Session 1566

Implementation of Assessment Procedures into the Mechanical Engineering Curriculum

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Abstract

The Department of Mechanical Engineering Stevens Institute of Technology (SIT) is aiming at devising a modern engineering program that reflects the recent nationwide trend towards enhancement of traditional lecture-based courses with a design spine and a laboratory experience that propagates through the entire educational program. Another thread to be woven into the whole educational experience is the fostering of independent entrepreneurship through Technogenesis, a cornerstone of the institute's strategic plan. Technogenesis is the educational frontier at SIT wherein faculty, students, and colleagues from industry jointly nurture the process of conception, design, and marketplace realization of technology.

The scope and complexity of the planned curriculum developments to address the above require careful planning of assessment procedures to ensure the educational integrity of the resulting program. Therefore, the School of Engineering (SoE) formed an assessment committee and charged it with the implementation of outcomes-based assessment by quantitative measurements of performance and attitudes throughout a hierarchical matrix of curricular goals, objectives, and performance criteria. A Microsoft Windows application termed the Stevens Educational Assessment Application (SeaApp) was developed to automate the assessment system. This application was designed for the usage by instructors and graders. It assists them in relating the course objectives to the curriculum objectives and in monitoring the performance of students according to curriculum performance criteria.

This paper outlines the multi-layered assessment structure of curriculum performance criteria and assessment performance criteria of the Stevens assessment process and discusses the application of these general assessment procedures to the design of the mechanical engineering curriculum in general and one specific junior course in mechanical engineering - ME 358 Machine Dynamics and Mechanisms - in particular.

I. Introduction

The assessment system that is currently being developed and implemented at the SoE at SIT is focused on the academic aspects of accreditation as expressed in ABET Criteria 2, 3 and 8. The system aims at implementing outcomes-based assessment by quantitative measurements of performance and attitudes throughout a hierarchical matrix of curricular goals, objectives, and performance criteria.[1] An inter-linked feedback system, represented by three assessment loops at the engineering curriculum, program and course levels is designed to share and manage a broad range of assessment data analyses.[2] This approach to grading, called distributed grading, produces targeted reports of student achievement. Attitudinal measures of self-assessment provide metrics of student and faculty attitudes about the learning process.[3, 4]

According to ABET Criterion 2, each engineering program for which an institution seeks accreditation or reaccredidation must have in place (a) detailed published educational objectives that are consistent with the mission of the institution and these criteria, (b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated, (c) a curriculum and process that assures the achievement of these objectives, and (d) a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

Following ABET Criterion 3, engineering programs must demonstrate that their graduates have (a) an ability to apply knowledge of mathematics, science and engineering, (b) an ability to design and conduct experiments, as well as to analyze and interpret data, (c) an ability to design a system, component, or process to meet desired needs, (d) an ability to function on multi-disciplinary teams, (e) an ability to identify, formulate, and solve engineering problems, (f) an understanding of professional and ethical responsibility, (g) an ability to communicate effectively, (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context, (i) a recognition of the need for, and an ability to engage in life-long learning, (j) a knowledge of contemporary issues, and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Finally, ABET Criterion 8 states that each program must satisfy a set of applicable program criteria. These program criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline.

II. The Stevens Assessment System

SIT is widely recognized for its long-standing tradition of excellence in engineering education. As reflected in its mission statement, Stevens has expressed this commitment both in terms of the ideals to which its educational programs aspire and the measurable consequences of pursuing these ideals in the classroom and after graduation. The terms of this commitment are reflected in our educational programs and form the grounds upon which our efficacy in these programs may be evaluated by ourselves and by the professional community.

The Stevens Engineering Assessment Center (SEAC) was formed in order to provide a coordinating and advisory body for the faculty in the development and implementation of the assessment plan of the SoE. This center represents an official contact point on assessment issues for all faculty, students and administrators. Furthermore, it manages the SEAC website[2], the SoE assessment server and software as well as the assessment database, supports faculty assessment activities and assists the faculty in the design and implementation of surveys.

In order to scrutinize the educational programs against the desired outcomes, the educational mission of SIT was expressed in a hierarchical structure that begins in the broadest of terms and follows through to the assessable consequences. The elements of the hierarchy are goals, objectives, curriculum performance criteria and assessment performance criteria. Goals are statements describing the broad educational outcome desired. They are far reaching and describe the best situation that could possibly be hoped for. Objectives are statements derived from the goal that define the circumstances by which it will be known if the desired change has occurred. Curriculum Performance Criteria (CPC) identify the performance required in order to meet the objective. The performance must be confirmable through concrete evidence. Assessment Performance Criteria (APC) are course-specific statements identifying the performance necessary to meet the requirements of a course. These criteria are course-specific applications of the CPCs.

As is shown in the listing below, a total of thirteen institute-wide educational goals are grouped into three categories:[5,6]

I. Broad Based Technical Expertise
- Goal 1: Scientific and engineering foundations
- Goal 2: Experimentation
- Goal 3: Tools
- Goal 4: Technical design
- Goal 5: Design assessment

II. Professional Advancement and Communications
- Goal 6: Professionalism
- Goal 7: Leadership
- Goal 8: Teamwork
- Goal 9: Communication

III. World View and Personal Development
- Goal 10: Ethics and morals
- Goal 11: Diversity
- Goal 12: Lifelong learning
- Goal 13: Entrepreneurship

The Stevens assessment process is characterized by three major thrusts that are referring to assessment activities at the course level (CL), program level (PL) and engineering curriculum level (EL). The three corresponding assessment loops are shown in the schematic in Figure 1 below.

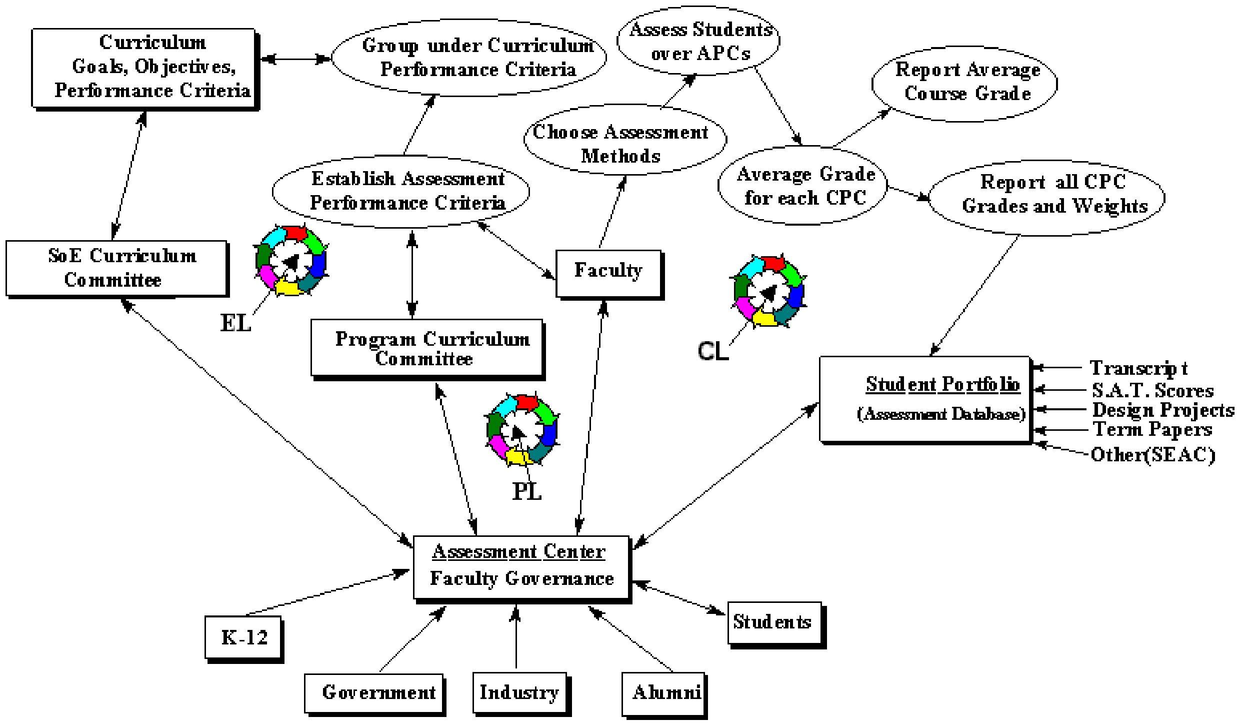

Figure 1: The three loops of the Stevens Assessment Process[2]

At the course level (e.g., ME 358 Machine Dynamics and Mechanisms; loop CL in the schematic), the program faculty are concerned that students are meeting the APCs for their course and with instituting course changes that will remove measured deficiencies. While the faculty is actively engaged in establishing the learning objectives in the program, the constituency most relevant to this process is the student body.

At the program level (e.g., mechanical engineering program; loop PL in the schematic), the program curriculum committee is concerned with defining the APCs for the individual courses in the program. It is responsible for monitoring the program objectives in courses and for setting achievement standards or metrics consistent with those identified for the engineering school. The focus of the program curriculum committee is on the aggregate data for the program.

At the engineering curriculum level (including all engineering programs at SIT; loop EL in the schematic), the school-wide curriculum committee has the responsibility for the integrity of the goals, objectives and performance criteria as well as their possible modification. The processes in loop EL assure in a unified way that the outcomes expressed in ABET Criterion 3 are met.

III. The Mechanical Engineering Curriculum at SIT

The Department of Mechanical Engineering at SIT offers a challenging program. The program is designed to lead to graduation in a period of four years. During the freshman and sophomore years, the mechanical engineering students take the standard set of core courses that provide breadth in the sciences, engineering and the humanities while at the same time allowing for later specialization in the particular engineering disciplines. This succession of core courses applies to all engineering majors. During the junior and senior years, additional core courses are then accompanied by various mandatory and elective courses in mechanical engineering.

A set of program objectives for the mechanical engineering program was derived from the general educational goals of the SoE at SIT. The mechanical engineering department strives to provide its students an educational experience, which is balanced in its attention to fundamental principles, design methodologies and professional practice while promoting innovation and creativity.

The objectives of the mechanical engineering program can be summarized as follows:

1. Educate the students in fundamentals of science and engineering with emphasis on mechanical engineering applications and engineering design throughout the curriculum.
2. Instill responsibility and effective understanding of social factors including legal, political, ethical, economic, and public relations aspects of mechanical engineering.
3. Encourage the systems approach and project orientation with emphasis on creativity and innovation throughout the curriculum.
4. Prepare the students to interact and communicate effectively in multi-disciplinary teams.
5. Continually enhance the mechanical engineering curriculum to incorporate effective pedagogy and information technology tools.
6. Integrate education and research into the undergraduate curriculum.
7. Motivate excellence in the creation and use of new knowledge and prepare the student for life-long learning.

Keeping these general objectives in mind, a list of specific program goals was then established for the mechanical engineering department. The complete listing of all departmental goals and objectives is available at the website of the SEAC.[2] For each departmental goal, specific Curriculum Performance Criteria (CPC) were formulated. These CPCs serve as the program outcomes that are mandated by ABET Criteria 2 and 8. Their statements at the program level are in terms indicative of the mechanical engineering program and include the broader statements as they apply at the general engineering level. At the mechanical engineering program level, some general institute-wide CPCs that are not exactly relevant to the program are not adopted. The CPCs serve as categories for the more detailed and directly assessable versions of performance criteria for the individual courses, which are termed Assessment Performance Criteria (APC). The APCs constitute the learning objectives for the individual courses in the program.

For illustrational purposes, a sample course was selected here, ME 358 Machine Dynamics and Mechanisms. All mechanical engineering majors take this course in the junior year. The syllabus is structured in the traditional way, i.e., it follows a logical sequence of topics. But in addition to the listing of the topics discussed in the course, explicit APCs (skills) are formulated and linked to the appropriate program CPCs (in parentheses). The subset of program goals and objectives that applies to the sample course is listed in Appendix I, and a detailed course syllabus is given in

Appendix II. The code used to identify the CPCs is to be interpreted as follows: The first numeral refers to the program goal, the letter refers to the program objective, and the second numeral denotes the curriculum performance criterion addressed.

The mapping of the individual course APCs of all courses to the program CPCs forms the foundation for tracking the student performance not only in the traditional course-based manner but in addition, the student's performance as it relates to certain skills (APCs) can be identified in a cumulative fashion across several or all courses of the curriculum. Therefore, this approach provides for a much richer assessment process than was previously possible based on traditional grading methods.

In order to track the students' individual skills (APCs) as outlined above, the instructor must adopt a more detailed record keeping than is traditionally carried out. It is not sufficient anymore to record cumulative scores for each assessment method (homework assignment, midterm and final exam, design project, laboratory assignment, etc.) but instead the assignments have to be structured such that individual problems (or parts of problems) relate to individual APCs and the corresponding scores are recorded separately. A MS Windows based application termed the Stevens Educational Assessment Application (SeaApp) was therefore developed to facilitate the assessment system. This tool is described below.

IV Course-level Assessment Data Processing using Distributed Grading Software

SeaApp - **S**tevens **E**ducational **A**ssessment **APP**lication - is a Microsoft Windows Application automating the course-level loops in the distributed grading system.[7, 8] Designed for the use by instructors and graders, SeaApp assists the faculty in relating the course objectives to the curriculum objectives and monitors the performance of students according to curriculum performance criteria. It thus is a tool, which aims at minimizing the additional faculty effort that the distributed grading methodology requires compared with traditional grading schemes.

SeaApp identifies the curriculum goals, objectives and performance criteria (CPC) addressed by the individual course. It relates the assessment methods (exams, quizzes, projects, homework, etc.) of the course to the course objectives. SeaApp maintains a roster of students for the class. It creates a Microsoft EXCEL™ workbook for entering and maintaining the scores for each individual assessment method and processes the scores into a report on the curriculum objectives and the student performance listed by performance criteria. SeaApp also creates a curriculum map of courses in any program and the student performance by listed CPCs. SeaApp is made available to instructors for downloading via the web.

Comprehensive information on the distributed grading methodology can be found by following the URL: http://attila.stevens-tech.edu/assess. The distributed grading methodology requires the instructor to identify the course objectives and relate all course assessment methods (exams, quizzes, projects, homework, etc) to the course objectives. Figure 2 shows the goals-objectives-criteria hierarchy for the curriculum, which is used by the instructors to relate the course objectives to curriculum objectives.

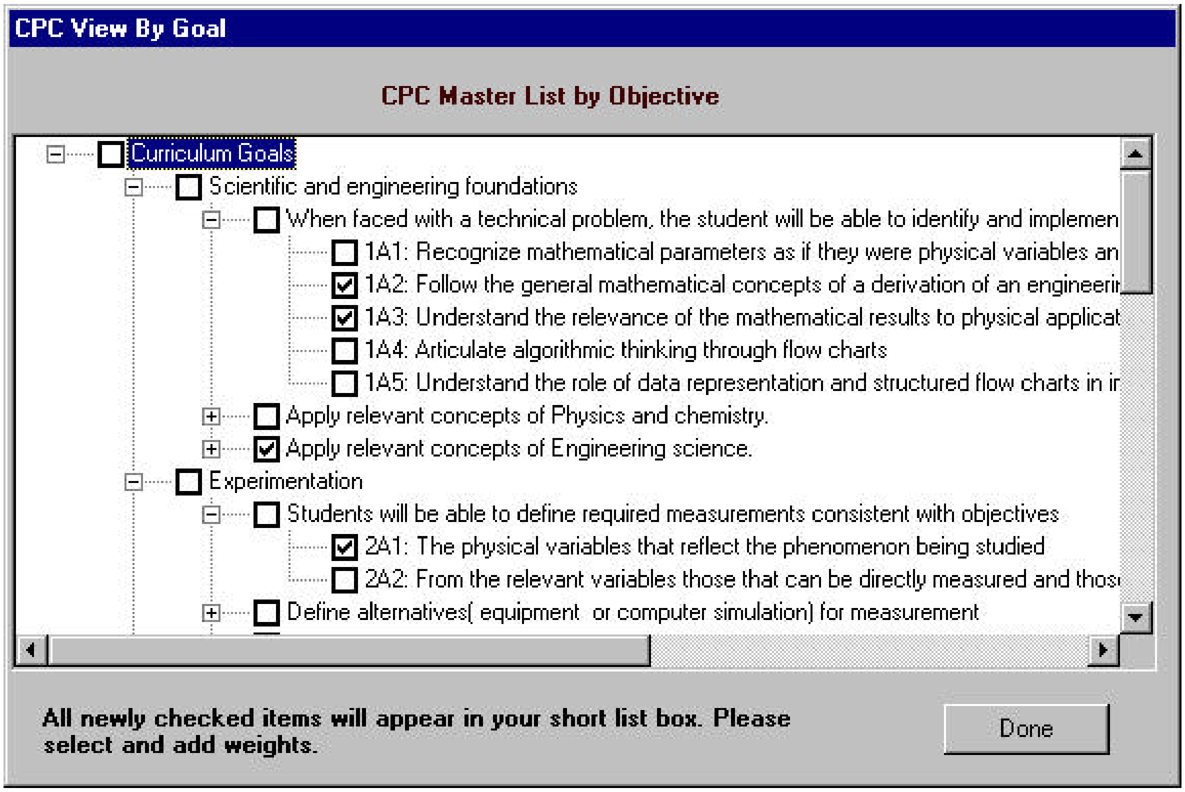

Figure 2: SeaApp provides a consistent and complete list of curriculum objectives (CPCs) to the course instructors and tracks the relationship between the course objectives (APCs) and the curriculum objectives (CPCs).

The methodology will then calculate the student performance by course objective instead of the traditional student performance by assessment method. SeaApp automates this transformation allowing instructors to record scores as usual (i.e., by exam) and calculating the performance by objective report. It also records the performance by objective reports at a central location for all courses in the SoE enabling a performance by objective report for any program in the school.

Most professors write down their course objectives in their syllabus. These objectives lists are central to the distributed grading system. The identified course objectives are called APCs. The next step in distributed grading is relating the course objectives (APCs) to the Curriculum Performance Criteria (CPCs). For example, if the course APC is “Model the stiffness of a system with a parallel or serial network of linear springs,” it will be related to Goal 5, Objective B, Criterion 1 (or CPC 5B1) which states: “The student will be able to link components or units together realistically to meet the system objectives: Given an input and a desired output, the students will be able to construct at least one rational sequence of operations that could achieve the desired output.”

A course will have many APCs. Each APC can refer to one or more CPCs. After this exercise, the instructor will have identified all the CPCs appropriate for the course. Some CPCs are addressed to a larger extent in the course than others. Therefore, the importance of a CPC is tracked by a weight. Figure 3 shows the user interface where the instructors short list a relevant set of CPCs and assign a target weight with which assessments methods in the course will reflect the CPC.

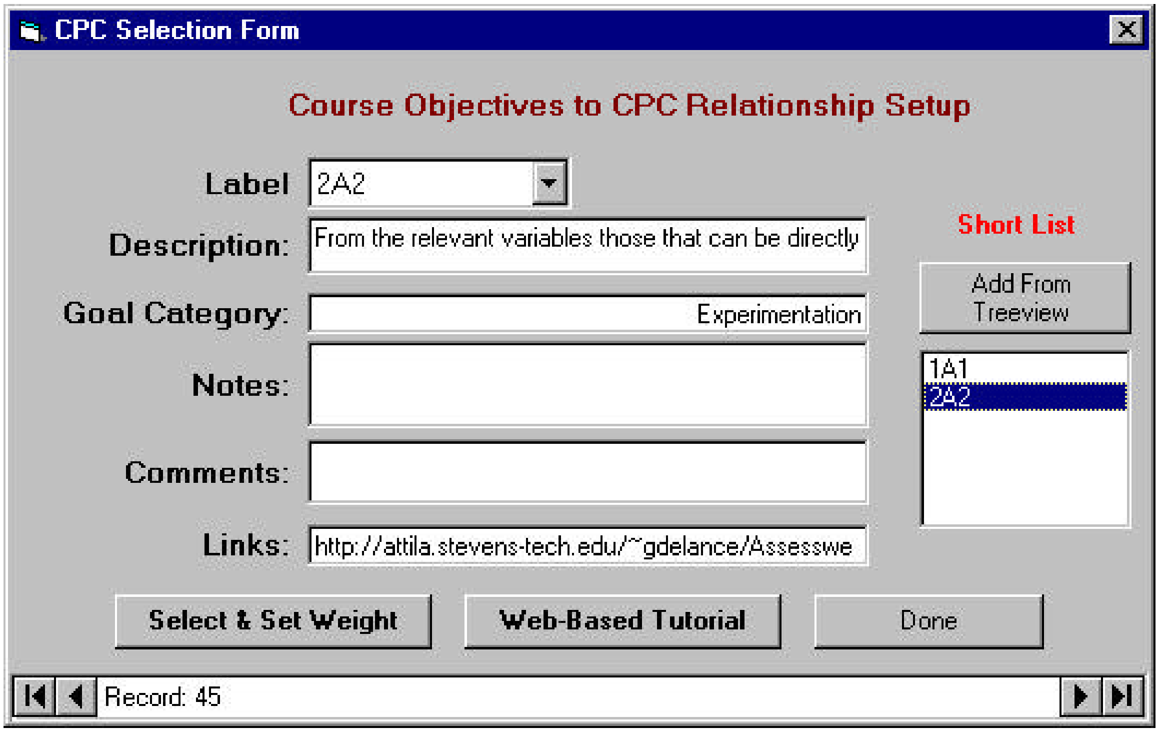

Figure 3: A short list of CPCs relevant to each course can be established where only relevant CPCs will appear after this selection.

The target weight is a "pre-assigned" number, which is the weight intended by the instructor or the importance of that CPC. This is a relative weight, i.e., a CPC with a weight of 0.5 has half the importance of a CPC with a weight of 1.0. SeaApp allows one to work in any scale comfortable to the instructor as it normalizes the weights such as to sum up to 1.0.

The computed weight is based on the assessment methods (exams, quizzes, projects, homework, etc.) and their relation to the CPCs. Say, a course has two quizzes (each has one question for 100 points) and a final exam (one question with 100) points and the final course grade is calculated with a 25% weight for each quiz and 50% for the final. The distributed grading methodology requires the instructor to identify the relation between each of these assessment methods and the course CPCs. Say the instructor identified that Quiz 1, Question 1 relates to CPC 1C3; Quiz 2 Question 1 to CPC 1C2 and the Final Question 1 to CPC 1C3, then the computed weight for each

CPC is 1C2 = (100*0.25+100*50)/100 = 0.75 and 1C3 = 0.25. Figure 4 shows the interface for defining assessment methods in SeaApp and relating each question to a particular CPC.

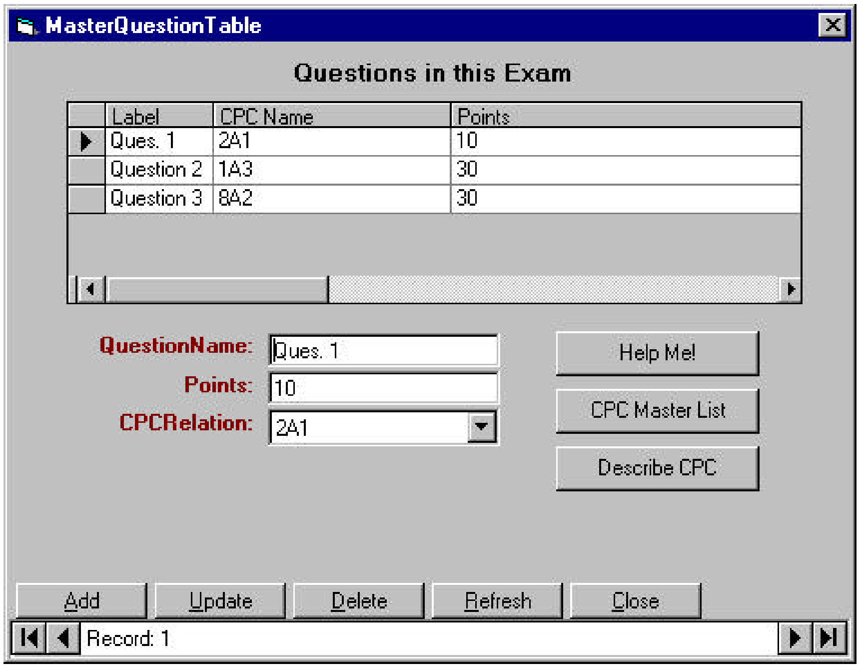

Figure 4: The key characteristic for the distributed grading system is relating each assessment method directly with course objectives (indirectly with curriculum) objectives. The panel here shows the relationship between three questions in an exam to that of the selected CPCs.

Figures 5 and 6 show portions of the report uploaded by SeaApp to a central server from which program characteristics or entire curriculum characteristics can be compiled and analyzed.[9, 10]

Assessment Methods

Exam Name	Weight	Total	CPC Name	Questions	Points
Exam 1	0.05	100	1A3	Problem1	100
Exam 2	0.05	100	1C2	Problem1	100
Exam 3	0.10	100	4B1	Problem1	100
Final	0.30	100	4C1	Problem1	50
Final	0.30	100	4A1	Problem2	50
Homework1	0.05	30	1A1	Q1	10
Homework1	0.05	30	1A3	Q2	10
Homework1	0.05	30	1C2	Q3	10
Homework2	0.05	30	1A2	Prob1	10
Homework2	0.05	30	1C1	Prob2	10
Homework2	0.05	30	4A1	Prob3	10
Homework3	0.05	40	4A1	Prob1	10
Homework3	0.05	40	4A3	Prob2	10
Homework3	0.05	40	5A1	Prob3	10
Homework3	0.05	40	4C1	Prob4	10
Laboratory	0.30	90	2A1	Ex1	20
Laboratory	0.30	90	2A2	Ex2	30
Laboratory	0.30	90	3B2	Ex3	30
Laboratory	0.30	90	3B3	Ex4	10
Quizzes	0.05	100	1A2	Problem1	100

Figure 5: Typical assessment methods for a course. The table shows the weight towards the course grade, the relationship to the CPCs and the points.

Student Performance by CPC

CPC Code	Targeted Weight	Assessed Weight	Average Distribution* by CPC (%)
1A1	0.067	0.017	1.450
1A2	0.067	0.067	4.750
1A3	0.067	0.067	5.613
1C1	0.067	0.017	1.450
1C2	0.067	0.067	5.188
3B2	0.067	0.100	8.000
3B3	0.067	0.033	2.667
4A1	0.067	0.179	15.987
4A2	0.067	0.000	0.000
4A3	0.067	0.013	0.950
4B1	0.067	0.100	6.590
4C1	0.067	0.163	12.375
5A1	0.067	0.013	0.913
2A1	0.067	0.067	5.333
2A2	0.067	0.100	8.000

*Average Distribution by CPC: This is sum of average performances (in percent) of all questions relating to that CPC multiplied by the weight for course grade for each question

Average Grade for the whole course is (%): 79.266

Figure 6: Distributed grading shows the performance data and weight for each CPC addressed by the course. When no assessment methods address a CPC such as 4A2, attitudinal surveys[3] or other methods may be used to obtain the student perceptions of learning regarding that objective.

Summary

This paper discusses the Stevens assessment process that is currently being instituted and the related formulation of the program educational objectives as well as the program outcomes of the Mechanical Engineering Department. These departmental objectives and outcomes are in accordance with the institute's mission that was devised with the ABET 2000 criteria in mind. The multi-layered assessment structure of curriculum performance criteria, assessment performance criteria and their linkage to the program and institute missions are discussed on the example of one specific course and a software tool designed to aid the faculty with the various assessment activities is presented. The junior-level course ME 358 Machine Dynamics and Mechanisms was one of the first courses where the assessment procedures described above were implemented. It was therefore selected as an example for the presentation of this paper. Similar developments are currently underway for all courses in the SoE.

Acknowledgements

The design and implementation of the mechanical engineering curriculum and its assessment via the methods described herein are based on the Stevens assessment procedures developed over the course of the last few years by the members of the institute-wide assessment committee. This work is gratefully acknowledged.

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Appendix I – Selected Mechanical Engineering Program Goals, Objectives and Curriculum Performance Criteria as applicable to ME 358 Machine Dynamics and Mechanisms

I. Broad Based Technical Expertise

Graduates of the Stevens Mechanical Engineering curriculum will have

Goal 1: (**Scientific and engineering foundations**) the ability to use applied scientific knowledge. When faced with a technical problem, the student will be able to identify and implement relevant principles of:

Objective A: mathematics and computer science, the students will be able to

Criterion 1: recognize mathematical parameters as if they were physical variables and vice-versa;

Criterion 2: follow the general mathematical concepts of a derivation of an engineering or scientific result and will possess the mathematical skills to link those concepts;

Criterion 3: understand the relevance of the mathematical results to physical applications;

Objective C: engineering science. Both inside and outside their major, students will be able to:

Criterion 1: utilize mass, energy, momentum and entropy balances in diverse applications;

Criterion 2: resolve mechanical problems involving equilibrium, stresses, strains, deformation, stability and safety factors;

Goal 2: (**Experimentation**) the ability to design experiments, conduct experiments, and analyze experimental data. Students will be able to:

Objective A: define required measurements consistent with objectives. The students will select:

Criterion 1: the physical variables that reflect the phenomenon being studied;

Criterion 2: from the relevant variables those that can be directly measured and those that must be derived from direct measurements on the basis of physical laws.

Goal 3: (**Tools**) an ability to use the relevant tools necessary for engineering practice. Students will be able to use:

Objective B: Computer-based and information technology-based tools. The students will have the ability to effectively use:

Criterion 2: computational tools for finding graphical, numerical, and analytical solutions to problems;

Criterion 3: systems simulations appropriate to engineering practice;

Goal 4: (**Technical design**) the technical ability to design a prescribed engineering subsystem. Students will be able to:

Objective A: understand the functionality of the required components or units. The student will be able to:

Criterion 1: delineate the physical and chemical principles upon which the functions of each unit are based;

Criterion 2: identify input, output and operating variables as appropriate in various units;

Criterion 3: identify technical relationships between the input, output and variables and use the relationships to predict mutual changes.

Objective B: utilize design equations to specify units or components,

Criterion 1: Given appropriate input and desired outputs, the students will be able to specify the characteristics of the component or unit required for its construction or acquisition.

Objective C: utilize the design equations for interconnected components or units.

Criterion 1: The students will be able to apply standard design procedures for units connected in parallel, in series or by feedback.

Goal 5: (**Design assessment**) The ability to develop and assess alternative engineering designs based on technical and non-technical criteria. Students will be able to:

Objective A: define overall needs and constraints,

Criterion 1: specify the product, function, or service of the system in terms of performance criteria.

Appendix II – Assessment Performance Criteria for Sample Course

ME 358 Machine Dynamics & Mechanisms

Chapter 1: Mechanisms

Section 1: Introduction
The students will be able to

- classify joints (lower/higher/compound pair, types of joints) and replace higher pair joints by kinematically equivalent lower pair joints (1A1, 1A3)
- classify linkages (planar/spatial) and represent linkages by kinematic sketches (1A1, 1A3)
- identify degrees of freedom of rigid bodies, joints, and linkages in planar and spatial cases (1A1, 1A3)
- determine mobility, connectivity, idle degrees of freedom, overconstraint in planar mechanisms (1A1, 1A3)
- identify type of four-bar linkages using Grashof's inequality (1A1, 1A3)
- determine motion limits of slider-crank mechanisms (1A1, 1A3)

Section 2: Kinematics
The students will be able to

- identify the meaning of the terms in the general position, velocity and acceleration equations (1A1, 1A3, 1C2)
- calculate the magnitudes of the velocity and acceleration components (radial, tangential, relative, normal, Coriolis, etc.) and identify their directions (1A1, 1A3, 1C2)
- represent the geometry of four-bar linkages, slider-crank mechanisms, and mechanisms containing higher-pair joints (pin-in-a-slot, cam contact, rolling contact) by vector loops (1A2, 1A3, 1C2)
- formulate and solve analytically the position, velocity, and acceleration vector loop equations for four-bar linkages, all inversions of slider-crank mechanisms (including rotating sliding joints), and mechanisms containing higher-pair joints (pin-in-a-slot, cam contact, rolling contact) and points not on the vector loop (1A2, 1A3, 1C2)

Section 3: Kinetics
The students will be able to

- perform analytical kinetostatic analyses of mechanisms under single loading conditions (1C1, 1C2)
- apply the principle of superposition to the analytical kinetostatic analysis of mechanisms under complex loading conditions (1C1, 1C2)

Section 4: Synthesis of Mechanisms
The students will be able to

- synthesis the type and dimensions of mechanisms (graphically and analytically) (4A1, 4A2, 4A3, 4B1, 4C1, 5A1)

Chapter 2: Cams

Section 1: Kinematics
The students will be able to

- derive equations for rises and returns for uniform, parabolic, harmonic, cycloidal, general, and polynomial motion programs (1C2)
- calculate follower displacement, velocity, acceleration (1C2)
- determine analytically cam profile for radial flat-faced follower, determine radius of curvature and minimum face width, check for cusps (1C2)
- numerically design cam profile for offset radial roller follower, determine radius of curvature, check for cusps (4B1, 5A1)

Section 2: Kinetics
The students will be able to

- perform analytical static force analyses of cams (1A1, 1A2, 1A3, 1C2)
- perform analytical dynamic force analyses of cams (1A1, 1A2, 1A3, 1C2)

Section 3: Synthesis
The students will be able to

- select appropriate cam and follower types (4B1)
- size cam-follower systems (4C1, 5A1)

Chapter 3: Gears

Section 1: Kinematics
The students will be able to

- distinguish gear types (1A1)
- understand the characteristic gear parameters (1A1, 1A3)
- analyze the kinematics of gears using the formula method and the tabular method (1C2)

Section 2: Kinetics
The students will be able to

- perform static force analyses of gears (1A1, 1A2, 1A3, 1C2)
- perform dynamic force analyses of gears (1A1, 1A2, 1A3, 1C2)

Section 3: Synthesis
The students will be able to

- select the appropriate gear type for a given task (4B1)
- perform a detailed design of gears (4A1, 4A2, 4A3, 4B1, 4C1, 5A1)

Chapter 4: Machines

The students will be able to

- balance (statically and dynamically) a machine (1A3, 1C1, 1C2)
- analyze flywheels (1A3, 1C1, 1C2)
- design flywheels (4A1, 4A2, 4A3, 4B1, 4C1)
- analyze presses (1A3, 1C1, 1C2)
- design presses (4A1, 4A2, 4A3, 4B1, 4C1)
- analyze the vibrational behavior of machines (1A3, 1C1, 1C2)
- design vibration isolators for machines (4A1, 4A2, 4A3, 4B1, 4C1)

Laboratory

The students will be able to

- analyze the vibrational behavior of machines (2A1, 2A2, 3B2, 3B3)
- measure and analyze the unbalance (statically and dynamically) of a machine (2A1, 2A2, 3B2, 3B3)