

Application of Value Engineering Techniques in Curriculum Development and Review*

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A novel process for curriculum review developed in Mechanical and Aerospace Engineering at Utah State University is described. The process, based on value engineering techniques, is quantitative, allows faculty freedom to innovate and is sufficiently flexible that it can be applied to many engineering programs. 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. A curricular review process is then described which employs these matrices to adjust the relative importance of goals and to insert or delete possible new goals. The review process provides a formal way of closing the feedback loops at all programmatic levels from the course level to the objective level. An example of implementation of the curricular review process is presented.

INTRODUCTION

FACULTY OF THE Mechanical & Aerospace Engineering (MAE) program at Utah State University (USU) began preparation for a program review by the American Board for Engineering and Technology (ABET) several years ago. As we reviewed the ABET EC 2000 criteria, we realized many of our processes already resulted in continuous quality improvement, although not all processes were as formal as we might like. Tools used in value engineering and engineering decision-making could help formalize some of our review processes, especially when we needed to measure the curriculum and decide between alternatives based upon multiple criteria. Tools to aid in these processes include concept selection, quality function deployment, and relative worth analysis.

This paper describes a new curricular review process that incorporates value-engineering tools in the form of curricular review matrices. The review process is sufficiently flexible that it could be applied to a variety of engineering programs seeking ABET accreditation, or other assessment-based accreditation processes. As an example, we will show how the review matrices are applied to the MAE program at USU. The review process not

only establishes performance criteria and assessment methods, but also systematizes corrective actions to continuously improve the overall program. 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.

First we will first provide a background section that includes a literature review on current assessment strategies and curriculum review as much has been written on the subject. In this section, we will also provide a brief review of value engineering. Next, we will briefly introduce four programmatic levels that define the goals of the MAE undergraduate program and the schemes to measure progress in meeting the goals. Then we will introduce three curricular review matrices and show their application to the MAE program. Finally, we will show how the review matrices can be included in a complete curricular review process culminating in further development and improvement of the program, again using MAE as an example.

BACKGROUND

Several authors have noted the similarities of the EC 2000 criteria and ISO 9001 [1–3]. Aldridge and

* Accepted 14 September 2001.

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 has 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 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 points to a need for a systematic process to act upon assessment results as emphasized by Lohman [22]. We came to a similar conclusion as we began to sift through the ABET 2000 requirements and their application to

our program. Quantitative answers to the following basic questions highlight the fundamental nature of the information we were seeking:

- How well do our outcomes satisfy our objectives?
- Are we placing proper relative emphasis on the outcomes?
- How well do our classes meet our outcomes?
- How well does an individual class meet the outcomes?
- How efficient is a class at meeting outcomes?
- Are prerequisite tasks lined up properly and covered properly?
- Are students meeting the objectives?

We found no single model for handling all such questions quantitatively. It was clear that a curricular review *process* is what is needed to understand and act upon results from the assessment methods. For ideas on this, we looked to value engineering and engineering decision making.

Tools to aid in these processes include concept selection, quality function deployment (QFD), and relative worth analysis (RWA). Concept selection uses multiple weighted criteria to decide among alternative concepts [23]. This selection method has been applied in many fields with many names. Utility theory, upon which concept selection is based, is the mathematical foundation for concept selection and similar tools [24]. Quality function deployment provides a formal mechanism for translating customer requirements into design targets and major quality assurance checkpoints to be used throughout product development and production [25]. Relative worth analysis uses the weighted importance of product components relative to two different criteria, cost and functional importance, to measure the 'worth' of individual components in a product. The goal would be to have components that are not overpriced but the value of the product is as high as possible. Elements of each of these value-engineering tools were used in our curriculum development and measurement methods.

BRIEF REVIEW OF MAE UNDERGRADUATE PROGRAM GOALS

The ABET Engineering Criteria 2000 requires that an engineering program have in place a set of educational objectives and outcomes [26]. MAE elected to add two additional programmatic levels: attributes and courses. Objectives are defined as statements that describe the expected accomplishments of graduates during the first few years after graduation. Attributes of graduated engineering students are statements that describe specific skills of graduates that are essential for success in accomplishing the undergraduate program objectives. Outcomes are statements that describe broadly what students are expected to know and are able to do by the time of graduation. Among

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

Fig. 1. Example goals and measurement cycles of the four MAE programmatic levels.

the goals of the MAE outcomes are the eleven required by ABET, Criteria 3 [26]. 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.

The curriculum review process is split into four corresponding cycles of:

- objective evaluation
- attribute appraisal
- outcome assessment
- course validation.

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, as illustrated in Fig. 1.

CURRICULAR REVIEW MATRICES

Using value-engineering ideas, we propose three types of matrices to quantify and document a 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 the attainment for each goal and the entire level. Correlation matrices are used to compare attainment from one level to the next.

Importance matrices

We have goals at three programmatic levels: objectives, attributes, and outcomes. The process of identifying the relative importance of goals at each level must occur before the measurements are taken, as this weighting is part of how to measure. Since constituents drive objectives, constituents must also decide their relative importance. We have two objectives—work preparedness and graduate school preparedness (Fig. 1). Based upon constituent input, we decided that the relative importance is 60% for graduate school preparedness and 40% for work preparedness.

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 Fig. 2.

This follows the requirements flow down method as used in QFD, RWA, and other value engineering tools. We took each of the four attributes of our curriculum described in Fig. 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 the 16% as 60% of the importance (the relative importance of work preparedness), the final importance of the attribute

communication is 19%: $(0.25 \times 40\%) + (0.16 \times 60\%)$. This number is used throughout the following matrices when that attribute is discussed.

In a similar requirements flow down manner, the importance of each outcome was derived from the importance of each attribute. This is shown in Fig. 3.

We rated the outcomes using a 1–10 scale and then normalized to have a percentage relative importance for each attribute. For example, we ranked fundamentals as 3 out of 10 for relative importance in meeting the communication attribute which lead to a relative importance of 3/31, or 10%. This means that 10% of the attribute of communication is achieved through the fundamentals outcome which is probably not surprising since the fundamentals outcomes states students will be able to formulate and solve problems using math, chemistry, physics and basic engineering sciences. The learning outcome does not have a strong oral or written component. The outcome ‘communication’, which includes oral and written communication as well as developing engineering drawings and specifications and participating in team-based engineering projects, was ranked 10 out of 10 for relative importance in meeting the communication attribute which lead to a relative importance of 10/31 or 32%. By using the attribute weights, we derive an overall outcome importance percentage. For example, the communication outcomes final importance is 12% which is found by summing the relative importance of communication weighted by the attribute importance (7×31) , the relative importance of communication weighted by the computer-based engineering attribute importance (8×25) , the relative importance of communication outcome weighted by the communication attribute (32×19) and the relative importance of communication weighted by the independent learning attribute (9×24) . The summation is normalized by 100 to arrive at the final figure of 12%.

Measurement matrices

We have four cycles of measurement and action—objective evaluation, attribute appraisal,

Objective Importance	40		60		
Objectives	A. Work Preparedness		B. Graduate School		Attribute Importance
Attributes					
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 Independent Learning	6	19%	9	28%	24%
Total	32	100%	32	100%	100%

Fig. 2. Example of an Attribute Importance Matrix.

Attributes	31%		25%		19%		24%		Outcome Importance
Outcomes	I Synthesis & Problem Solving		II Computer-based Engineering		III Communication		IV Independent Learning		
1. Fundamentals	9	21%	9	24%	3	10%	8	24%	20%
2. Communication	3	7%	3	8%	10	32%	3	9%	12%
3. Laboratory Experience	5	12%	2	5%	5	18%	3	9%	10%
4. Computer-based Engineering	9	21%	10	26%	5	18%	5	15%	20%
5. HASS	3	7%	0	0%	2	8%	2	8%	5%
6. Design & Synthesis	10	23%	8	21%	5	18%	3	9%	18%
7. Independent Learning	4	9%	6	16%	1	3%	10	28%	15%
Total	43	100%	38	100%	31	100%	34	100%	100%

Fig. 3. Example of an Outcome Importance Matrix.

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 rank the importance of each goal evaluation method, we measure attainment relative to a benchmark for each metric, and we utilize the relative importance of each metric.

A fictitious Objective Evaluation Matrix (Fig. 4) will be used as an example. 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.

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%. The number of job interviews students have is rated as 10% in importance compared to all evaluation data. On the other hand, the number of students who are placed in a job two months after graduation is rated as 28% in importance compared to all evaluation data. The benchmark or target is recorded in the fifth column in units particular to that evaluation method. In column six, we record the actual measurements. The evaluation level is recorded in column seven as the ratio of the actual result and the target value.

The critical result obtained from the Objective Evaluation Matrix is the overall evaluation level, shown in column seven. While the evaluation level

Objectives	Relative Importance (%)	Evaluation Method	Method Importance	Target or Benchmark (units)	Measured Results (units)	Evaluation Level (%)	Objective Evaluation
A. Work Preparedness	40	% Multiple Interviews	10	66%	45%	68	82
		% Multiple Offers	16	30%	36%	117	
		Average Salary	19	National Average	5% above Nat Avg	105	
		% Promoted	7	25%	15%	60	
		% in 90 th ile on FEE	20	10%	8%	80	
		% placed by 2 months out	28	90%	85%	94	
B. Graduate School Preparedness	60	% in 90 th ile on FEE	7	10%	8%	80	83
		% apply to grad school	13	50%	40%	80	
		% of applicants accepted	18	50%	45%	90	
		% to 25 th ile schools	19	10%	8%	80	
		% attending with assistantships	22	65%	50%	77	
		% taking GRE within 6 mo.s	6	60%	50%	83	
		% in 90 th ile on GRE	5	10%	6%	60	
		% of attending done in 2 years	7	70%	80%	114	
		% placed by 2 months out	5	90%	85%	94	
Total Evaluation = 0.40*82 + 0.60*83							87

Fig. 4. Example of an Objective Evaluation Matrix for a program.

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. This value is obtained by summing the evaluation levels weighted by the method importance. The objective level evaluation for worked preparedness was found to be 92 by performing the following calculation: $(68 * 10 + 117 * 16 + 105 * 19 + 60 * 7 + 80 * 20 + 94 * 28) / 100$. 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.

Another fictitious matrix associated with attribute appraisal is shown in Fig. 5. Here, we have only one or two appraisal methods, but in most cases have exceeded the target values for sake of example. The attribute appraisal level, shown in column 7 is the sum of the products of the appraisal level and the method importance for each attribute.

Specific numerical values for the example matrices in Figs 4 and 5 will be used in the next section. Measurement matrices for outcome assessment and course validation were developed, but are not shown in the paper.

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 consistent. Results from these matrices can be used in a curriculum review 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 useful 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.

A fictional Objective-Attribute Correlation Matrix is shown in Fig. 6 as an example of correlation matrices. The purpose is to compare the objective evaluation with the cumulative, weighted appraisal of the attributes. Note that the information in this matrix is not based upon any real measurements taken. In fact, we have intentionally produced objective evaluation levels and attribute appraisal levels that are skewed to illustrate the value of this matrix. The top part of the matrix is formed from results from importance and measurement matrices described early.

The objectives with their relative importance are shown at the top—40 and 60. Below the objective importance row are the attributes and their relative importances from Fig. 2. The column to the far left is the attribute appraisal level developed in Fig. 5. Below the attributes is the objective evaluation level, developed in Fig. 6.

The row entitled 'Appraised Objective Level' 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. For example, the work preparedness result of 128 is obtained by the following calculation: $(127 * 31 + 167 * 25 + 97 * 19 + 120 * 24) / 100$. These appraised-objective level values (92 and 83 in this example) 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

Attributes	Relative Importance %	Appraisal Method	Method Importance	Target or Benchmark (units)	Measured Results (units)	Evaluation Level (%)	Attribute Appraisal Level (%)
I Synthesis	31	Self-Assessment Questions	25%	3	5	167	127
		FEE Score	75%	75%	85%	113	
II Computer-based	25	Self-Assessment Question	100%	3	5	167	167
III Communication	19	Self-Assessment Questions	70%	3	2	67	97
		Senior Design Comm Score	30%	3	5	167	
IV Independent Learning	24	Self-Assessment Question	33%	3	4	133	120
		FEE Score	67%	75%	85%	113	
TOTAL APPRAISAL = $0.31 * 127 + 0.25 * 167 + 0.19 * 97 + 0.24 * 120$							128

Fig. 5. Example of an Attribute Appraisal Matrix.

appraised objectives level is shown in their ratio, the evaluation/appraisal correlation (0.72 and 0.64 in this example). If these numbers are far from 1.0 in either direction, there is a need for corrective action.

Finally, these two evaluation/appraisal correlations using the relative importance of the objectives in the total correlation, here shown to be 0.87. The calculation to arrive at 0.87 is $(40 * 0.72 + 60 * 0.64) / 100$. This final result indicates the level of the overall correlation between objectives and attributes. In this contrived example, the total correlation of 0.67 would be unacceptable. We would be forced to review specific goals within our objectives and attributes, as well as the evaluation and appraisal schemes.

Similar analysis was performed to develop an Attribute-Outcome Correlation Matrix and an Outcome-Course Correlation Matrix. These results are not shown in this paper.

CURRICULAR REVIEW PROCESS

The five major entities involved in the review process ongoing in the MAE program at USU are 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 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. 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.

Shown in Fig. 7 is a 'solar system' metaphor illustrating our review process. The three planets orbiting the MAE curriculum represent programmatic levels with an ever-increasing period of review. The objective evaluation is shown in the outmost orbit because it occurs on a six-year cycle while the outcome assessment is shown in an inner orbit because it occurs on a one-year review cycle.

The satellite is a metaphor for the corrective action committee. The satellite receives quantitative signals from the objective evaluation, attribute appraisal, outcome assessment, and course validation. It also receives qualitative signals from our constituents in industry, government, and academia. The satellite (corrective action committee) broadcasts changes in goals at any programmatic level based on the incoming signals. Students are represented as a space shuttle that is grounded in the MAE curriculum. During the educational process, students should develop sufficient skills to satisfy the individual courses, outcomes, attributes, and objectives of the program as they are propelled into careers in government, academia, or industry.

OBJECTIVE EVALUATION

The curricular review process is split into four cycles. Objective evaluation, due to its long-range focus, occurs nominally once every six years corresponding with the ABET review process. 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 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

		Objectives			
		A. Work Preparedness	B. Grad School Preparedness		
Attribute Appraisal Level	Attributes	Objective Importance	40	60	Attribute Importance
		I Synthesis	31	31	
		II Computer-based	25	25	
		III Communication	25	16	
		IV Independent Learning	19	28	
		Objective Evaluation Level	92	83	
		Appraised Objectives Level	128	130	
		Evaluation/Appraisal Correlation	0.72	0.64	Total Correlation = 0.67

Fig. 6. Example of an Objective-Attribute Correlation Matrix.

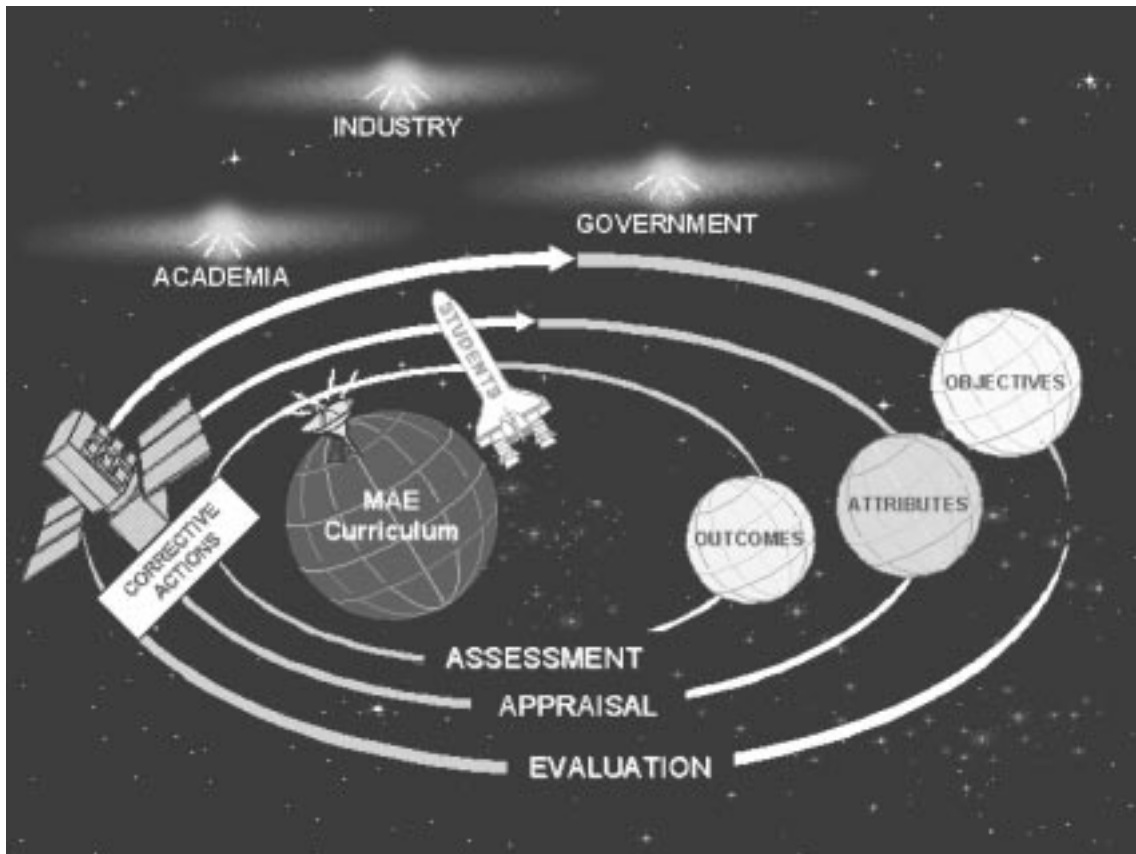


Fig. 7. Illustration of the circular review process using a solar system metaphor.

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 employ the Objective Evaluation matrix to analyze the evaluation data against benchmarks previously set by the corrective action committee and approved by the faculty, and note any deviations. Data are reported to the full faculty on a yearly basis. 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 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.

ATTRIBUTE APPRAISAL

Attribute appraisal occurs nominally once every three years. Data to determine whether the attributes are realized are 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 and faculty may acquire informal qualitative input on the attributes from constituents. Both the objective evaluation and the attribute appraisal processes are shown in Fig. 8.

On a yearly basis, the Department Head and corrective action committee analyze the appraisal data against previously set benchmarks and results are reported to the full faculty. 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

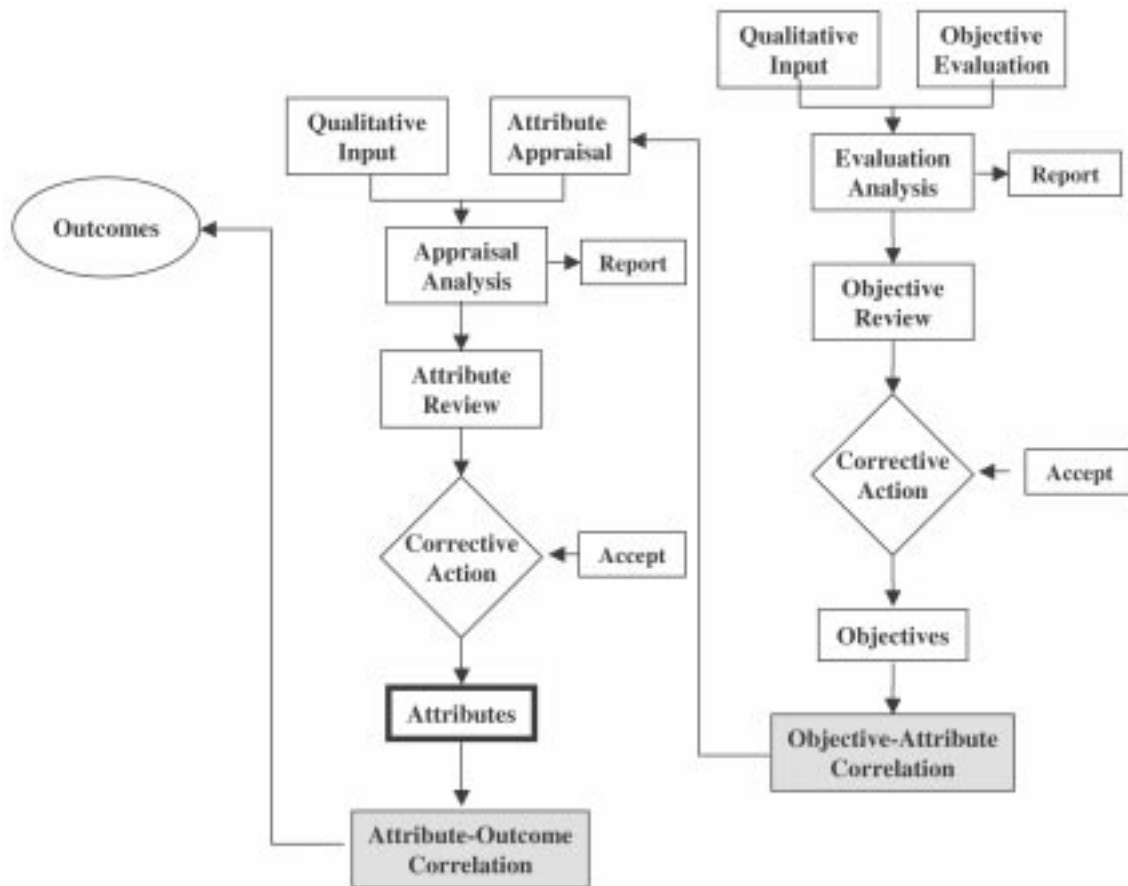


Fig. 8. Undergraduate curriculum review process with flow down from objective evaluation to attribute appraisal. Not shown are outcome assessment or course validation.

committee collate and review the quantitative and qualitative attribute appraisal data every three years and decide what type of corrective actions may be needed. The department head then formally charges the corrective action committee who then formulates their response to the charge and presents their 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.

The curriculum review processes for outcome assessment and course validation proceed in a similar fashion with yearly or semester length cycles, respectively. Measurement matrices are used to compare quantitative data with benchmarks to determine whether corrective actions are necessary. Importance matrices are used as input to the correlation matrices. Matrices for attribute-outcome and outcome-course correlations can be developed to insure the goals and measurement schemes are correct.

CONCLUSIONS

Implementation of our review process permits us to provide quantitative answers to the

questions posed in the background section. Importance matrices allow us to know which outcomes are relatively more important in meeting our undergraduate program objectives. The same can be done at each level. The importance matrices can also be used to help in resource allocation decisions. Lastly, the importance matrices quickly identify lower level goals that do nothing to meet higher level goals or higher level goals that are not backed by lower level goals.

The measurement matrices allow us to answer the question, 'How are we doing in meeting our goals?' This question can be answered at each programmatic level and we can track improvement as well. If strides are not being made to reach targets or benchmarks, the corrective action process begins. The more complex correlation matrices answer questions such as, 'Does meeting the attributes lead to meeting the objectives?' By comparing how well lower level goals should be meeting higher level goals with how well the higher level goals are actually being met, the correlation matrices close the feedback loop between levels. Altogether, these three sets of matrices, along with a curricular review process, enable the systematic, continuous improvement of an undergraduate curriculum.

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