2006-63: AN ASSESSMENT AND CONTINUOUS IMPROVEMENT MODEL FOR ENGINEERING TECHNOLOGY PROGRAMS

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An Assessment and Continuous Improvement Model for Engineering Technology Programs

Abstract

Assessment and continuous improvement are essential and critical processes for higher education. Development and implementation of such processes are not only required by the Accreditation Board for Engineering and Technology (ABET) but it is also a necessary condition for the maturation and development of any engineering technology program.

The assessment and continuous improvement plan discussed here was developed at Old Dominion University (ODU) and implemented during the last accreditation cycle within the Engineering Technology Department. The plan is based on two cycles of assessment and evaluation, a short cycle of one year and a long term cycle of three years. The plan includes a variety of assessment methods and tools. In addition to assessing the achievement of program outcomes, the plan allows assessment of program objectives and goals. A method for individual course assessment is also presented. Issues related to institutionalization of the assessment process are also discussed.

I. Introduction

The Accreditation Board for Engineering and Technology criteria, EC-2000 requires an assessment and continuous improvement plan. Since the first publication of outcome based criteria in 1995, considerable discussion has taken place on this issue[1,2]. In 2001 a similar outcome based criteria were published for the engineering technology programs. A number of studies were conducted and published under the Gateway Engineering Education Coalition outlining strategies for developing and institutionalizing such programs [3,4,5]. Many of these studies address important but only specific areas of the EC-2000 and TC2K criteria. For example, a study by Besterfield-Sacre et al.[6] defines the eleven outcomes a-k in terms of blooms taxonomy[5]. McGourtny, et. al.[7] , discuss incorporation of student peer review and feedback into the assessment process. While others have attempted to present a serialized model based upon plan-do-check-act derived from six-sigma methodology[10-12], very few comprehensive models for assessment and continuous improvement have been published. It should be emphasized that a realistic model for assessment and continuous improvement must be dynamic and be able to evolve as learning and improvements take place. At the same time it should incorporate data from various assessment tools to continuously assess attainment of outcomes and objectives.

Three engineering technology programs at Old Dominion University underwent the TAC of ABET accreditation review process during fall of 2005. In preparation for the accreditation visit a comprehensive assessment and continuous improvement plan was developed within the engineering technology department and adopted by all three programs. This plan incorporates some of the ideas presented in publications by various participants within the Gateway Engineering Education Coalition.

II. Strategies for Development and Implementation

Developing and implementing a comprehensive assessment and improvement plan presents several challenges. Administrators must provide resources to initiate and sustain such a program. Faculty must take the ownership of the design and implementation of the plan. Success of an assessment and improvement plan also requires changes in the student perception of such activities. Students must take a proactive role in the process.

McGourty[4,9] suggests the following four strategies in support of assessment initiatives:

1. Initiate a structured process to involve faculty and staff in the ongoing planning, development and monitoring of the program.
2. Offer "Just-in-time" educational sessions to develop faculty and student knowledge and skills in assessment.
3. Create an assessment toolbox providing administrators and faculty with templates that can be used in and outside the classroom; and
4. Identify, review and modify as required, key institutional practices to ensure that they are aligned with educational objectives and outcomes.

Above strategies were utilized in the development and implementation of the assessment and continuous improvement plan in the Engineering Technology Department at ODU.

III. Five Step Implementation Process

A five step implementation model for assessment and continuous improvement plan was presented by McGourtny[4]. While many of the activities can be done in parallel, the process is essentially serial and may require multiple iterations. The five steps are:

1. Identification and development of educational objectives.
2. Identification and selection of assessment methods.
3. Developing and pilot testing new assessment methods.
4. Expanding the assessment process, and
5. Applying results for improvement

This five step implementation model was used in the development and implementation of a continuous improvement plan at ODU.

Educational objectives for each program were determined in consultation with the key stakeholders and all members of the constituency. Resulting educational objectives for the MET program are given here as an example. Students should be able to:

1. Identify, formulate and solve mechanical and technical problems which include the steps of planning, specification development, design, analysis, procurement of equipment and materials, implementation, and performance verification.
2. Conduct necessary engineering experiments, make observations, collect and analyze data, and formulate conclusions.
3. Understand the ethical and societal impact of engineering solutions.
4. Communicate and function effectively and productively both as an individual and as part of an engineering team.
5. Recognize the need for and have the desire to engage in life-long learning.

Outcome for all the Engineering Technology programs were exactly the same as those listed in the TAC of ABET criteria. Nine assessment tools were identified to collect data for the assessment of outcome achievement for the continuous improvement plan. It should be noted that some assessment methods can only be used to assess certain specific outcomes. Table 1 maps the assessment tools for assessing each of the a-k program outcomes.

Table -1 Assessment Tools for Outcomes for the Engineering Technology Programs

	Engineering Technology Program Outcomes										
Assessment Tools	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
Advisory Committee Feedback	X	X	X	X	X	X	X				X
	Used to assess program objectives										
Course Assessment	X	X	X	X	X	X	X	X	X	X	X
Alumni Surveys	Used to assess program objectives										
Capstone/Senior Project Assessment	X	X	X	X	X	X	X				
CAP/Coop Supervisor Ratings	X		X	X	X	X	X		X		X
Employer Surveys	Used to assess program objectives										
Exit Exam of Writing Proficiency							X				
Senior Surveys –Dept.	X	X	X	X	X	X	X	X	X	X	X
Senior Surveys –Univ.	X	X	X	X	X	X	X	X	X	X	X

The two shaded rows in the table above indicate tools that are used every three years to collect assessment data. The remaining tools are used on an annual basis. The classification of these tools into direct and indirect measurement tools is provided later in Table 2.

The faculty periodically reviews the results of the assessment process to assess achievement of outcomes and program objectives. This is done by compiling assessment data to calculate performance index for each of the tools according to the schedule provided in the annual assessment cycle shown in Figure 2. This process is explained later in section V.

IV. The Assessment and Continuous Improvement Model

The plan for assessment and continuous improvement presented here takes into account the dynamic nature of this process and includes two iterative loops for continuous improvement. The inner loop is a short term annual cycle which looks at the student performance using course evaluation and assessment. Cumulative results for all courses within a program are presented in a program assessment report. The department chair takes this data to prepare a departmental assessment report of student performance. Primary assessment methods utilized here include individual course assessments, senior capstone project assessment, senior survey, exit examination of writing proficiency, cooperative education reports and feedback from the advisory committee. The model is shown in Figure 1.

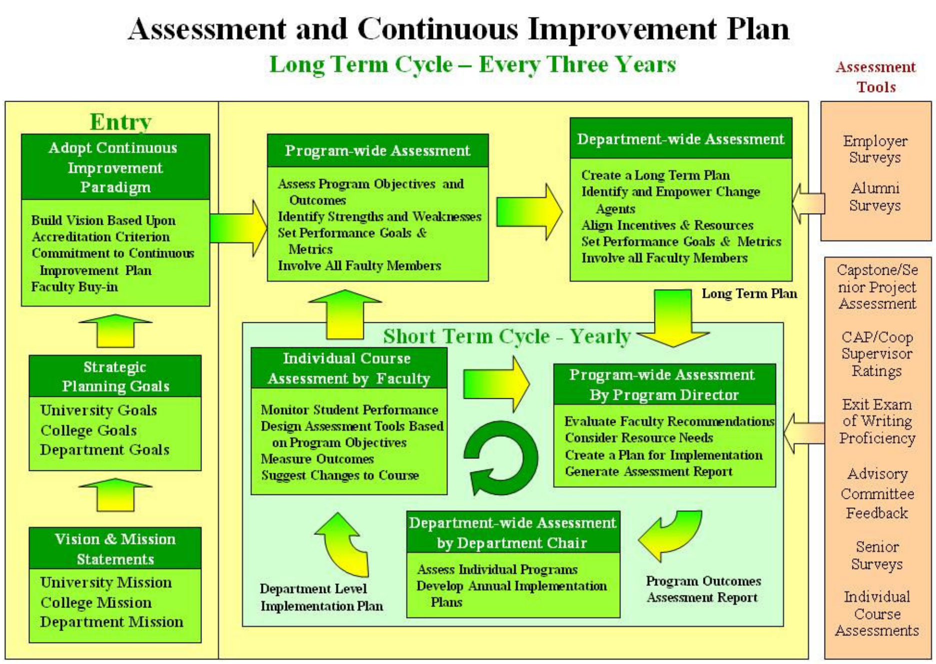

Figure-1 Assessment and Continuous Improvement Plan

The outer loop is a long term program assessment in which major reviews are done every three years. Primary assessment tools utilized here are alumni survey and employer surveys which are conducted every three years. In addition to these two long term tools, the major program review also utilizes the cumulative results from the short term tools used in the annual cycle.

The assessment process starts with the mission statement and vision of the Institution, College and Department. These are translated into the objectives and goals for the Institution, College, Department and Programs. The continuous improvement paradigm must be adopted at the highest level in the university and supported with resources for execution and implementation.

The schedule for the annual cycle is shown in more detail in Figure 2. This figure shows the schedule for various assessment activities and feedback resulting from them. It also shows the timeline for various meetings and assessment tools. Assessment methods come from those listed in Table 1.

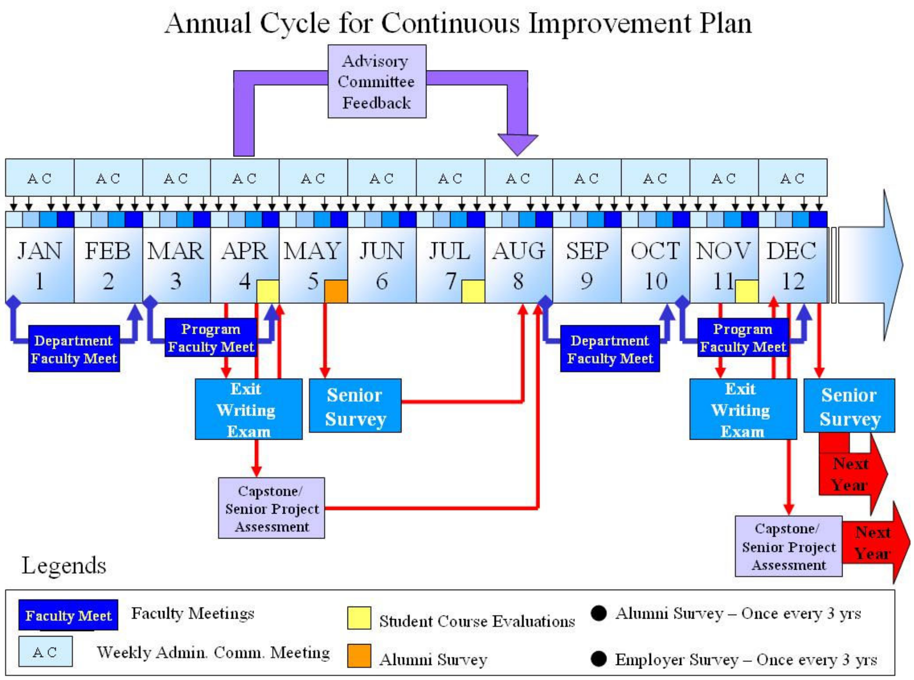

Figure-2 Short Term Annual Cycle of the Plan

V. Calculation of Outcome Attainment Index

Out of nine assessment tools used to assess program, six are used to assess outcomes attainment and the remaining three are used to assess objectives attainment as shown in Table 2. The first five tools in the table are direct measurement tools where as the remaining four are indirect measuring tools. Alumni survey, employer survey and advisory committee feedback are used to assess objective attainment. A performance index is calculated for each of the tools and the average of these indexes pertaining to outcome assessment is used to calculate an Outcome Attainment Index. This index provides an indication of the level of attainment.

Table -2 Assessment Tools, Performance Metrics and Performance Index

Type	No	Instrument	Assesses	Performance Metric	Perf. Index	Perf. Index
Direct	1a	Course Assessment	Outcomes a-k	Avg. of Student Performance	CA_i $i=1\text{-}11$	Outcomes Attainment Index = Avg. of each outcome
	1b	Capstone Assessment	Outcomes a,c,d,e,f,g	Avg. of Rubric Based Eval. +Class Perf.	P_i $i=1\text{-}11$	
	2	Employer Survey	Objectives 1-5	Avg. of Employer Response	ES_i $i=1\text{-}5$	
	3	Exit Writing Exam.	Outcome g	Avg. of Student Perf.	W_i $i=1\text{-}11$	
	4	Co-op Survey	Outcomes a,c,d,e,f,g,I,k	Subjective Assessment Converted to 1-10	CP_i $i=1\text{-}11$	
Indirect	5	Alumni Survey	Objectives 1-5	Avg. of Alumni Response	AS_i $i=1\text{-}5$	Objectives Attainment Index = Avg. of each outcome
	6	Advisory Comm.	Objectives 1-5 & Outcomes a-g,k	Assessment of MET Program	AC_i $i=1\text{-}5$	
	7a	Dept. Senior Survey	Outcomes a-k	Avg. of Senior Response	DS_i $i=1\text{-}11$	
	7b	University Senior Survey	Outcomes a-k	Avg. of Senior Response	US_i $i=1\text{-}11$	

VI. Calculation of Objective Attainment Index for Employer Survey

We use the employer survey as an example to show how objective attainment index is calculated. The employer survey uses a rating scale as follows: 0 – No Basis for Response (not used in determining average rating); 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree and 5 – Strongly Agree. The questions on the survey are first mapped to eleven outcomes. These eleven outcomes are then mapped to five program objectives as shown in Table-3. This table shows that program objective 1 is related to outcomes a, b, d and f. The performance indices for these outcomes are 4.19, 4.0, 4.23 and 4.22 from Table 4. The average of these numbers is 4.16 which is the performance index for program objective 1 shown in the last column. Similarly the indices for objectives 2, 3, 4 and 5 were calculated to be 4.16, 3.99, 3.99 and 4.14 respectively. These are shown in Table – 4.

VII. Example of Individual Course Assessment

Course assessments are a key part of the assessment and continuous improvement plan within the engineering technology department. Individual course assessments are used as a basis to calculate a course assessment index for the entire program by the process shown in Figure 3.

Table -3 Mapping of Program Objectives to Outcomes

Program Outcomes	Program Objectives				
	1. Identify, formulate and solve mechanical and technical problems which include the steps of planning, specification development, design, analysis and procurement of equipment and materials, implementation, and performance verification.	2. Conduct necessary engineering experiments, make observations, collect and analyze data, and formulate conclusions.	3. Understand the ethical and societal impact of engineering solutions.	4. Communicate and function effectively and productively both as an individual and as part of an engineering team.	5. Recognize the need for and have the desire to engage in life-long learning
a. an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines	X				
b. an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering & technology	X				
c. an ability to conduct, analyze and interpret experiments and apply experimental results to improve processes		X			
d. an ability to apply creativity in the design of systems, components or processes appropriate to program objectives,	X	X			
e. an ability to function effectively on teams				X	
f. an ability to identify, analyze and solve technical problems	X				
g. an ability to communicate effectively				X	
h. a recognition of the need for, and an ability to engage in lifelong learning					X
i. an ability to understand professional, ethical and social responsibilities			X		
j. a respect for diversity and a knowledge of contemporary professional, societal and global issues			X	X	
k. a commitment to quality, timeliness and continuous improvement.					X

Table -4 Calculation of Objective Attainment Index from Outcome Index for the Employer survey

General Satisfaction	**MET** (Avg. Rating)	**Program Outcomes**	**Program Objectives**	**Objective Rating**
1. ODU ET graduates are well prepared for careers in engineering and technology.	4.26			
2. ODU ET graduates make a valuable contribution to the success of this organization. .	4.33			
3. My organization plans to continue to recruit new employees from the ODU ET programs.	4.29			
Program Outcomes				
1. ODU ET graduates have an appropriate mastery of the knowledge, techniques, skills, and tools of the engineering and technology discipline.	4.19	a	1	**1= 4.16**
2. ODU ET graduates can apply current knowledge and adapt to emerging technologies.	4.00	b	1	**2=4.16**
3. ODU ET graduates have ability to conduct, analyze and interpret experiments and apply results to improve processes.	4.09	c	2	**3=3.99**
4. ODU ET graduates have ability to apply creativity to the design of systems, components, or processes to satisfy the design objectives	4.23	d	1,2	**4=3.99**
5. ODU ET graduates can function on multi-disciplinary teams.	4.37	e	4	**5=4.14**
6. ODU ET graduates can identify a technical problem, collect and analyze relevant data, and develop an appropriate solution.	4.22	f	1	
7A ODU ET graduates are prepared to present ideas and technical material to audiences using: **written** means (reports, memos, etc.) .	3.85	g	4	
7B using **oral** communication (meetings, presentations, etc.)	3.82			
7C using **visual** means (graphics, plots, presentations, etc.)	3.92			
8. ODU ET graduates understand the importance of life-long learning.	3.92	h	5	
9. ODU ET graduates understand professional, social, and ethical responsibility.	4.07	i	3	
10. ODU ET graduates respect diversity and understand the impact of engineering solutions in a societal and global context.	3.92	j	3	
11. ODU ET graduates display a commitment to quality, timeliness, and continuous improvement.	4.37	k	5	

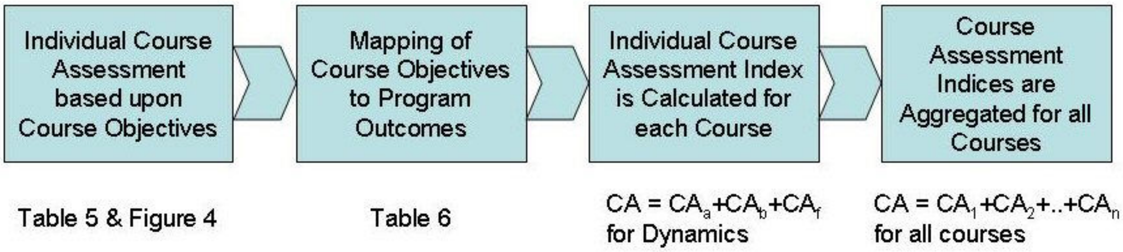

Figure-3 Individual Course Assessment

Table -5 Individual Course Assessment

MET-310, Dynamics, Summer 2002

			Final Examination Question Number						Avg. Max. 10
Obj.	**Learning Objective**	**Method**	**Q-1**	**Q-2**	**Q-3**	**Q-4**	**Q-5**	**Q-6**	
O1	Perform kinematic analysis of particle motion for rectilinear and curvilinear motion	Final Exam.	6.79	7.23					7.01
O2	Calculate the position, velocity and acceleration at an instant given the expressions for the displacement		6.79	7.23					7.01
O3	Draw motion diagrams and solve kinematic problems graphically		6.79						6.79
O4	Use Newton’s laws of motions in solving dynamics problems				8.88				8.88
O5	Solve problems in both USCS and SI system of units.		6.79	7.23	8.88				7.63
O6	Perform kinematics analysis of rigid bodies in rectilinear motion, curvilinear motion, pure rotation and general plane motion				8.88				8.88
O7	Draw motion diagrams for various types of rigid body motions and solve problems graphically		6.79						6.79
O8	Use Newton's laws of motion to solve dynamics problems associated with rigid bodies				8.88	8.00			8.44
O9	Calculate area and mass moment of inertia of composite planes and bodies					8.00	6.50		7.25
O10	Use work and energy principle to solve problems involving particle motion, rigid body motion and problems involving connected bodies						6.50	8.54	7.52
O11	Use Impulse momentum principle to solve problems involving impact and explosive forces							8.54	8.54
O12	Select appropriate method for solving dynamics problems					8.00		8.54	8.27
							Grand Avg.		7.75

An example of individual course assessment is shown in Table 5 and Figure 4. Course objectives of each course are mapped on to the program outcomes as shown in Table 6. An assessment index is calculated for each course. Assessment indices for all courses are aggregated to calculate an assessment index for the entire program.

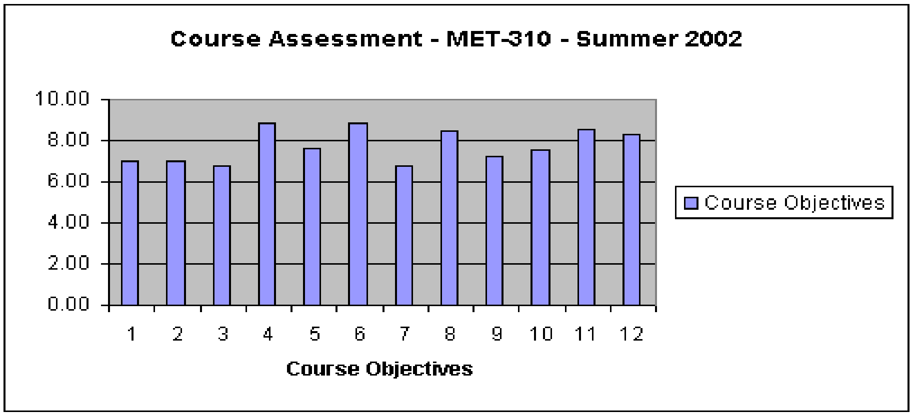

Figure-4 Results from Individual Course Assessment

Table -6 Mapping of Individual Course Objectives to Program Outcomes

MET 310, DYNAMICS		OUTCOMES										
OBJECTIVES		a	b	c	d	e	f	g	h	i	j	k
1	Perform kinematic analysis of particle motion for rectilinear and curvilinear motion	x	x				x					
2	Calculate the position, velocity and acceleration at an instant given the expressions for the displacement.	x	x				x					
3	Draw motion diagrams and solve kinematic problems graphically.	x	x				x					
4	Use Newton's laws of motions in solving dynamics problems	x	x				x					
5	Solve problems in both USCS and SI system of units	x	x				x					
6	Perform kinematics analysis of rigid bodies in rectilinear motion, curvilinear motion, pure rotation and general plane motion.	x	x				x					
7	Draw motion diagrams for various types of rigid body motions and solve problems graphically.	x	x				x					
8	Use Newton's laws of motion to solve dynamics problems associated with rigid bodies	x	x				x					
9	Calculate area and mass moment of inertia of composite planes and bodies	x	x				x					
10	Use work and energy principle to solve problems involving particle motion, rigid body motion and problems involving connected bodies	x	x				x					
11	Use Impulse momentum principle to solve problems involving impact and explosive forces	x	x				x					
12	Select appropriate method for solving dynamics problems.	x	x				x					

VIII. Use of Assessment Data for Program Improvement and Role of Faculty

A program faculty group consists of all faculty within the MET program, along with the faculty member designated as the Program Director of MET. Each faculty program group meets at least once a semester to discuss issues related to curriculum, laboratory facilities, assessment information and accreditation. The meeting is coordinated by the Program Director. Additional meetings both formal and informal may be held as needed. In addition to the formal meeting described above, faculty provide input to the Program Director concerning equipment, facilities, equipment, and other concerns via e-mails and informal conversations.

Issues involving curriculum, course objectives, and outcomes are considered by the group, subject to constraints imposed by the University, the College, and by TAC of ABET. The Program Director summarizes this information and discusses them with the Department Chair.

The role of the program faculty in the assessment and continuous improvement plan is as follows:

a. Faculty members are responsible for establishing course objectives and assessing whether they are being met. Faculty members complete the course assessment form which measures student performance for each of the course objectives. A sample of this form is shown in Table 5.
b. Faculty discuss their course assessment results shown in Figure 4 during the program faculty meeting.
c. The program director includes the results of these course assessment efforts in the program outcome assessment report.
d. Results from program outcome assessment reports are presented to faculty during the department faculty meeting.
e. Faculty are responsible for implementing any curricular changes as a result of program review during the assessment process.
f. Faculty determine the acceptable levels for various performance metrics used in the assessment process.
g. Faculty provide input in the design of various survey instruments.

Assessment data helps and guides faculty in making curricular changes. Any low score on a particular course objective, outcome assessment index or program objective attainment index raises a red flag and faculty try to get to the root cause of the problem. If the issue affects other courses within the program, the issue is raised in the program faculty meeting. If the issue affects other programs within the department then, the issue is raised at the departmental faculty meeting. Finally, if the issue affects other departments, then the issue is raised within the UG committee for the college.

An example from Dynamics, MET-310 is discussed here to illustrate how assessment data is used by faculty to make changes in individual courses. Unusually low score on Quiz #2 (4.5 / 10) involving calculation of relative velocity using vector diagram was discovered by the instructor during Spring 2005. As a first step, the quiz solution was discussed in class and material related to calculation of relative velocity was reviewed. Students were asked to identify sources of difficulty. A test quiz was subsequently designed to assess student's knowledge in vector addition which is covered in Statics, CET-200. The score on test quiz confirmed that students had difficulty in using the concept of vector addition and subtraction to calculate resultant force. The results were discussed with the instructor of Statics, CET-200. The discussions with the instructor identified the source of the problem.

IX. Conclusions

A comprehensive model for assessment and continuous improvement has been presented which takes into account the dynamic nature of the process while providing short term and long term review of outcomes and objectives. The model also takes into account the iterative nature of the process by incorporating feedback loops for both short term and long term review process. The annual cycle provides a schedule of activities necessary to accomplish the review process. Performance indices from assessment tools are aggregated to calculate the outcome attainment index, which provide an easy method of quantifying progress in achieving outcomes. The objective attainment index is calculated from the outcome indices. The plan has been implemented successfully in the three engineering technology programs at ODU.

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