Matrix Based Approach to Assessment of an Educational Program along ABET Criteria

S. Verma
Texas A & M University – Corpus Christi

Abstract

This paper describes a spreadsheet based matrix method to quantify the performance of an educational program and its various courses against criteria set forth by the Accreditation Board for Engineering and Technology (ABET). Inputs to the spreadsheet are: student learning outcomes for each course, connection of these outcomes to the ABET criteria, student scores in various classroom assessment activities, and the credit hours of each course. This approach generates performance profiles for all courses and aids in the identification of their strengths and weakness and of the whole program. The matrix method becomes an integral part of a continuous improvement plan.

Introduction

The goals of an educational program and the characteristics of the program graduates have been analyzed and annotated extensively. However, meaningful and quantified assessment of a program and or its courses has been a challenge to educational programs for a long time (Rogers 2004). The Engineering Accreditation Commission (EAC) and the Technology Accreditation Commission (TAC) of ABET has listed in their TC2K criteria, the desired attributes of program graduates as outcomes (a)-(k) in Criterion 3 for Engineering programs, and outcomes (a)–(k) in Criterion 2 for Engineering Technology programs. Our discussion in this report will be centered on the outcomes (a)–(k) of Criterion 2 of the TAC which are analogous to the outcomes (a)-(k) Criterion 3 of the EAC.

ABET also requires that these attributes of the program graduates be demonstrated through the use of multiple instruments of assessment. Suitable methods of quantification of these attributes and changes or improvement in these indicators through time is left up to individual programs. Most commonly, student grades have been used as one of the quantitative indicators of the success of a program and a measure of the quality of its graduates. However, the suitability of student grades as a valid tool is questionable.(Rogers 2003)

In this paper we present a method by which the data on student performance (not their grades per se) in the classroom is transformed into quantitative indicators of course performance and in turn the course performance indicators are converted to highlight the strong and weak points of the program along the ABET criteria. The approach suggested here is just one method of evaluating courses and programs. As mentioned before, additional assessment methods, the so called triangulation method, should be utilized to meet the requirements of the ABET guidelines (Bennett et. al. 2004, Blandford et al 2003).

Course Assessment

The proposed matrix method uses three Excel spreadsheets linked to each other to generate a course performance profile. A fourth sheet can be added for graphical representation of the data. The information used in these spreadsheets are: student learning outcomes (SLO) for each course, Outcomes (a)-(k) of the ABET Criterion 2, students scores in the various classroom assessment activities, and the weight given to each of the assessment activities. The current paper is an extension of a semi-quantitative approach proposed by Felder and Brent (2003). Our approach uses student scores in the assessment process. Abunawass (2004) has presented a method of capturing assessment data using Modular Object-Oriented Dynamic Learning Environment for Computer Science Program assessment. Our method uses a set of Excel spreadsheets and extends the assessment process to include evaluation against accreditation criteria.

At this time it is necessary to elaborate on a few important terms used in the report. We will use an Engineering Technology course (ENTC 3316-Strength of Materials) as an example in this report. The student performance data shown in these tables are for illustrative purposes only.

Student Learning Outcomes (SLO)

The course instructor is responsible for generating a set of learning outcomes for the course. The outcomes for each course are observable skills or activities that a student can exhibit to successfully complete the course. Many textbooks published in the recent years contain, at the beginning of a chapter, a list of skills that the student should master by the end of the chapter. This is a good place to start constructing the list of outcomes for a course. These outcomes are usually included on the syllabus for the students enrolled in the course. Because these outcomes must be observable and measurable activities, use of passive words such as understand, learn, know, etc. are not acceptable in the formulation of outcome statements. Instead, use of action words such as calculate, explain, analyze, etc. is required. It is further recommended that choice of action words be based on the taxonomy of critical thinking skills, e.g. one proposed by Bloom (Bloom 1984, Pimmel 2003). Healy (2004) has presented such a list of action words suitable for engineering disciplines. This method of constructing outcome statements provides further insight into the “intellectual weight” of the course in the program. However, a discussion on this topic is beyond the scope of the present paper.

We recommend that between ten to twenty five SLOs be generated for each course. These SLOs become the driver for the classroom activities. This list is essentially a charter for a student. It can also be considered as a contract between a student and the course instructor.

Assessment Activities

Typical classroom assessment activities include mid-term and final examinations, quizzes, homework assignments, laboratory exercises and reports, project work and reports, oral presentations etc. However, assessment activities need not be confined to the classrooms. The course instructor usually assigns % weights to each of these assessment activities (e.g. 15% each for each exam, 10% for laboratory reports etc.).

ABET Elements

Although different programs at various universities and colleges have their own program outcomes, they all have a common characteristics. In order to attain brevity, these outcomes statements incorporate catenated phrases that contain similar, although significantly important in their own right, characteristics of the program or its graduates. Because our readers are familiar with the ABET recommended program outcome phraseology, we will use these as examples in this report. For example, Outcome C2(k) states "… a commitment to quality, timeliness, and continuous improvement". There are three important aspects to this outcome: C2(k1) "a commitment to quality", C2(k2) "a commitment to timeliness", C2(k3) "a commitment to continuous improvement". Therefore, we recommend that to ensure a comprehensive evaluation process, the catenated outcomes be divided into their constitutive elements. This subdivision ensures that no aspect of the desired outcomes is missed in the assessment process. These subdivided elements of ABET Criterion 2 will be referred to as ABET elements in this paper.

Program Outcomes

The Engineering Technology faculty at Texas A&M University-Corpus Christi (TAMU-CC) felt that if we were to generate our own program outcomes, it would remain our responsibility to prove that they covered all aspects of the (a)-(k) outcomes. We also felt that the (a)-(k) attributes of program graduates are sufficiently comprehensive in and by themselves that any rephrasing will be only an exercise in creative writing. Therefore, although not required by ABET guidelines, we decided to make the program outcomes identical to the (a)-(k) outcomes of Criterion 2 of TAC. This also ensures that our future efforts will not be directed at debates about the interpretation of new phrases or the validation, monitoring and measurement of the new phrases. These (a)-(k) outcomes will be interchangeably referred to as Program outcomes (a)-(k) or ABET outcomes (a)-(k).

Spreadsheet-1: SLOs - ABET Elements Matrix

It is the responsibility of the course instructor to indicate how a particular SLO helps students develop or master skills specified in an ABET element. For example, the SLO "Deliver an oral presentation on a project report as a team" can be considered to address element C2(e) "an ability to function effectively on teams, element C2(g) "an ability to communicate effectively", element C2(k1) "a commitment to timeliness", and any other technical and professional attributes that the project work entailed. The link between an SLO and the ABET elements is established by placing an 'x' in the cell that is common to both the outcome and the elements. The spreadsheet named "ABET Elements" is used to establish this link. See Figure -1. Just as one SLO may influence several elements, an element would also be influenced by several SLOs.

Needless to say, an SLO that does not address at least one of the Program outcomes, or an ABET outcome in the present example, is a clear indication that the program resources are not directed toward supporting the program's goals and objectives.

Figure -1 Spreadsheet: ABET Elements (Partial View)

ENTC 3316 STRENGTH OF MATERIALS Fall 2003 Total Credit Hours 4

	Elements of ABET criteria	appropriate mastery of knowledge of discipline	appropriate mastery of techniques of discipline	appropriate mastery of skills of discipline	appropriate mastery of modern tools of discipline	apply current knowledge of mathematics and science	apply current knowledge of engineering and technology	adapt to emerging applications of mathematics and science	adapt to emerging applications of engineering and technology	conduct experiments	analyze and interpret experiments	use experimental results to improve process	apply creativity in design of systems	apply creativity in design of components	apply creativity in design of processes	function effectively on teams	identify technical problems
		1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	1
	Student Learning Outcomes	a				b				c			d			e	f
1	Calculate normal stress, direct shear stress and bearing stresses	x	x	x		x	x										
2	Solve problems based on modulus of elasticity, Poisson's ratio	x	x	x		x	x										
3	Recognize indicators of strength properties of metals	x		x			x										
4	Describe the responsibilities of designers	x		x			x										
5	Define the relationship between design stress, allowable stress, design factor, codes and standards	x		x		x	x										
6	Calculate stress concentration related to the part geometry.	x	x	x		x	x										
7	Evaluate safety of a given design for various types of loading	x	x	x		x	x										
8	Recommend shape and dimension of a component for safe loading	x	x	x		x	x						x	x			
9	Determine allowable load on a component	x	x	x		x	x										

Spreadsheet-2: SLO - Assessment Activities Matrix

As mentioned above, all classroom activities now become outcome driven. Thus, all questions in the examinations, quizzes, homework, projects, written or oral reports etc. must be directly related to one or more SLOs. Each classroom assessment activity can be linked to one or more SLOs. The classroom average for each assessment activity, expressed as percentage, is entered in the spreadsheet named "SLO" against the appropriate outcomes as the semester progresses. See Figure 2. At the end of the semester, the average score of an outcome weighed according to the %weight of each of the relevant assessment activity becomes the score of the course in that SLO. Use of a spreadsheet make this process automatic.

Figure 2 : Spreadsheet: Student Learning Outcomes (Partial View)

ENTC 3316 STRENGTH OF MATERIALS Semester Fall 2003

		Various classroom activities to assess student				
	Normalized class average for each outcome	Exam#1	Exam#2	Exam#3	Final	Hon wor
	100	15	15	15	30	
	Student Learning Outcomes					
1	Calculate normal stress, direct shear stress and bearing stresses	75				
2	Solve problems based on modulus of elasticity, Poisson's ratio	67	73			
3	Recognize indicators of strength properties of metals	67	77			
4	Describe the responsibilities of designers		69			
5	Define the relationship between design stress, allowable stress, design factor, codes and standards	77				
6	Calculate stress concentration related to the part geometry.		75			
7	Evaluate safety of a given design for various types of loading		67			
8	Recommend shape and dimension of a component for safe loading			78		
9	Determine allowable load on a component			59		

It is to be noted here that student grades at the end of the semester are not being used to generate the course assessment indices. Instead, the class average for each of the stated outcomes for the course is being used.

This score for an SLO is then assigned to all the ABET elements that the SLO has been linked to.

Spreadsheet-3: Course Assessment –ABET Elements Matrix

A course assessment index for an ABET element can be obtained by averaging the score of all SLOs for that element. This information then can be presented in a tabular form on the spreadsheet named "Course Assessment", Figure 3, or alternatively in a graphical form, "Course Profile" Figure 4. A look at Figure 4 indicates those ABET criteria in which the Strength of Materials course, taken here as an example, is lacking or doing well. Tracing back to the

Figure 3 Spreadsheet: Course Assessment Data

ENTC 3316 STRENGTH OF MATERIAL **Fall 2003** **Total Credit Hours** **4**

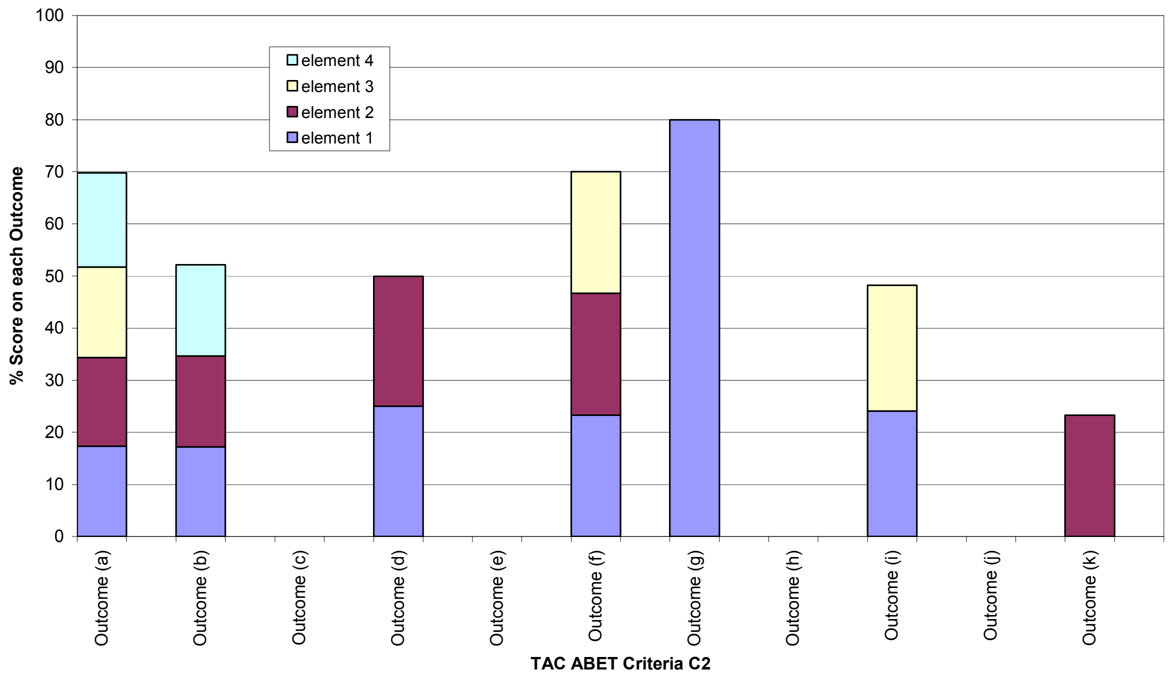
ABET Criterion	element 1	element 2	element 3	element 4
a	appropriate mastery of knowledge of discipline 69.5	appropriate mastery of techniques of discipline 68.0	appropriate mastery of skills of discipline 69.5	appropriate mastery of modern tools of discipline 72.1
b	apply current knowledge of mathematics and science 68.8	apply current knowledge of engineering and technology 69.8	adapt to emerging applications of mathematics and science	adapt to emerging applications of engineering and technology 70.0
c	conduct experiments	analyze and interpret experiments	use experimental results to improve process	
d	apply creativity in design of systems 74.9	apply creativity in design of components 74.9	apply creativity in design of processes	
e	function effectively on teams			
f	identify technical problems 70.0	analyze technical problems 70.0	solve technical problems 70.0	
g	communicate effectively 80.0			
h	recognize the need for lifelong learning	engage in lifelong learning		
i	understand professional responsibility 72.3	understand ethical responsibility	understand social responsibility 72.3	
j	respect for diversity	knowledge of contemporary professional issues	knowledge of contemporary societal issues	knowledge of contemporary global issues
k	commitment to quality	commitment to timeliness 70.0	commitment to continuous improvement	

"ABET Elements" spreadsheet, one can identify the causative SLO and tracing further back, on the "SLO" spreadsheet identify the assessment activities that led to the poor score. The instructor can now determine a more effective method of delivering that lesson or the set of lessons. The options may include spending more time on the lessons, modifying method of instruction, assigning additional homework problems, better defined homework problems, modifying laboratory exercise etc.

Program Assessment and ABET Outcomes C2(a)-(k)

TAMU-CC offers four-year Bachelor of Science degrees in mechanical engineering technology (MET) and control systems engineering technology (CSET) at present. In addition to the core

Figure-4 ENTC 3316 Strength of Materials:Profile Along TAC ABET Outcomes C2(a)-(k)
Fall 2003



science, math and humanities courses, the MET program has a total of twenty four courses, and the CSET program has a total of sixteen courses. Six engineering technology courses are common to both tracks. When constructing a program profile, one may choose to includes all courses, only core technology courses or courses that are specific to one or the other technology tracks. In this report, we choose to include courses that are offered under MET track including those that are common to both MET and CSET tracks.

The program performance index is generated from the set of all relevant courses. This may be accomplished by at least two methods: one method shows the performance of each individual course in the program against the ABET Outcomes C2(a)–(k); the second method shows the performance of the whole program against the ABET Outcomes C2(a)–(k).

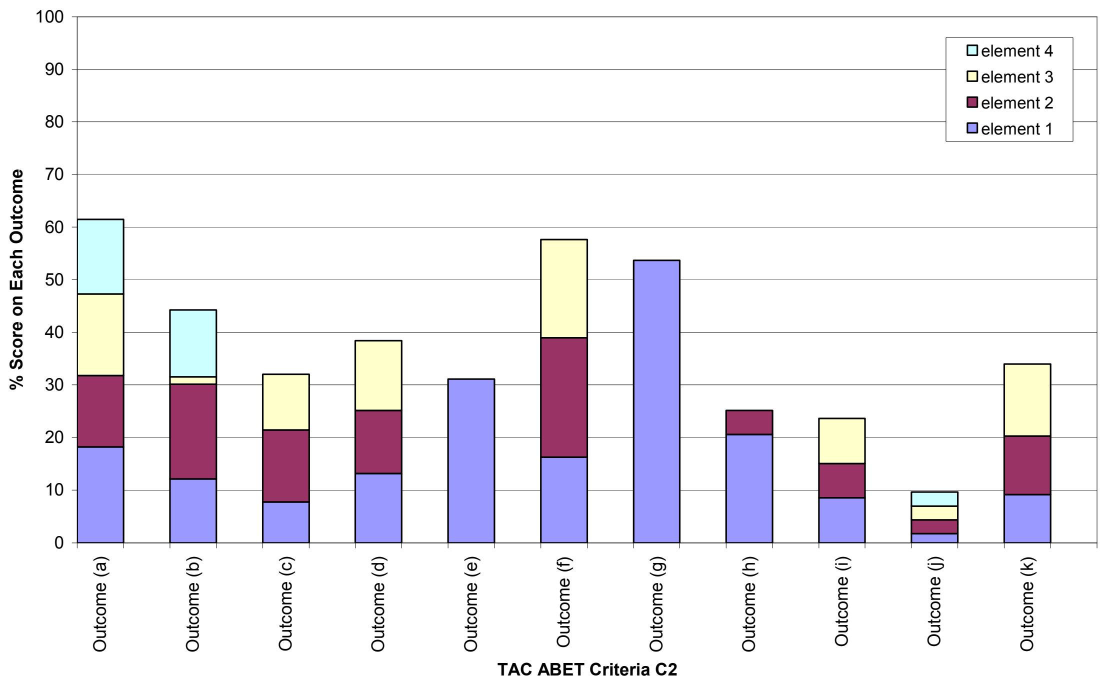
In the first method, the score of a course on an ABET Outcome is obtained by averaging the score of the course on all elements of that criteria. This information can be tabulated in a matrix form as ABET Outcomes C2(a)-(k) vs. courses. See Figure 5 “Program Assessment”.

In the second method, the credit hours of each course is used as the weight factor for each ABET element. The weighted average of all courses in the program becomes an indicator of performance of the program on that ABET element. Again, this information is presented in graphical form “Program Profile” in Figure 6.

Figure - 5 PROFILES OF INDIVIDUAL MET COURSES COURSE OFFERED IN SPRING 2003

ABET OUTCOMES TAC C2(a)-(k)		ENTC 1203 Intro to Process	ENTC 1304 Engineering Design Graphics 1	ENTC 2202 Manufacturing Processes 1	ENTC 2204 Manufacturing Processes 2	ENTC 2305 Engineering Design Graphics 2	ENTC 2403 Statics and Dynamics	ENTC 2414 Circuits Analysis 1	ENTC 3310 Material Science 1	ENTC 4315 Project Management	ENTC 4320 Heat Transfer
	CREDIT HOURS	2	3	2	2	3	4	4	3	3	3
a	an appropriate mastery of the knowledge, techniques, skills and modern tools of the discipline	18	64	78		65	39	78	72		20
b	an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology	18	50	56		33	26	59	54		41
c	an ability to conduct, analyze and interpret experiments and apply experimental results to improve process	72		76				53	74		
d	an ability to apply creativity in the design of systems, components or processes appropriate to program objectives	72	44	26		45		27			
e	an ability to function effectively on teams		63	76				78	74		
f	an ability to identify, analyze and solve technical problems	23	21	78		66	34	79	47		52
g	an ability to communicate effectively	73	65	74		65			77		84
h	a recognition of the need for, and an ability to engage in lifelong learning	38	32					82			
I	an ability to understand professional, ethical, and social responsibilities	75									
j	a respect for diversity and a knowledge of contemporary professional, societal and global issues	57									
k	a commitment to quality, timeliness, and continuous improvement	74	64	80				26	25		

Figure 6 MET Program Profile Along TAC ABET Outcomes C2(a)-(k)
Fall 2003



A course by itself is not expected to address all program outcomes, in this case ABET Outcomes C2(a)-(k). However, it is important that when information from all courses in the program are pooled together, the program as a whole must address all program outcomes, again, outcomes ABET C2(a)-(k) in the present case.

A look at Figure 6 indicates that the program can use reinforcement in ABET Outcomes C2(h), (i) and (j). These are typically considered 'soft skills' and are traditionally weak points of many engineering/technology program. Thus, there is a need to introduce curriculum changes to provide more exposure to students in these areas. A look at Figure 5 indicates that not many courses have activities in these areas. Additionally, the course scores in these areas are low. The instructors and program coordinators can now sit down and chart a suitable course and program improvement plan. The plan may include introducing additional SLOs, classroom activities, new courses etc.

An electronic copy of the data for all courses and the program as a whole can be saved at the end of each semester as documentation of the status of the program. This data may be compared from one course offering to another to monitor improvements in courses or the program. The process thus becomes an integral part of the continual improvement plan of a program.

This matrix based approach is very versatile. With appropriate modifications it can be used for monitoring and assessing virtually any science, engineering or humanities program against a relevant set of criteria. It is based on a spreadsheet software that is readily available.

Epilogue

This method is just one method to quantify the performance of courses and program. It assumes that the tools – exams, report, presentations- used to assess student learning outcomes are valid, and data generated from such activities are relevant, reliable and accurate. Variations in teaching styles, grading habits of instructors, batches of students from one semester to another, degree of difficulty of the examination questions etc. all will cause variations in the scores and a cure for these are not addressed by the proposed method. Like all mathematical analyses it is prone to GIGO (garbage-in garbage-out). Thus, any interpretation of data (and subsequent recommendations for improvement) must take into account all of the above factors. Moreover, it would require a few semesters to gather sufficient data for any reliable mathematical analysis. It is strongly recommended that a few "benchmark" questions be repeated from one course offering to another so that the sources of variance may be identified and accounted for as time progresses. At TAMU-CC, we implemented the matrix method in Spring 2004.

It is expected that once this matrix method of outcomes based course and program assessment is adopted, a process will begin that will critically examine the relevancy of student learning outcomes for each course, various classroom assessment tools and activities, and the relationship of these activities to the program outcomes. This self-examination itself will be the start of a continual improvement plan.

Bibliography

1. Rogers, G. 2004. How are We Doing? Assessment Tips with Gloria Rogers: Communications Link, ABET Quarterly News Source, Spring 2004, 4-5.

2. ABET 2004. Criteria for Accrediting Engineering Programs; Engineering Accreditation Commission; ABET Inc. 111 Market Place, Suite 1050, Baltimore, MD 21202; 2004-2005 Accreditation Cycle, www.abet.org

3. ABET 2004. Criteria for Accrediting Engineering Technology Programs; Technology Accreditation Commission; ABET Inc. 111 Market Place, Suite 1050, Baltimore, MD 21202; 2004-2005 Accreditation Cycle, www.abet.org

4. Bennett R.J., D. Ricci, A. Weimerskirch 2004. Assessing Educational Performance A Strategic Approach, Proceedings 2004 Annual ASEE Conference. American Society for Engineering Education. Session 1793.

5. Blandford, D. K., D.J. Hwang 2003. Five Easy but Effective Assessment Methods. Proceedings of SIGCSE 2003, ACM Press 41-44.

6. Abunawass A., W. Llyod, E. Rudolph. 2004. COMPASS A CS Program Assessment Project, 9th Annual Conference on Innovation and Technology in Computer Science Education, Leeds UK, June 2004

7. Rogers, G. 2003. Do Grades Make the Grade for Program Assessment? Assessment Tips with Gloria Rogers: Communications Link, ABET Quarterly News Source, Fall/Winter 2003, 8-9.

8. Felder, R.M., and R. Brent 2003 "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria, Journal of Engineering Education", 92 (1): 7-25.

9. Pimmel, R.L. 2003 "Student Learning of Criterion 3 (a)-(k) Outcomes with Short Instructional Module and the Relationship to Bloom's Taxonomy", 92 (4):351-359.

10. Healy, T. 2004 "An Approach to Teaching Lifelong Learning", Proceedings 2004 Annual ASEE Conference. American Society for Engineering Education. Session 1793.

11. Bloom, B.S. and D.R. Kratwohl, 1984. Taxonomy of Educational Objectives. Handbook I: Cognitive Domain. New York: Addison-Wesley

Biography

SATYAJIT VERMA, Ph. D.
Satyajit Verma received his Ph.D. in Chemical Engineering from Louisiana State University, Baton Rouge. He has more than 20 years of experience as product development engineer and process development engineer with Allied-Signal and Hoechst Celanese in the high density polyethylene and polyacetal areas. Currently he is an assistant professor in the Mechanical Engineering Technology Program at Texas A&M University-Corpus Christi.