A Combined Outcomes-Based Materials Curriculum

Lawrence J. Genalo
Iowa State University

1. Introduction

Beginning with the 1999 catalog, Iowa State will be moving from two degrees (Metallurgical Engineering and Ceramic Engineering) to a single degree in Materials Engineering (1). Under the new program graduates will be more well-rounded materials engineers, a desired outcome based on input from our Industrial Advisory Council and others. While building this new program from the ground up, desired outcomes (in particular, ABET 2000) were the driving force. Each course, as it was being developed, was looked at in terms of how it helped to meet these outcomes and each course has its own course-specific outcomes. We have developed a matrix mapping desired program learning outcomes to these courses and are deciding how to assess the achievement of these outcomes.

The new program includes four specialization areas, from which each student must choose two. These areas are Ceramic, Electronic, Metallic, and Polymeric Materials. In addition to a core materials curriculum taken by all majors, each specialty area is a series of four courses which add depth in a particular area. This unique program will allow students to have both the breadth and depth needed to function in the current materials workplace.

2. Learning Outcomes in Materials at ISU

The Materials Engineering Program at Iowa State University has established the following desired learning outcomes in their graduates. Of course, this includes the 11 outcomes in ABET's Criterion 3;

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs
d. an ability to function on multi-disciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global/societal context
i. a recognition of the need for and an ability to engage in life-long learning
j. a knowledge of contemporary issues

k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

It also includes the four materials-specific outcomes specified by ABET;

i. an ability to apply advanced science (such as chemistry and physics) and engineering principles to materials systems
ii. an integrated understanding of the scientific and engineering principles underlying the above four major elements of the field
iii. an ability to apply and integrate knowledge from each of the above four elements (structure, properties, processing, & performance) of the field to solve materials selection and design problems
iv. an ability to utilize experimental, statistical and computational methods consistent with the goals of the program.

In addition, three outcomes specified for Materials Engineering graduates at Iowa State are;

1. to demonstrate mastery of creative, independent, problem solving skills, under time and resource constraints, in a broad range of materials-related applications critical to the success of the final product
2. to have gained experience in materials engineering practice through co-ops or internships in industry, national laboratories, or other funded research work
3. to demonstrate hands-on skills with a broad range of modern materials processing and characterization equipment and methods, with special in-depth concentration in two student-selected areas from among ceramic, electronic, metallic, and polymeric materials.

These last three were selected due to the emphasis in our program on hands-on laboratory work, our vertically-integrated design courses, and our strong emphasis on experiential learning through placements in co-ops, internships, or national laboratories.

3. Department Assessment Plan

A matrix was created which mapped each of the new courses in the combined curriculum to the desired outcomes in order to see where the contributions were being made toward meeting those outcomes. More importantly, this showed the areas of weakness in meeting the desired outcomes. A portion of that matrix is shown in Figure 1.

Assessed in course Δ
Contained, not assessed = X

ABET Program Outcomes

	<----General Engineering---->											ABET/Mat				ISU		
Course	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**i**	**ii**	**iii**	**iv**	**1**	**2**	**3**
MSE Core (27)																		
Mat E 211 Intro(5)	Δ	Δ		Δ	Δ		Δ				Δ	Δ	Δ	Δ	Δ			Δ

Mat E 212 Thermo	Δ	X	X	X	Δ		Δ				Δ	Δ	Δ	X	X		
Mat E 214 Char	Δ	Δ		Δ	X		Δ				Δ	Δ	Δ	Δ	Δ		Δ
Mat E 315 Kinetics	Δ	Δ	X	X	Δ		Δ		X		Δ	Δ	Δ	X	Δ		Δ
Mat E 316 Stat/Com	Δ	Δ		Δ	Δ		Δ		X		Δ	Δ			Δ		
Mat E 318 Mech	Δ	Δ	Δ	Δ	Δ		Δ	X		X	Δ	Δ	Δ	Δ	Δ		Δ
Mat E 213 Des (1)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Mat E 313 Des (2)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Mat E 413 Des (2)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Mat E 414 Des (2)	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ

Figure 1: A portion of the outcomes matrix

Using the Angelo and Cross text Classroom Assessment Techniques (2), assistance is being given to our faculty to help them learn the paradigm of learning-centered education that leads to successful outcomes-based measures. Each course has a specific set of outcomes to be measured in that course. These outcomes, naturally, are more content-based than the final outcomes. For example, the desired outcomes for the core curriculum course in Statistics and Computations in Materials include (3) ; Students to be able to…

1. Design experiments that improve the likelihood of statistically significant results which improve the performance of a material or system.
2. Conduct experiments, gather data, analyze data, and report, both orally and written, on the experiment.
3. Apply mathematical software packages to solve materials problems.
4. Use visualization tools in the design, selection, and analysis of materials.
5. Apply programming concepts (such as finite differencing and finite elements) to solve materials problems (such as diffusion).
6. Perform and interpret the results of linear regressions, including general response surfaces (Kth order polynomials involving N control variables).
7. Assess the appropriateness for modeling data with a given probability distribution such as Normal, Lognormal, or Weibull.
8. Calculate confidence intervals for sample means and confidence bands for response surfaces.
9. Present oral and written reports on an experiment designed, executed, and analyzed by a team of students.
10. Functions in teams.

Each course will have a portfolio to document the learning outcomes achieved (or not). For example, the portfolio for the Statistics/Computations course has the following table of contents (adapted from several works of Barbara Olds, see for example reference 4).

I. Course information
   A. Relationship of course to ABET outcomes
   B. Relationship of course to university, college, and department goals

C. Relationship of course to industry practices
D. Course description - catalog information
E. Content-specific outcomes, goals, objectives
F. Syllabus
G. Assignments and Learning Activities (a list)
H. Grading standards

II. Pedagogy
- A. Description of teaching practices, philosophy, and goals
- B. Relationship to other program courses
- C. Relationship to industry practices

III. Evidence of Student Learning
- A. Assessment
  1. Assessment questions
  2. Assessment practices
     a. method
     b. sample assessment tools
  3. Assessment Results
     a. summary of results
     b. sample of results
- B. Sample Student Work
  1. Written reports
  2. Assignments
  3. Tests and quizzes

IV. Future Plans
- A. Self-reflective memo
  1. Is the course meeting its goals ?
  2. What changes should be made ?
- B. Changes to be made
  1. Changes to be made as a result of assessment activities
  2. Changes to curriculum as a result of this course
- C. Professional Growth
  1. Papers written, presentations given which discuss this course
  2. Papers read, presentations attended which effected this course

Each specialty area will also have a portfolio, as will the core materials curriculum. The overall program will have a book which describes the assessment process and defines how the program meets all of the ABET criteria.

The program level assessments that will be carried out include;

1. Industrial Advisory Council review
2. alumni surveys documenting professional achievements and career development (life-long learning)

3. employer surveys
4. placement data
5. student portfolios documenting the individual student's academic career, including work, intern, and co-op experience
6. student exit surveys that seek input on the student's experience in MSE
7. focus groups to study perceived problems

4. Conclusions

A great deal of effort is being placed on the paradigm switch to outcomes-based education. As engineers this should be a natural change. Our research work has always been outcomes-based and the complaints about the shortcomings of our graduates (or high school graduates being fed into our programs) have always been outcomes-based…why can't these students solve a trig problem? Why can't your graduates communicate ? In the long run it will be beneficial for our students and our profession. In the short run some of the anxiety can be relieved by keeping in mind that ABET is looking for a good process to be put in place that finds the shortcomings and attempts to correct them. It is not expected that each student outcome will be met 100 % of the time, but that we attempt to measure how often it is met and strive to continually improve.

1. "A Revised, Outcomes-Based Materials Engineering Program at Iowa State University," Genalo, Lawrence J., Rose-Hulman Assessment Conference, October, 1998.
2. Classroom Assessment Techniques, 2nd Edition, Angelo, Thomas A. and Cross, K. Patricia, Jossey-Bass Publishers, San Francisco, 1993.
3. "A Project-Based Approach to DOE in Materials", Genalo, Lawrence J., Proceedings of the ASEE Annual Conference, June, 1998, Session # 1364.
4. "A Portfolio-Based Assessment Program", Olds, Barbara M. and Pavelich, Michael J., Proceedings of the ASEE Annual Conference, June 1996, Session #2343.

LAWRENCE J. GENALO

obtained his Ph.D. degree from Iowa State University in 1977 in Applied Mathematics. He has served ASEE as Program and Division Chair for Freshman Programs and DELOS. His current interests include bringing engineering education to K-12 students, teachers, and their classrooms, technological literacy for future K-12 teachers, and computations in materials.