A Curricular Review Process for Systematic Continuous Improvement

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Abstract

This paper describes a novel process for curriculum planning, assessment, and improvement. The process is quantitative but allows faculty freedom to innovate. The review process is sufficiently flexible that it can be applied to many engineering programs. The curricular review process is split into cycles corresponding to the various programmatic levels, *i.e.*, validating courses, assessing outcomes, appraising attributes, and evaluating objectives, each with its own review cycle period. The review process provides a formal way of closing the feedback loops at all programmatic levels from the course level to the objective level. The review results are easily documented and can be used to ensure continuous improvement. Results are tabulated in three systems of matrices. Importance matrices are used to show the relative importance of goals at each programmatic level. Measurement matrices document the level of performance at each programmatic level relative to a set of benchmarks. Correlation matrices are used to correlate the goals from one programmatic level to the next. While other assessment methods may use something similar to our measurement matrices, the use of correlation matrices is unique to this curricular review process. The correlation matrices are used to see if the goals of each level are correct. The matrices are used in the corrective action process to adjust the relative importance of goals and to insert or delete possible new goals. Examples of implementation of the curricular review process are provided.

I. Introduction

Recently we conducted a survey of published literature in engineering education and found much has been written on ABET EC-2000. Several authors have noted the similarities of the EC-2000 criteria and ISO 9001.[1-3] Aldridge and Benefield provide a general roadmap to assist programs in implementing the ABET 2000 criteria in order to prepare for future ABET reviews.[4, 5] A number of authors describe a particular institution's preparation and experiences with the ABET 2000 review process. For example, Lohman describes Georgia Tech's experiences, as a pilot program, with the ABET review process, and provides suggestions for those preparing for a site visit.[6] Similarly, Phillips[7] presents lessons learned from the ABET review of Harvey Mudd College and Rudko[8] provides a similar report on the review of Union College. McGourty, *et al.* provide an overview of NJIT's assessment program and preliminary results from four assessment processes.[9] Much as been written highlighting specific assessment tools and assessment processes that demonstrate educational outcomes are being achieved. Numerous authors, including Rogers and Williams,[10] Mourtos,[11] Olds,[12] and Morgan, *et al*.[13] provide insight into the use of portfolios as effective assessment tools. Terenzini, *et al*. report on a course-level

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questionnaire designed to respond to assessment needs.[14] Regan and Schmidt describe the use of surveys to provide feedback from undergraduate students as well as alumni.[15]

We found less has been written on establishing performance criteria and formal processes to close the feedback loop in order to improve the program in a continuous manner. Trevisan, Davis, Calkins, and Gentili[16] describe a general process for designing performance criteria while Napper and Hale[17] develop specific performance criteria for a biomedical engineering program. Pape and Eddy[18] describe review of a single course which includes establishing performance criteria and a formal process for changing course content based on assessment results. In very general terms, Yokomoto, Goodwin, and Williamson[19] provide an outline for a curriculum review cycle which includes definition of learning outcomes, performance level expectations, assessment strategies and data collection, evaluation of whether performance levels are met and use of these results in the curriculum revision process. Sarin[20] provides a general, detailed plan to assist faculty with the development of a curricular review process. Continuous improvement, including the importance of documentation, is discussed but no formal process is described. A curriculum renewal process, including analysis of existing curriculum, followed by design and implementation of a new curriculum is provided by Leonard, *et. al*.[21] Once the renewed curriculum is in place, they provide an accreditation preparation methodology for assessment and continuous improvement. They too emphasize the importance of documentation.

Our literature review, described in the previous paragraphs, points to a need for a systematic process to act upon assessment results as emphasized by Lohman.[22] The purpose of this paper is to describe the curricular review process that we have developed for the Mechanical and Aerospace Engineering (MAE) program at Utah State University (USU). It not only establishes performance criteria and assessment methods, but also systematizes corrective actions to continuously improve the overall program. Our proposed review process is novel in several respects and has not been reflected in the current literature. It is also sufficiently flexible that it can be applied to any engineering program seeking ABET accreditation. Our process provides a formal way of closing the feedback loop at all programmatic levels from the course level to the objective level. It can be used systematically to ensure continuous improvement occurs throughout the program.

II. Curricular Review

The ABET Engineering Criteria 2000 requires that an engineering program have in place a set of educational objectives and outcomes.[23] We have added two additional programmatic levels: attributes and courses. Undergraduate program objectives and outcomes are defined in the usual fashion. Attributes of graduated engineering students are statements that describe specific skills of graduates that are essential to meeting the undergraduate program objectives. In addition, courses are the basic building blocks that lead to successfully meeting the undergraduate program outcomes. Figure 1 shows paraphrased examples of all four levels of goals - objectives, attributes, outcomes, and courses – from the USU MAE curriculum.

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OBJECTIVES	ATTRIBUTES	OUTCOMES	COURSES
A. Graduates will be recruited for entry-level engineering positions and they will have the necessary attributes to succeed in their chosen career.	I. Graduates will be able to synthesize mathematics, science, engineering fundamentals, and laboratory and work-based experiences to formulate and solve engineering problems.	1. Fundamentals	MAE 1010, MAE 2020, *etc.*
B. Graduates will be encouraged to pursue advanced degrees in engineering or other fields and they will have the necessary attributes to succeed.	II. Graduates will have proficiency in computer-based engineering, including modern numerical methods, software design and development, and the use of computational tools.	2. Communication	MAE 1050, MAE 3050, *etc.*
	III. Graduates will be able to communicate and work effectively on team-based engineering projects.	3. Laboratory Experience	MAE 2040, MAE 4040, *etc.*
	IV. Graduates will recognize the importance of and have the skills for continued independent learning.	4. Computer-based Engineering	MAE 1100, *etc.*
		5. Humanities, Arts, and Social Sciences	MAE 1110, *etc.*
		6. Design and Synthesis	MAE 2010, *etc.*
		7. Independent Learning	MAE 2020, *etc.*

Figure 1: Example goals at all four programmatic levels - objectives, attributes, outcomes, and courses.

The goal of the USU MAE curricular review process is to ensure the highest possible quality of undergraduate education. This process is highlighted by quantitative analysis of - from most abstract level to most specific level - objectives, attributes, outcomes, and courses. The review process is therefore split into four corresponding cycles of objective evaluation, attribute appraisal, outcome assessment, and course validation (Figure 2). Objective evaluation, due to its long-range focus, occurs nominally once every six years corresponding with the ABET review process. Accordingly, attribute appraisal occurs nominally every three years, outcome assessment occurs every year, and course validation occurs each time that the course is taught. However, the data collection in each of these cycles is a continuous process and the framework for change is designed to be flexible enough to allow for critical changes at any juncture.

There are five major entities involved in the review process – the Department Head, the corrective action committee, the curriculum committee, stakeholders, and the faculty. The corrective action committee is a permanent committee tasked with overseeing the undergraduate program. Specifically, the committee reviews data and assigns responsibility for corrective actions to the appropriate committee or individual. Corrective actions, as discussed later, can include refocusing efforts to better achieve goals or changes in goals at any level. The curriculum committee is a separate body charged with the daily governance of curricular issues such as responding to student petitions for course substitutions and technical electives. The formal curricular review process is detailed below. However, faculty often receive informal feedback from students and colleagues. If the lines of communication remain open, the formal review process should allow for informal, "bubble up" input at any time. Since the purpose of this paper is to concentrate on the process of curricular review, we have omitted significant discussions on how to develop a process that fits our department and the first time work of

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developing baseline objectives, attributes, outcomes, and courses along with their relative importance.

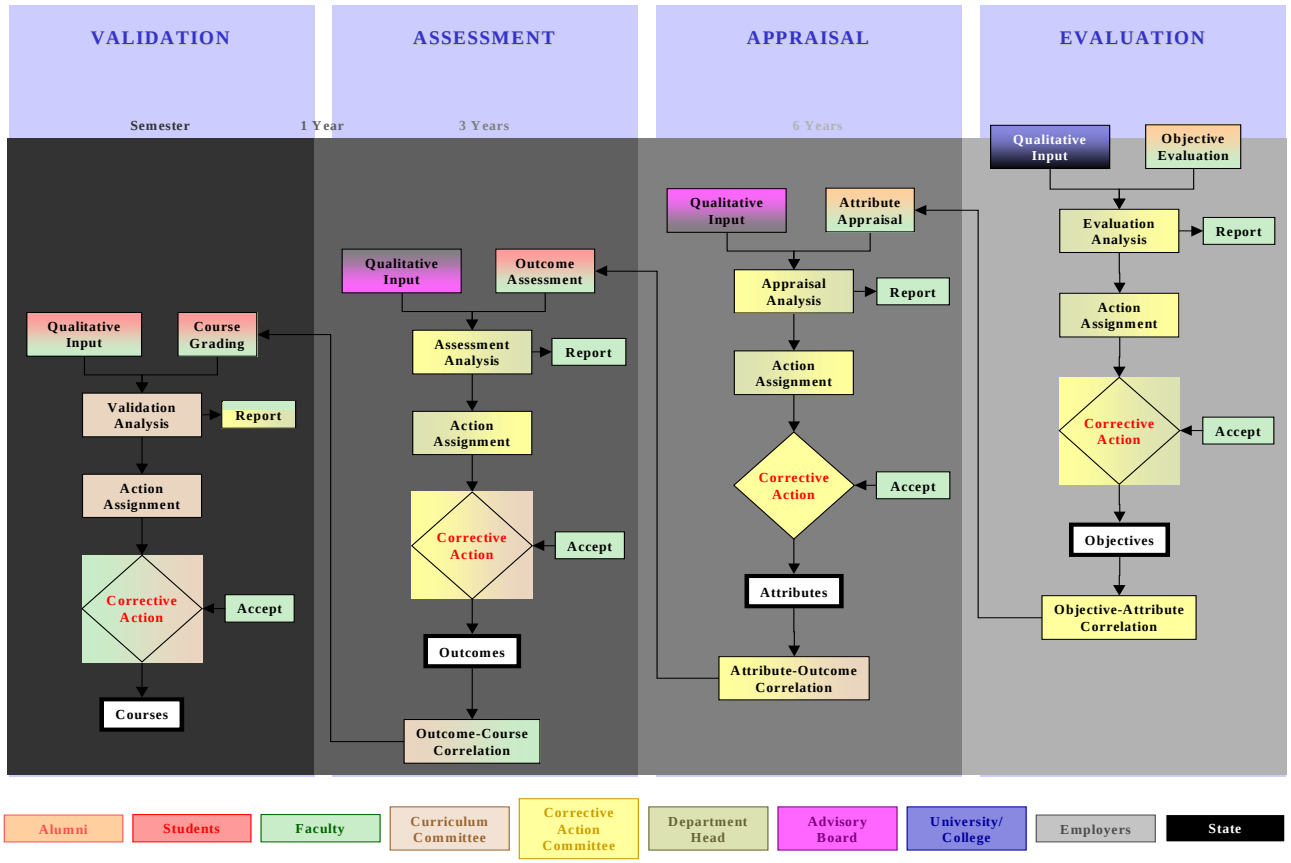

Figure 2: The undergraduate curriculum review process showing the four cycles of course validation, outcome assessment, attribute appraisal, and objective evaluation.

Objective Evaluation

Data to determine whether the objectives are being met can be acquired in a number of ways. At USU, we conduct a telephone survey of newly graduated students and alumni that graduated two years prior. The corrective action committee and the department staff developed the surveys. The department staff, who maintain close contact with alumni, conduct the telephone surveys each summer. If, based upon the objective assessment matrix, specific objectives are not achieving their benchmark then those outcomes are flagged for action. The industrial advisory board also has some informal, qualitative input into the evaluation of the objectives. In addition, the State, University, or College may have more formal and binding qualitative input on the objectives of the undergraduate curriculum.

Annually, the Department Head and corrective action committee analyze the evaluation data against benchmarks previously set by the corrective action committee and approved by the faculty and note any deviations. The data is reported to the full faculty on a yearly basis. Data analysis is aided by the use of the objective evaluation matrix. In the absence of any special needs or bubble up input, the Department Head and corrective action committee collate and

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review the quantitative and qualitative objective evaluation data every six years and decide what type of corrective actions may be needed. Corrective actions may take the form of any, or all, of the following: changes to objectives, changes to objective benchmark criteria, or changes to objective evaluation methods.

The department head then formally charges the corrective action committee with the appropriate task(s) with the approval of the entire faculty. The corrective action committee then formulates its response to the charge and presents its findings to the full faculty for acceptance. It may be the case that the corrective action committee suggests no action. Any changes to the objectives themselves must be reconciled with the attributes as well.

Attribute Appraisal

Within the MAE program at USU, data to determine whether the attributes are realized is acquired from the "two year out" alumni telephone surveys. If, based upon the attribute appraisal matrix, specific attributes are not achieving their benchmark then those attributes are flagged for action. Another major source of appraisal data is "flow down" from the object evaluation cycle. If objective benchmark criteria are not being met, but it is determined that the objectives, the objective benchmark criteria, and the objective evaluation methods are correct, then the attributes are the source of curricular problems. The causal attributes are then identified by their relative importance in meeting the objectives using the objective-attribute correlation matrix. The industrial advisory board also has some qualitative input into the appraisal of the attributes. In addition, the Department Head may acquire informal qualitative input on the attributes from constituents.

On a yearly basis, the Department Head and corrective action committee analyze the appraisal data against benchmarks, previously set by the corrective action committee and approved by the faculty, and note any deviations. The data is reported to the full faculty annually. Data analysis is aided by the use of the attribute appraisal matrix. In the absence of any special needs or bubble up input, the Department Head and corrective action committee collate and review the quantitative and qualitative attribute appraisal data every three years and decide what type of corrective actions may be needed. Corrective actions may take the form of any, or all, of the following: changes to attributes, changes to attribute benchmark criteria, or changes to attribute appraisal methods.

The department head then formally charges the corrective action committee with the appropriate task(s) with the approval of the entire faculty. The corrective action committee then formulates its response to the charge and presents its findings to the full faculty for acceptance. It may be the case that the corrective action committee suggests no action. Any changes to the attributes themselves must be reconciled with the outcomes and objectives as well.

Outcome Assessment

A variety of assessment techniques are proposed to measure outcomes. At USU, data are obtained from graduating senior paper exit interviews, graduating senior focus groups, and telephone surveys of the seniors six months after graduation. If, based upon the outcome assessment matrix, specific outcomes are not achieving their benchmark then those outcomes are flagged for action. Another major source of assessment data is "flow down" from the attribute

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appraisal cycle. If attribute benchmark criteria are not being met, but it is determined that the attributes, the attribute benchmark criteria, and the attribute appraisal methods are correct, then the outcomes are the source of curricular problems. The causal outcomes are then identified by their relative importance in meeting the attributes using the attribute-outcome correlation matrix. Specific outcomes will also be assessed via external sources including external faculty (for laboratories), industry (for design activities), industry and technical writing faculty (for communication skills), and the national FE Exam (required of every student). In addition, the Department Head may acquire informal qualitative input on the outcomes from constituents.

Again, on a yearly basis, the Department Head and corrective action committee analyze the assessment data against benchmarks, previously set by the corrective action committee and approved by the faculty, and note any deviations. The data is reported to the full faculty on a yearly basis. Data analysis is aided by the use of the outcome assessment matrix. In the absence of any special needs or bubble up input, the Department Head and corrective action committee collate and review the quantitative and qualitative outcome assessment data once each year and decide what type of corrective actions may be needed. Corrective actions may take the form of any, or all, of the following: changes to outcomes, changes to outcome benchmark criteria, or changes to outcome assessment methods.

The department head then formally charges the curriculum committee with the appropriate task(s) with the approval of the entire faculty. The curriculum committee then formulates its response to the charge and presents its findings to the full faculty for acceptance. It may be the case that the curriculum committee suggests no action. Any changes to the outcomes themselves must be reconciled with the courses and attributes as well.

Course Validation

Data to determine whether the courses are supporting educational goals is acquired from students at the end of each semester with the help of learning outcome surveys. The students offer their view of whether the proposed educational goals were met for each class. Another major source of validation data is “flow down” from the outcome assessment cycle. If outcome benchmark criteria are not being met, but it is determined that the outcomes, the outcome benchmark criteria, and the outcome assessment methods are correct, then the courses are the source of curricular problems. The causal courses are then identified by their relative importance in meeting the outcomes using the outcome-course correlation matrix. The students also validate courses using a university-wide teaching evaluation. In addition, the Department Head may acquire informal qualitative input on the courses from faculty, students, or recent graduates.

On a yearly basis, the curriculum committee analyzes the validation data against benchmarks, previously set by the curriculum committee and approved by the faculty, and notes any deviations. The data is reported to the responsible faculty, the Department Head, and the corrective action committee on a yearly basis. Data analysis is aided by the use of the course validation matrix. In the absence of any special needs or bubble up input, the curriculum committee collates and reviews the quantitative and qualitative course grading data each year and decides what general type of corrective actions may be needed. Corrective actions may take the form of any, or all, of the following: changes to courses and content, changes to course benchmark criteria, or changes to course grading methods.

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The curriculum committee then formally charges the responsible faculty (for course and content changes) or the curriculum committee (for benchmark criteria or course grading methods) with the appropriate task(s) with the approval of the entire faculty. The responsible faculty or curriculum committee then formulates its response to the charge and presents its findings to the full faculty for acceptance. It may be the case that the responsible faculty or curriculum committee suggests no action. Any changes to the courses themselves must be reconciled with the outcomes as well.

III. Curricular Review Matrices

There are three types of matrices that are used to quantify and document the above curricular review process. Importance matrices are used to show the relative importance of goals. Measurement matrices document the level of performance in each metric and also the attainment for each goal and the entire level. Correlation matrices are used to compare attainment from one level to the next. Each of the matrices is described below with examples given to show the way in which the matrices are used. The examples are not intended to show the specific goals, measurements, and importances contained in individual matrices, just the matrix structures and elements.

Importance Matrices

To determine how good a curriculum is, it is important to know not only *what* goals you are trying to achieve, but, on a relative basis, *how* important each of those goals is. To do this it is necessary to weight the relative importance of each goal. In the case of our curricular review process, we have goals at three levels: objectives, attributes, and outcomes. The process of identifying the relative importance of goals must occur before the measurements are taken, as this weighting is part of how to measure.

Importance of the goals within the educational objectives is clearly an important issue. Since constituents drive objectives, constituents must also decide their relative importance. There exist many methods for determining relative importance: weighting and normalization, pairwise comparison, *etc*. All of these methods have in common the need for input from constituents as their basis of weighting. Regardless of the method chosen, the necessary result is percentage weights for each objective that total to 100% for all objectives. In the case of the USU curriculum, we have two objectives -- work preparedness and graduate school preparedness (Figure 1). Based upon constituent input as well as considerable soul searching within the department, we decided that the split between the two would be 60/40 weighted towards graduate school preparedness.

Once we began the process of better understanding and comparing our objectives, it became clear that using a similar process to develop relative weights for goals at other programmatic levels did not make sense. The purpose of the attributes in our curricular review process is to ensure that the objectives are met; in turn, the outcomes ensure that attributes are met and courses ensure that outcomes are met. The development of lower-level relative importance measures was based upon the premise that importance is derived from the importance of higher-level goals met, as shown in Figure 3. We took each of the four attributes of our curriculum

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described in Figure 1 – synthesis and problem solving, computer-based engineering, communication, and independent learning – and determined how important each was in achieving each of the two objectives. We rated the attributes using a 1-10 scale and then normalized to have a percentage relative importance for each objective. Then, by using the objective importance as a multiplier, we calculated the relative importance of each attribute. For example, communication was rated an 8 out of 10 for work preparedness, which lead to a relative importance of 8/32, or 25%. This means that 25% of the objective of work preparedness is achieved through the attributes of communication. Communication was rated a 5 for graduate school preparedness, which leads to a relative importance of 5/32, or 16%. By weighting the 25% as 40% of the importance (the relative importance of work preparedness) and 16% as 60% of the importance (the relative importance of work preparedness), the final importance of the attribute communication is 19%. This number is used throughout the following matrices when that attribute is discussed.

Objective Importance		**40**		**60**	
Objectives / **Attributes**	A. Work Preparedness		B. Graduate School Preparedness		Attribute Importance (%)
I Synthesis & Problem Solving	**10**	31	**10**	31	31
II Computer-based Engineering	**8**	25	**8**	25	25
III Communication	**8**	25	**5**	16	19
IV Indendent Learning	**6**	19	**9**	28	24
Total (100%)		100		100	100

Figure 3: Example of an Attribute Importance Matrix for a program with two objectives and four attributes.

In a similar manner, the importance of each outcome was derived from the importance of each attribute. This is shown in Figure 4. Notice the attributes' importances provide the weighting factors to arrive at the outcomes' importances. Similarly, the importance of each course was derived from the outcome importances. As with all weighted measures, the accuracy of the importance is dependant upon the accuracy of the input. We acknowledge the low accuracy in this flow-down style of weighting. However, given the curricular review process, which does not encourage hair trigger reactions to numbers, it takes a larger change in measurement to spur the corrective action committee into change.

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Attribute Importance	31		25		19		24		
Attributes / **Outcomes**	I Synthesis & Problem Solving		II Computer-based Engineering		III Communication		IV Independent Learning		Outcome Importance (%)
1. Fundamentals	**9**	21	**9**	24	**3**	10	**8**	24	20
2. Communication	**3**	7	**3**	8	**10**	32	**3**	9	13
3. Laboratory Experience	**5**	12	**2**	5	**5**	16	**3**	9	10
4. Computer-based Engineering	**9**	21	**10**	26	**5**	16	**5**	15	20
5. HASS	**3**	7	**0**	0	**2**	6	**2**	6	5
6. Design & Synthesis	**10**	23	**8**	21	**5**	16	**3**	9	18
7. Independent Learning	**4**	9	**6**	16	**1**	3	**10**	29	15
Total (100%)		100		100		100		100	100

Figure 4: Example of an Outcome Importance Matrix for a program with four attributes and seven learning outcomes.

Measurement Matrices

As with any assessment process the collection and use of data is at the heart of our process. To document and effectively use the collected data, we have a series of matrices to accompany each level of our curricular review process. As stated previously, we have four cycles of measurement and action – objective evaluation, attribute appraisal, outcome assessment, and course validation. Each of the measurement matrices is similar in that we use the relative importance of each goal (objective, attribute, outcome, and course), we use several metrics to measure each goal, we measure attainment relative to a benchmark for each metric, and we utilize the relative importance of each metric.

A fictional Objective Evaluation Matrix (Figure 5) will be used as an example to explain the role of measurement matrices in the curricular review process. The two curricular objectives – work preparedness and graduate school preparedness - are listed in the first column followed by their relative importance in the second column. The third column shows the evaluation methods (metrics) used for each objective. Here, six different evaluation metrics are used to measure work preparedness. Each method or metric has an attached importance. This defines how meaningful a particular metric is when evaluating the objective relative to the other metrics for that objective. The sum of the importances for all of the metrics for each objective must be 100%. In this example, the six metrics for work preparedness are each weighted equally. The benchmark or target is recorded in the fifth column in units particular to that evaluation method.

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Objectives	Relative Importance (%)	Evaluation Method	Method Importance (%)	Target or Benchmark (units)	Evaluation Level (%)	Objective Evaluation Level	Measures			
							SP00	SU00	FA00	SP01
A. Work Preparedness	40	% Multiple Interviews	16.67	50%	95		0	0	0	0
		% Multiple Offers	16.67	30%	54		0	0	0	0
		Average Salary	16.67	National Average	63		0	0	0	0
		% Promoted	16.67	25%	100		0	0	0	0
		% in 90%ile on FEE	16.67	10%	95		0	0	0	0
		% placed by 2 months out	16.67	90%	54	77	0	0	0	0
B. Graduate School	60	% in 90%ile on FEE	11.11	10%	63		0	0	0	0
		% apply to grad school	11.11	50%	100		0	0	0	0
		% of applicants accepted	11.11	50%	95		0	0	0	0
		% to 25%ile schools	11.11	10%	54		0	0	0	0
		attending with assistantships	11.11	25%	63		0	0	0	0
		% taking GRE within 6 mo.s	11.11	50%	100		0	0	0	0
		% in 90%ile on GRE	11.11	10%	95		0	0	0	0
		of attending done in 2 years	11.11	90%	54		0	0	0	0
		% placed by 2 months out	11.11	90%	63	76	0	0	0	0

Total Evaluation	77

Figure 5: Example of an Objective Evaluation Matrix for a program.

An important part of the documentation process is to record specific measurements obtained for each metric. In many cases, the measurements are obtained on a semester-by-semester basis and a value average over time will be used for analysis. The specific measurements made of all metrics appear in the last four columns under the heading measures. In this example, data would be collected and recorded on a semester basis beginning with the Spring 2000 semester. The measurements are all left as 0 in this yet unused matrix. However, as an example of how the matrix might be used, in column six the evaluation level is recorded for each evaluation method. This column records how close the measurements are to achieving the target or benchmark levels on a percentage basis. This can be done as a percentage of the target or as a percentage of the difference between the target and an initial baseline.

One of the critical results obtained from the Objective Evaluation Matrix is the overall evaluation level. Column seven shows the objective evaluation level, which is the sum of the products of the evaluation level and the method importance for each objective. While the evaluation level records how well the particular metric is attained, the objective evaluation level records how close we are to achieving each objective on a percentage basis. The last row of the matrix, entitled "Total Evaluation," shows the total evaluation for all of the objectives. This is the sum of the products of the individual objective evaluation levels and the objective importances. As expected, this is the measure of attainment for the objectives in total.

The Attribute Appraisal Matrix and the Outcome Assessment Matrix are developed in a similar fashion. They are shown in Figures 6 and 7.

Attributes	Attribute Importance	Appraisal Method	Method Importance (%)	Target or Benchmark (units)	Appraisal Level (%)	Attribute Appraisal Level	Measures			
							SP00	SU00	FA00	SP01
I Synthesis	31	1	50	5	100		0	0	0	0
		2	50	5	95	98	0	0	0	0
II Computer-based	25	3	50	5	90		0	0	0	0
		4	50	5	100	95	0	0	0	0
III Communication	19	5	50	5	87		0	0	0	0
		6	50	5	75	81	0	0	0	0
IV Independent Learning	24	7	50	5	87		0	0	0	0
		8	50	5	87	87	0	0	0	0

Total Appraisal =	**91**

Figure 6: Example of an Attribute Appraisal Matrix for a program with eight appraisal methods to measure four student attributes.

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Outcomes	Relative Importance	Assessment Method	Method Importance (%)	Target or Benchmark (units)	Assessment Level (%)	Outcome Assessment Level	Measures			
							SP00	SU00	FA00	SP01
1 Fundamentals	20	A	50	5	75		0	0	0	0
		B	50	5	100	88	0	0	0	0
2 Communication	13	C	50	5	87		0	0	0	0
		D	50	5	75	81	0	0	0	0
3 Laboratory Experience	10	E	50	5	100		0	0	0	0
		F	50	5	87	94	0	0	0	0
4 Computer-based Eng.	20	G	50	5	90		0	0	0	0
		H	50	5	100	95	0	0	0	0
5 HASS	5	I	50	5	87		0	0	0	0
		J	50	5	75	81	0	0	0	0
6 Design & Synthesis	18	K	50	5	100		0	0	0	0
		L	50	5	50	75	0	0	0	0
7 Independent Learning	15	M	50	5	75		0	0	0	0
		N	50	5	50	63	0	0	0	0

Total Assessment =	83

Figure 7: Example of an Outcome Assessment Matrix for a program with fourteen assessment methods to measure seven learning outcomes.

The Course Validation Matrix, a truncated version of which is shown in Figure 8, is developed in a slightly different manner. Each course is broken down into specific topics and each of those topics is in turn matched against the outcomes. Since courses can only be validated for what they teach as opposed to what students learn (outcomes), the topics' impact on outcomes are shown by a measure of the hours of coverage and the level of coverage. The level of coverage is based on a 1-3 scale where 1 indicates a beginning level emphasizing knowledge and comprehension, 2 indicates an intermediate level emphasizing application and analysis, and 3 indicates an advanced level emphasizing synthesis and evaluation. A course validation matrix exists for each individual course and a single Curriculum Validation Matrix can be assembled from all of the individual course matrices.

Correlation Matrices

The last type of matrix is the correlation matrix. Other assessment methods may use something similar to our measurement matrices, and we have seen a less thorough implementation of importance in some curricula. However, the use of correlation matrices is unique to this curricular review process. The correlation matrices are used to see if the goals of each level are correct. The matrices are used in the corrective action process to adjust the relative importance of goals and to delete goals or to insert possible new goals at each programmatic level. The correlation matrices are necessary because the situation could arise where the measurement at a higher programmatic level is high but the measurement at the next lower programmatic level is low. This would indicate that the upper level goals are being met although the lower level goals are not. This inconsistency would point towards a poor matching between the goals of the two levels and a need to revise at the lower level.

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			OUTCOMES													
			Fundamentals		*Communication*		*Lab. Experiences*		*Comp-based Eng.*		*HASS*	*Des. & Synth.*		*Ind. Learning*		Eff. Hr.s
Topics		**Hours**	Diff. Eq.	Solids	Oral Pres.	Written	Experiment.	Analysis	Soft. Dev.	Num. Sol.	Eng. & Soc.	Synth. Fund.	Integrate	Ind. Study	Ethics	Weighted Eff. Hr.s
Lecture Topics	Topic 1	3				2 2										5 10
	Topic 2	1				1 2										4 8
	Topic 3	5		1 1	1 2											7 14
	Topic 4	6									1 1					7 16
	Topic 5	7														8 16
	Topic 6	4								1 1	1 3			2 2		5 10
	Topic 7	6														6 11
	Topic 8	2						1 2								4 7
	Exams/Instructor Topics	13														
	Total Lecture Hours	*45*	*0* *0*	*1* *1*	*1* *2*	*3* *8*	*0* *0*	*1* *2*	*0* *0*	*1* *1*	*2* *4*	*0* *0*	*0* *0*	*2* *4*	*0* *0*	*46* *92*
Independent Study Topics	Topic 1	90								20 2						90 180
	Topic 2	30					10 1	10 3								50 100
	Topic 3	15								5 2						25 45
	Total Study Hours	*135*														*165* *325*
Laboratory Topics	Topic 1	3														5 10
	Topic 2	1	1 1	1 2			2 2									5 10
	Topic 3	5										1 2				5 10
	Topic 4	6								1 3	1 2		2 2			5 10
	Topic 5	7														5 10
	Topic 6	4				2 2										5 10
	Topic 7	6			1 3				2 2							5 10
	otal Laboratory Hours	*32*														*35* *70*
	Total Class Hours	**212**														
	Outcome Hours		**1**	**2**	**2**	**5**	**12**	**11**	**2**	**27**	**3**	**1**	**2**	**2**	**0**	
	Weighted Outcome Hours		**1**	**3**	**5**	**10**	**14**	**32**	**4**	**54**	**6**	**2**	**4**	**4**	**0**	
	Total Outcome Hours		**21**		**11**		**69**		**56**		**34**	**45**		**10**		
	tal Weighted Outcome Hours		**40**		**22**		**108**		**136**		**68**	**93**		**20**		
															Total Effective Hours	**246**
															otal Weighted Effective Hours	**487**

Figure 8: Example of a Course Validation Matrix for a program with eight lecture topics, three independent study topics, and seven laboratory topics.

A fictional Objective-Attribute Correlation Matrix is shown in Figure 9 as an example of correlation matrices. Note that the information in this matrix is not based upon any real measurements taken. The objectives with their relative importance are shown at the top. Below that are the attributes and their relative importances. Out to the left is the attribute appraisal level, which represents the measurement of each attribute from the attribute appraisal matrix. Below the attributes is the objective evaluation level, which is similarly from the objective evaluation matrix. Below this number is the appraised objectives level, which is used to measure the objective-attribute correlation. This number is the sum of the products of the attribute appraisal level and the relative attribute importance for each of the attributes. There is one for each objective. These numbers represent what the evaluation level of the objectives should have been based upon the appraisal level of the attributes. This number should be very close to the objective evaluation level if the attributes and their weights are correct expressions of the objectives. The discrepancy between the objective evaluation level and the appraised objectives level is shown in their ratio, the evaluation/appraisal correlation. If this number is far from 1.0 in either direction there is a need for corrective action. These two correlations are combined, using

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the relative importance of the objectives in the total correlation, here shown to be 0.84 to indicate an overall correlation between objectives and attributes.

Attribute Appraisal Level			Objectives: A. Work Preparedness	Objectives: B. Grad School	
		Objective Importance	*40*	*60*	
98	Attributes	I Synthesis	31	31	
95	Attributes	II Computer-based	25	25	
81	Attributes	III Communication	25	16	
87	Attributes	IV Independent Learning	19	28	
		Objective Evaluation Level	*77*	*76*	
		Appraised Objectives Level	91	91	
		Evaluation/Appraisal Correlation	**0.85**	**0.84**	**Total Correlation = 0.84**

Figure 9: Example of an Objective-Attribute Correlation Matrix with two objectives and four attributes.

Similar methods of analysis are performed for the other two possible cases – the Attribute-Outcome Correlation Matrix and the Outcome-Course Correlation Matrix as shown in Figures 10 and 11.

Outcome Assessment Level			Attributes: I Synthesis	Attributes: II Computer-based Eng.	Attributes: III Communication	Attributes: IV Independent Learning	
		Attribute Importance	*31*	*25*	*19*	*24*	
88	Outcomes	1. Fundamentals	21	24	10	24	
81	Outcomes	2. Communication	7	8	32	9	
94	Outcomes	3. Laboratory Experience	12	5	16	9	
95	Outcomes	4. Computer-based Eng.	21	26	16	15	
81	Outcomes	5. HASS	7	0	6	6	
75	Outcomes	6. Design & Synthesis	23	21	16	9	
63	Outcomes	7. Independent Learning	9	16	3	29	
		Attribute Appraisal Level	*98*	*95*	*81*	*87*	
		Assessed Attributed Level	84	83	84	80	
		Appraisal/Assessment Correlation	**1.17**	**1.15**	**0.96**	**1.09**	**Total Correlation = 1.10**

Figure 10: Example of an Attribute - Outcome Correlation Matrix with four attributes and seven outcomes.

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Course Grading Level			Outcomes 1	2	3	4	5	6	7	
		Outcome Importance	*20*	*13*	*10*	*20*	*5*	*18*	*15*	
94	Courses	MAE 1000	23	28	10	33	33	33	33	
88		MAE 2000	8	9	33	13	13	13	13	
81		MAE 2100	13	6	17	13	13	13	13	
94		MAE 3000	23	31	17	21	21	21	21	
63		MAE 4300	8	0	7	8	8	8	8	
69		MAE 5200	26	25	17	13	13	13	13	
		Outcome Assessment Level	*88*	*81*	*94*	*95*	*81*	*75*	*63*	
		Graded Outcomes Level	83	86	83	85	85	85	85	
		Assessment/Grading Correlation	**1.06**	**0.94**	**1.12**	**1.11**	**0.95**	**0.88**	**0.73**	**Total Correlation = 0.98**

Figure 11: Example of an Outcome - Course Correlation Matrix with seven outcomes and six courses.

IV. Summary

As we reviewed the abundant literature on the ABET EC-2000 process, we discovered little has been written on systematic processes to act upon assessment results. In this paper we describe a curricular review process that not only establishes performance criteria and assessment methods, but also systematizes corrective actions to continuously improve the overall program.

This review process is flexible in nature. Clearly, the review process must match the organizational structure of the department using it. Who is in charge of the various tasks and the frequency at which they take place is dependent upon the situation in which it is implemented. However, the structure of the review process that we have used at USU is what is important here. The review process has three main elements that are necessary for continuous improvement and continuity of goals – three sets of matrices, multiple programmatic levels, and review cycles.

The three sets of matrices used in this review process are importance matrices, measurement matrices, and correlation matrices. Importance matrices define the relative importance of goals at each programmatic level. Measurement matrices document the level of performance at each programmatic level relative to a set of benchmarks. Correlation matrices correlate the goals from one programmatic level to the next. These matrices allow a program to quantify their curriculum in terms of goals, attainment, and flow. Each matrix develops information used in the other matrices. The matrices provide an efficient means of documentation of the review process.

While other assessment methods may use something similar to our measurement matrices, the use of correlation matrices is unique to this curricular review process. The correlation matrices allow us to analyze whether the goals of each programmatic level are correct. The correlation matrices are necessary because a situation could arise where the measurement at a higher programmatic level is high but the measurement at the next lower programmatic level is low. This would say that the upper level goals are being met although the lower level goals are not.

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This inconsistency would point towards a poor matching of the goals of the two levels and a need to revise at the lower level.

Our review process contains four programmatic levels – objectives, attributes, outcomes, and courses. The number of levels used is unimportant. What is important is using levels of increasing detail to characterize the curriculum. Even more important is to take a top down approach to identifying the goals at each programmatic level. The objectives frame the attributes which frame the outcomes, *etc*. This creates a curriculum where the goals at each level are easily justified and changes to the goals are more rational and easily validated.

Review cycles of varying duration are a key element in our review process. The duration of the review process must match the scope of the programmatic level. Of course we would not want to change curricular objectives each year. Nor would we want to wait six years to change a course that does not fit our curricular outcomes. The exact durations are not as important as the commitment to fixed periods of review to allow for continuous assessment of goals and attainment as well as a definite mechanism to make changes at each programmatic level. This allows the curriculum to evolve and continuously improve in a fluid and rational manner rather than swinging back and forth in response to short term issues.

Developing the goals at each level is most definitely time consuming. This process was not discussed here. There is a difficult, long, and rewarding process of developing the objectives, attributes, and outcomes for the initial implementation of this review process. At USU this work took approximately one year. How we developed the goals is not discussed in this paper but it is a story in collaboration and teamwork. It is important to note that once the initial framework is in place, the implementation of the review process is quick and rather easy. In addition, the future periodic review processes are not nearly as time consuming. Our curricular review process requires an upfront investment of time. Once that investment is made, subsequent review processes require little involvement by the full faculty with the exception of considering recommendations for corrective actions. This is precisely the involvement we want from the faculty in a continuous improvement process.

There have been other, unintended benefits to the development and implementation of this curricular review process. To date we have developed the review process and have slowly begun to implement the process. The data collection associated with metrics at each programmatic level has been greatly assisted by knowing what we plan to do with data before we begin to collect it. Discussions among faculty and with constituents in initially establishing the relative importance of goals at the objective level proved valuable in developing goals and developing relationships with our stakeholders.

Development of the course validation matrices, a task left to each faculty member, was an arduous task. Faculty were initially reluctant to complete the matrix because of the level of detail required. Members of the ABET committee were challenged by the faculty to defend the value of the curriculum review process on numerous occasions. In the end, everyone agreed on the process to a great extent and faculty are beginning use the course validation matrices to help them visualize their course as a contribution to learning outcomes rather than a series of isolated topics.

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In closing, we are convinced a curricular review process that provides a formal way of closing feedback loops at all programmatic levels is critical if the goal of continuous improvement is to be attained and sustained. While it will be many years before we see all of the fruits of this labor, the immediate progress we have made is substantial. Having systematized this continuous improvement process, we can not go back to curriculum decision making by shooting darts.

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