-Dec-97

TABLE 2 - Program ABET Attributes Summary (See notes at end of table to explain abbreviations)

TOPIC NUMBER	MAJOR PROGRAM OUTCOMES TOPIC	ASSESSABLE COMPONENT(s) (0 (NP) to 3)			EXPECTED LEVEL COURSE END (I, A or D)	ASSESSMENT METHOD(s) (EX, HW, EXP, IP, TP, NA,Other) (1 to 3)			PREREQUISITES COURSE(s) (0 TO 3)			PREREQUISITES TOPIC(s) (0 to 3)	
OUTTOP	DESCRIPTION	COMP1	COMP2	COMP3	LEVEL	METHOD1	METHOD2	METHOD3	CORS1	CORS2	CORS3	TOPIC1	TOPIC2
1	1.0 ability to apply knowledge of mathematics, science and engineering	Hydrostatics	Continuity	Momentum	I	HW	EXAM		MATH 30	PHYS. 61	CE 99	Integra-tion	Newton's Laws of Motion
2	2.0 ability to design/conduct experiments and analyze/interpret data	Hero's Fountain			I	EXP.	TR			PHYS. 61			Pressure
3	3.0 ability to design system, component or process to meet desired needs	NP											
4	4.0 ability to function on multi-disciplinary teams	Perform Exp. in Teams	Write TR	TPS	A	EXP.	TR	TT					
5	5.0 ability to identify, formulate and solve engineering problems	Continuity	Momentum	Energy	D	HW	EXAM		MATH 30	PHYS. 61	CE 99	Integra-tion	Newton's Laws of Motion
6	6.0 understanding of professional and ethical responsibility	NP											
7	7.0 ability to communicate effectively	In-Class Problem-Solving in Teams	Team Tests		I	End-of-Semester Reflection	Students write a Poem on a fluid mechanics concept						
8	8.0 understand the impact of engineering solutions in a global/societal context	NP											
9	9.0 recognition of the need for and an ability to engage in life-long learning	Responsible to learn certain things on their own				End-of-Semester Reflection							
10	10.0 knowledge of contemporary issues	NP											
11	11.0 ability to use the techniques, skills and modern tools necessary for engineering practice	NP											

NOTES FOR TABLE 2 :	
Assessable Component(s)	NP = Not a Priority in this Class Otherwise, please list specific activities related to this attribute
Expected Level of Student Capability at Course End	I = Introduction to Topic or Concept. A = Advanced Theoretical Development. General models but not used for Design. D = Design or Application Level. Used for Design of Component, System or Process.
Assessment Method(s) Used To Evaluate Level of Student Capability. In Priority Order	EXP = Experiment TT = Team Test HW - Graded Homework Problems TPS = Team Problem Solving IP - Individual Project./Report TP = Team Project TR = Team Report NA- Not Assessed Other = Any other method that is applied