Fuzzy Logic to Assess ABET-Accredited Degree Program Emphasis

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Abstract

In the Self-Study Questionnaire, the ABET definition of well-defined processes necessary to administer engineering programs is: "Processes for all elements of criteria are quantitatively understood and controlled; clearly tied to mission, program objectives, and constituent needs; seen as benchmarks by other institutions." To date, there has been little discussion on approaches to benchmarking programs.

Benchmarking consists of comparing programs to assess program effectiveness and efficiency. Effectiveness measures the achievement level of Program Outcomes and Program Objectives, while efficiency measures the portion of the curriculum devoted to each Program Outcome and Program Objective. In order to perform benchmarking, programs with similar program objectives, program outcomes, and corresponding curriculum emphasis must be identified and the curriculum must be measurable. This paper presents an approach to defining curriculum metrics that can be used for benchmarking programs as well as assessing curriculum efficiency.

Introduction

In earlier versions of the ABET criteria, needs of program constituents were addressed in the context of accredited program requirements. The Criteria now requires that program constituents are involved in the strategic planning process. In the Self-Study Questionnaire, the ABET definition of well-defined processes necessary to administer engineering programs is:

> "Processes for all elements of criteria are quantitatively understood and controlled; clearly tied to mission, program objectives, and constituent needs; seen as benchmarks by other institutions."

Using the current ABET Criteria, a program emphasis should now reflect participation by program constituents. Typical differences in constituents include, but are not limited to:

- Number and interests of the faculty.
- Amount and type of research.
- Number and academic preparation of students.
- Organizations that recruit program graduates.

All accredited programs have the same program outcomes based on ABET Criterion 3 *a-k*. Although the *a-k* outcomes for all engineering programs are the same, programs often have different levels of *a-k* implementation. For example, it is reasonable to expect different mathematics requirements for industrial engineering and electrical engineering programs.

Within an engineering discipline, *a-k* outcomes are very similar. However, within a discipline the differences in accredited programs reflect constituent participation in the process. These differences should also be reflected in the Program Objectives and Signature Program Outcomes.

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Program Environment

ABET Criteria 2 and 3 address the strategic planning activities necessary for a well defined program. Common basic features of such programs are:

- 3 to 5 Program Objectives that characterize program graduates within three to five years after graduation.
- An articulation of Criterion 3 *a-k* Program Outcomes that support one or more Program Objectives and reflect the graduate's technical competence and understanding of engineering.
- An assessment process to measure the Program Objectives and Outcomes.

To benchmark a curriculum's effectiveness and efficiency, it is proposed in this paper that the following features be added to ABET Criteria 2 and 3.

- 2 – 4 Signature Program Outcomes that complement Criterion 3 *a-k*.
- 3 – 5 Course Outcomes per course that enable students to achieve competency in one or more Program Outcomes.

The Signature Program Outcomes reflect constituent participation and are also useful when identifying comparable programs for benchmarking. Using the Levels of Understanding from Bloom's Taxonomy to articulate Course Outcomes will enable Program and Course Outcomes to be tightly coupled and therefore much easier to measure. These Levels of Understanding are:

- **Knowledge:** List, Cite, Name, Recount, And Define.
- **Comprehension:** Restate, Identify, Discuss, Review, and Summarize.
- **Application:** Exhibit, Solve, Demonstrate, Show, And Apply.
- **Analysis:** Inquire, Group, Interpret, Classify, and Compare
- **Synthesis:** Plan, Develop, Predict, Create, and Hypothesize.
- **Evaluation:** Infer, Estimate, Conclude, and Determine.

Relationships between Program Objectives, Program Outcomes, and Course Outcomes are represented in Figure 1. The network flow is from left to right. Course outcomes are the inputs to develop the student's abilities as defined in the Program Outcomes; these Outcomes are inputs that enable the graduate to be successful as described by the Program Objectives. The planning process cascades from right to left. Program Objectives are the basis for necessary implementation levels of Criterion 3 *a-k* and Signature Program Outcomes. The Course Outcomes are then developed to support the Program Outcomes. Program Objectives as well as Program Outcomes should be "reasonably" orthogonal. Otherwise, the measurement criteria are redundant. Because Course Outcomes reinforce and expand a student's technical competence and understanding of engineering, there are correlations of Course Outcomes between courses. Not represented in Figure 1 are relationships between courses.

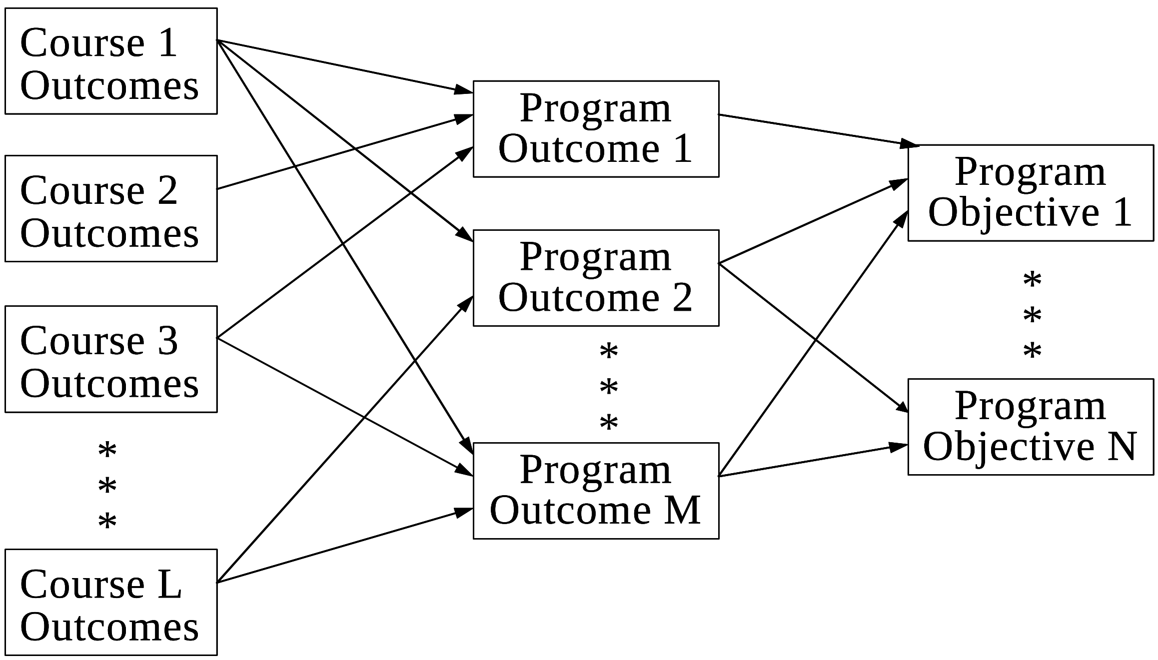

Figure 1: Representation of Program Network

At each level, the effort should focus on previously defined program effectiveness and efficiency. Participants represented in the strategic planning process include ABET, the discipline's professional society, faculty, alumni, industry representatives, and students. The leadership role of these constituents is dependent on their insight into various elements of the program. Faculty and industry representatives share the leadership in developing course content. Faculty and students share leadership for levels of achievement in each course. ABET, the governing professional society, faculty, alumni, industry representatives share the leadership for developing program outcomes. Faculty, alumni, and industry representatives provide leadership to ensure Program Outcomes enable graduates to achieve the success articulated in the Program Objectives.

A degree of association for links in Figure 1 that varies between 0 and 1.0 can be the basis for assessing program efficiency. An association of 1.0 indicates that the relationship is critical; an association of 0.0 indicates that little or no relationship exists. Course Outcome – Program

Outcome links represent an estimate of the Course Outcome's importance to that Program Outcome. In a similar manner, Program Outcome – Program Objective links are an estimate of the Program Outcome's importance to a Program Objective. The curriculum emphasis for each Program Outcome can be estimated using the expression in Figure 2.

```
for (p = 0; p < M; p++)                    // each program outcome
  {programOutcome [p] = 0;
   for (q = 0; q < L; q++)                 // each course
     {for (r = 0; r < K; r++)              // each course outcome
        {ProgramOutcome [p] +=
             CourseOutcomeAssociation[q][r] * creditHours [q];
        }
     }
  }
```

Figure 2: Curriculum Allocation to Program Outcomes

In a similar manner the curriculum emphasis for each Program Objective can be estimated using results from Figure 2 and the expression in Figure 3.

```
for (i = 0; i < M; i++)                    // each program objective
  {programObjective [i] = 0;
   for (j = 0; j < M; j++)                 // each program outcome
     {ProgramObective [i] +=
          OutcomeObjectiveAssociation[i][j] * ProgramOutcome [j];
     }
  }
```

Figure 3: Curriculum Allocation to Program Objectives

With program elements documented in this manner, it is possible to benchmark:

- Curriculum requirements for Outcomes and Objectives (Efficiency).
- Achievement levels for Outcomes and Objectives (Effectiveness).
- Sensitivity analysis on program revisions.

Industrial Engineering Program

For the most recent ABET visit, the Department of Industrial Engineering at Tennessee Technological University had the above components necessary to determine program effectiveness. Subsequent to that visit, efforts were begun to develop the components necessary to measure program efficiency. The remainder of this section provides an overview of the

Industrial Engineering Degree Program and examples of data requirements necessary to measure efficiency. The Industrial Engineering Degree Program Objectives are that graduates will:

- Lead the planning, designing, developing, and controlling of integrated systems.
- Apply industrial engineering concepts and tools to improve processes in service and manufacturing systems.
- Use analytical techniques to model complex systems and make inferences for effective decisions.
- Pursue graduate education in either a research or professional degree program.

Table 1 presents the basic Program Outcomes from the ABET Criterion 3 *a-k* and Signature Program Outcomes *l-o*. Table 1 also includes estimates for each Program Outcome's importance to a Program Objective. These values are based on faculty and Advisory Board estimates.

Table 1: Industrial Engineering Program Outcomes at Tennessee Tech University

Program Outcomes		**Program Objectives**			
		1	**2**	**3**	**4**
(a)	ability to apply knowledge of math, engineering, and science			1.00	0.80
(b1)	ability to design and conduct experiments		1.00	1.00	
(b2)	ability to analyze and interpret data		1.00	1.00	1.00
(c)	ability to design system, component or process to meet needs			0.70	
(d)	ability to function on multi-disciplinary teams	1.00		0.80	
(e)	ability to identify, formulate, and solve engineering problems	0.80	0.90	1.00	1.00
(f)	understanding of professional and ethical responsibility	0.80	0.70	0.70	0.80
(g)	ability to communicate effectively	1.00	0.80	0.90	0.90
(h)	broad education	0.90	0.70		0.90
(i)	recognition of need an ability to engage in life-long learning	1.00		1.00	1.00
(j)	knowledge of contemporary issues	1.00	0.70		0.80
(k)	ability to use techniques, skills, and tools in engineering practice	0.70	1.00	1.00	0.80
(l)	ability to specify data requirements to assess and improve system performance	0.50	0.70	1.00	0.70
(m)	ability to develop and evaluate abstract models of system performance.		0.70	1.00	0.80
(n)	ability to utilize analytical techniques for decision-making			1.00	
(o)	ability to provide leadership in individual and team situations	1.00			

In Table 2 are Course Outcomes *a-g* and percent of the course allocated to each Outcome for the three-credit-hour Engineering Economy course. Table 3 presents estimates of the Engineering Economy Course Outcome's importance to each Program Outcome. The faculty is working with the Industrial Advisory Board to develop similar data for the entire curriculum.

Table 2: IME 3100 Course Summary

IME 3100 Engineering Economy Course Outcomes	Course %	Credit Hrs.
a. Summarize concepts of time value of money.	5	0.15
b. Perform interest formula calculations for cash flow diagrams.	15	0.45
c. Develop the cash flow diagram for a project.	10	0.30
d. Perform an economic analysis, including sensitivity analysis, of alternative projects using interest formulas.	30	0.90
e. Determine the effect of taxes and inflation on profitability of projects.	20	0.60
f. Perform an economic replacement analysis for existing asset.	15	0.45
g. Perform basic capital budgeting analysis.	5	0.15

Table 3: Course Outcome – Program Outcome Links for IME 3100

Program Outcomes		IME 3100 Outcomes						
		a	b	c	d	e	f	g
(a)	ability to apply knowledge of math, engineering, and science	0.90	0.90	1.00	1.00	1.00	1.00	1.00
(b1)	ability to design and conduct experiments							
(b2)	ability to analyze and interpret data			1.00	1.00	1.00	1.00	1.00
(c)	ability to design system, component or process to meet needs							
(d)	ability to function on multi-disciplinary teams			0.80	1.00	1.00	1.00	1.00
(e)	ability to identify, formulate, and solve engineering problems	0.80		1.00	1.00	1.00	1.00	1.00
(f)	understanding of professional and ethical responsibility							
(g)	ability to communicate effectively	0.80		0.80	0.80	0.80	0.80	0.80
(h)	broad education							
(i)	recognition of need and ability to engage in life-long learning							
(j)	knowledge of contemporary issues							
(k)	ability to use techniques, skills, and tools in engineering practice	0.90	0.90	1.00	1.00	1.00	1.00	1.00
(l)	ability to specify data requirements to assess and improve system performance							
(m)	ability to develop and evaluate abstract models of system performance			1.00	1.00	1.00	1.00	1.00
(n)	ability to utilize analytical techniques for decision-making			1.00	1.00	1.00	1.00	1.00
(o)	ability to provide leadership in individual and team situations							

Data from Tables 1, 2, and 3 and expressions in Figures 1 and 2 can be used to prepare summary program information similar to that shown in Table 4. Information presented in this manner enables constituents as well as others interested in program metrics to have easy access to that information. It is not important that totals are 100 percent; however, well defined program objectives and outcomes that are nearly orthogonal will improve the quality of information.

There is increasing pressure on universities to show measurable cost benefit of academic programs. This approach can also be the basis for efficiently administering engineering programs within a college. For example, the same information can be used to assess program resource requirements as well as a needs assessment for service courses for the college.

Table 4: Curriculum Emphasis for Program Objectives and Outcomes

Program	Curriculum %
Objective # 1	37.3
Objective # 2	61.8
Outcome a	15.2
Outcome b1	8.5
Outcome b2	6.3

Conclusions

Although the importance of achievement levels for Outcomes and Objectives (effectiveness) are well documented in the ABET Criteria, it is proposed in this paper that strategic program management issues must also include curriculum requirements for Outcomes and Objectives (efficiency). The methodology will also enable the Department to benchmark with similar programs and perform sensitivity analysis on program revisions. It can also be the basis for administering programs within a college.

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