Development of a Dynamic Curriculum Assessment Examination

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Abstract

Program assessment has become increasingly important for obtaining accreditation. Furthermore, ABET Engineering Criteria 2000 mandates the use of multiple assessment measures. One important objective measure of program performance is a comprehensive examination given to students in their senior year. Many engineering programs now use the Fundamentals of Engineering (FE) examination as this comprehensive examination. While this nationally normalized examination is objective, there are a few significant disadvantages in using the FE as the only comprehensive examination:

- The department loses control over what questions are asked. ABET Criteria 2000 encourages more diversity between engineering programs; however, the FE exam is a "one test fits all" assessment tool.

- Neither the questions nor the detailed results of the FE are distributed to the academic departments.

- The difficulty and emphasis of a particular topic on the FE exam may vary from test to test.

For these and other reasons, the Chemical Engineering program at Tri-State University (TSU) has developed an internal curriculum assessment examination (CAE) that will be given to senior chemical engineering students. This examination contains sixty multiple-choice questions and was derived from the performance-based objectives of the required courses in Chemical Engineering. The examination is dynamic in the sense that most problems are linked to a spreadsheet, so that the parameters in the problem can be easily changed from year to year. This dynamic character of the CAE should help keep the examination secure while still maintaining test to test consistency.

This paper presents the role the CAE plays in TSU's chemical engineering assessment plan, how the CAE was developed based on curricular objectives, and how the problems were made dynamic. The paper also presents some preliminary student impressions of the examination.

INTRODUCTION:

Program Assessment has been increasingly important for obtaining accreditation. Both the North Central Association of Colleges and Schools (NCA) and the Accreditation Board for Engineering and Technology (ABET) have identified a need for assessment in the educational process and have mandated the use of multiple measures of program performance.

A pictorial diagram showing how student-related information is fed back to the faculty in Tri-State University's (TSU) chemical engineering program is shown below in Figure 1. As can be seen by this figure, both internal and external entities attempt to measure the students' performance and the students' satisfaction with the program.

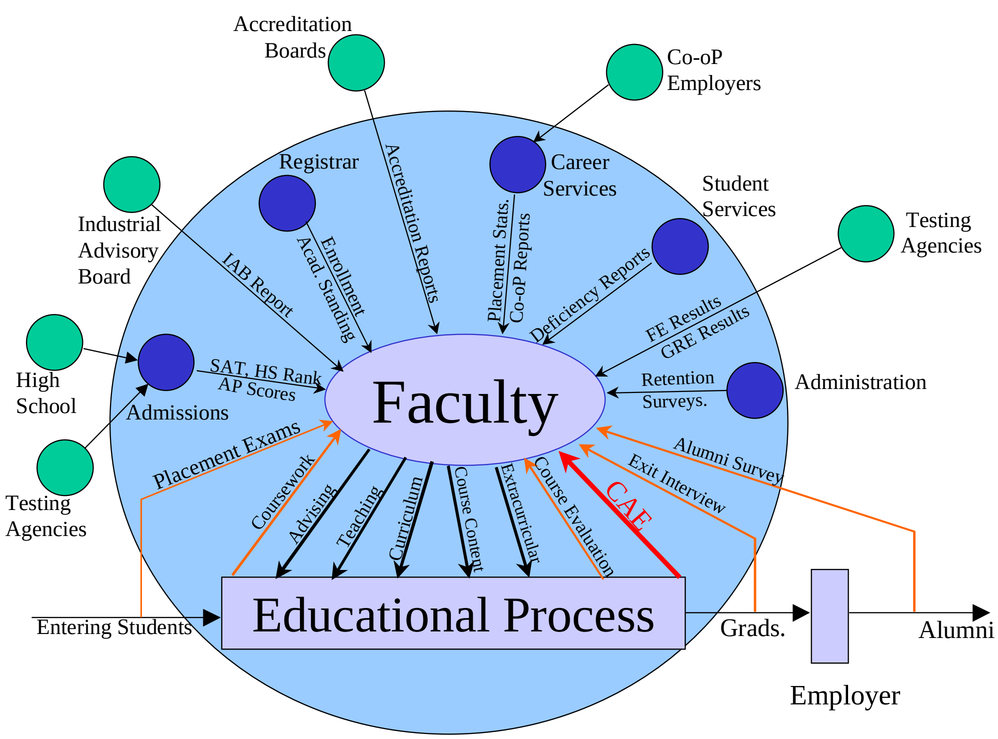


Figure 1 – Pictorial Outline of Information Gathering for the Assessment Process. Green circles represent external agencies that report on measurements made on students. Blue circles are entities that are internal to the university. Orange lines are measurements made directly by the faculty. Lines going from the faculty to the students are general educational inputs that the faculty has direct control over.

With all of the information that the faculty receives about the students' academic progress, it may not seem that another measure of student performance is either wanted or needed. However, something as complex as program performance can not be measured with a single instrument even if the measurement instruments were good. In fact, most of the metrics used have one or more of the following deficiencies:

- Very long delay time (e.g. alumni surveys)
- Not well correlated with program performance (e.g. GRE general tests, SAT Scores)
- Measurement instrument changes from year to year (e.g. student course work)
- Information overload (e.g. student portfolios)
- Measurement is subjective (e.g. exit interviews)

One objective measure of program performance is a comprehensive examination given to students in their senior year. Many programs now use the Fundamentals of Engineering (FE) examination as this measure. While the FE is an objective measure that is nationally normalized, it suffers from a few significant disadvantages as an assessment tool:

- The department loses control over what questions are asked. ABET Criteria 2000 encourages more diversity between engineering programs; however, the FE exam is a "one test fits all" assessment tool.
- Neither the questions nor the detailed results of the FE are distributed to the academic departments. This makes investigating the root cause of any performance problems difficult.
- The difficulty and emphasis of a particular topic on the FE exam may vary from test to test.

The Chemical Engineering program at TSU identified the need for a measurement of program effectiveness that is objective, relatively constant, and a direct measure of program objectives. In response to this need, the department developed the TSU ChE curriculum assessment examination or CAE.

The CAE consists of sixty multiple-choice questions that reflect the departmental curriculum objectives in chemical engineering. Each question on the CAE has five possible responses, only one of which will be correct. The test will be administered to chemical engineering seniors as part of the capstone design class. The examination was weighted as five percent of their course grade. We anticipate that the average score on the examination should be around 50% so that some type of grade adjustment will be done before it is averaged into the student's course grade. The exam will consist of two four hour sessions, each having thirty questions. To be able to compare the results of the examination from one year to the next, the test will be kept consistent from one year to the next. To ensure the security of the examination, the following features were added:

- All examinations will be collected from the students. The students will not be allowed to view their graded examination.

- The examination will be kept under lock and key at all times.

- The order of the questions will be altered from one year to the next.

- The order of the answers will be changed from one year to the next. This is easily accomplished, because the answers are linked to a spreadsheet that allows one to randomize the responses.

- Parameters in most of the problems will be changed from one year to another. The CAE is a dynamic examination in the sense that most of the questions are linked to a spreadsheet, so that the parameters in a particular problem can be changed from year to year.

EXAM DEVELOPMENT:

The key decision in the development of the examination was to limit the test to the current curriculum. It is very easy, especially among academics, for the exam planning process to degenerate into philosophical discussions on what are the essential ingredients for a chemical engineering education. While these discussions are very important, they do not typically result in quantifiable output in a timely manner. To avoid such entanglements, we decided that we would save such discussions for curriculum planning and limit the examination to cover the objectives of the curriculum.

The first step was to decide on the format of the examination. As mentioned above, we decided on a multiple-choice exam that is similar in format and length to the FE examination.

After deciding on the format, we defined what portion of the curriculum that we wanted the exam to concentrate. Table 1 presents the entire curriculum for an entering chemical engineering student at TSU. The minimum number of credit hours for a ChE degree is 132 semester credit hours. However, most of the curriculum is not under direct control of the ChE Faculty. It was, therefore, decided to assign subject areas “equivalent credit hours”. As shown in Table 1, core ChE courses were given one equivalent credit hour for every course credit hour, while courses in the areas of mathematics and the natural sciences were weighted less. The percentage of problems in each of the areas was then set proportional to this equivalent credit hour score.

The curriculum was then further divided into topical areas as shown in Table 2. The target number of questions that cover each topic are presented below the corresponding topics. For instance, at least eight questions deal with material balances or measurements. Each question can cover more than one topic, so that the total number given in the lower right hand side of table 2 is greater than the total number of questions on the test.

Non-Departmental Courses	**Credit Hours**	**Equiv. Credit Hours**	**ChE Department Courses**	**Credit Hours**	**Equiv. Credit Hours**
General Chem. with labs	10		ChE 202 Material Balances	2	2
Organic Chem. with lab	7	2	ChE 212 Energy Balances	2	2
Physical Chem. with lab	5	3	ChE 242 Numerical Methods	2	2
Instrumental Analysis	3	1	ChE 221 Measurements Lab	1	1
Physics	8	1	ChE 353 Thermodynamics I	3	3
Calculus	11	2	ChE 335 Unit Operations I	5	5
Differential Equations	3		ChE 363 Thermodynamics II	3	3
General Eng.	3	2	ChE 345 Unit Operations II	5	5
Oral and written Communications	9		ChE 333 Unit Operations Lab	3	3
Humanities and Social Sciences	16		ChE 453 Kinetics	3	3
Programming	2	2	ChE 473 Design I	3	3
Engineering Economics	2	2	ChE 463 Controls	3	2
Misc. Electives	9		ChE 483 Design II	3	
			ChE Electives	6	
Column Totals	88	15		44	34
Grand Totals	132	49			

Table 1 - ChE Curriculum with the coversion of each subject area to equivalent hours.

Problem File	Mat. Bal and Meas.	Energy Bal.	Num. Meth. and Prog	1st and 2nd law	Equilibrium	Fluid flow	Heat transfer	Dist. strip. and absorb.	Leaching and Extract	Humid and drying	Mass transport	Kinetics	Component Design	Eng. Econ	Process Control	Statistics	Safety	Ethics	Organic Chem.	Physical Chem.	Instrumental Analysis	Physics	Calculus	Total
Minimum	8	4	4	5	6	5	5	3	2	2	2	6	6	4	4	2	3	2	3	4	1	2	3	86

Table 2 – Topics covered by the examination questions – The numbers below each topic indicate the minimum number of questions that cover that topic

The last step in the development of the examination was actually writing and editing the problems. To make sure that the exam questions were representative of the curriculum, the objectives from the syllabus for each class were used in conjunction with some of the final examinations to define the particular questions. The problems were written in MS Word and the solutions as well as the some of the problem parameters were linked to a spreadsheet. This linking process is shown for an example examination question as Figures 2 and 3.

A soluble gas, A, is absorbed by water using a packed tower. The following equilibrium relationship applies:

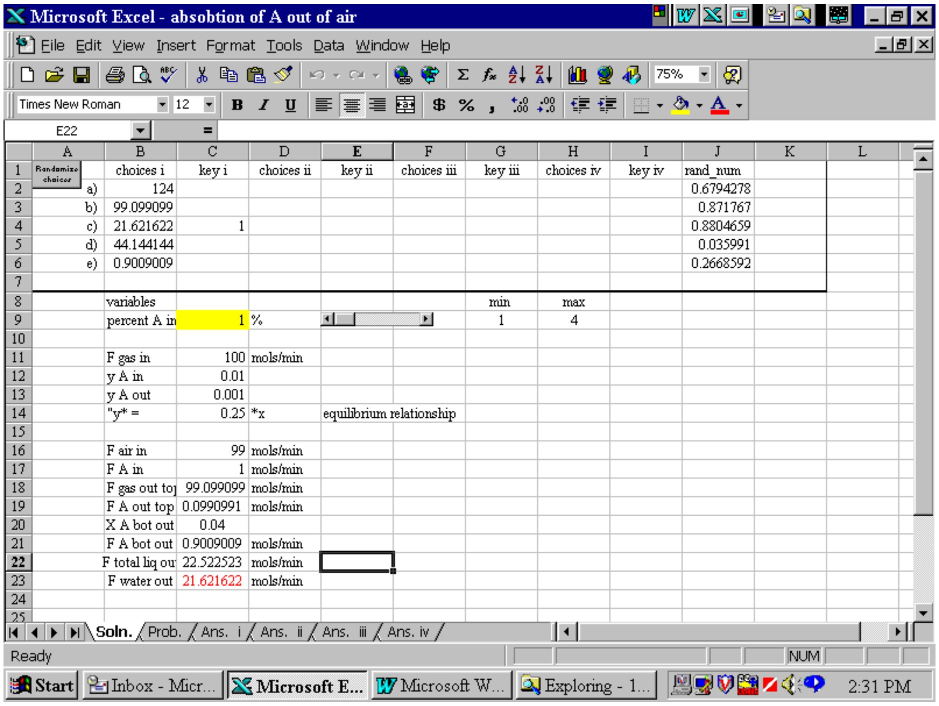
$y^* = 0.25\ x$

A water saturated gas stream containing 1 mole % component A in air and flowing at the rate of 100 mols/min enters the bottom of the absorber. The absorber must be designed so that the concentration of A in the gas leaving the absorber is 0.1 mole %. The water entering the column contains no component A.

The <u>minimum</u> flow rate of water (mols/min) is closest to:

a) 124.0
b) 99.1
c) 21.6
d) 44.1
e) 0.9

Figure 2 – Typical Curriculum Assessment Examination Question. Most of the parameters in the problem can be easily changed in the corresponding spreadsheet. The "1 mole % component A" is linked to a slider bar in the spreadsheet for easy modification. The use of the slider bar bounds the possible range of the variable so that infeasible problems will not be inadvertently created. The number 1 in the figure is formatted as "hidden" and represents the correct response.



	A	B	C	D	E	F	G	H	I	J
1	Randomize choices	choices i	key i	choices ii	key ii	choices iii	key iii	choices iv	key iv	rand_num
2	a)	124								0.6794278
3	b)	99.099099								0.871767
4	c)	21.621622	1							0.8804659
5	d)	44.144144								0.035991
6	e)	0.9009009								0.2668592
7										
8		variables					min	max		
9		percent A in	1	%			1	4		
10										
11		F gas in	100	mols/min						
12		y A in	0.01							
13		y A out	0.001							
14		"y* =	0.25	*x	equilibrium relationship					
15										
16		F air in	99	mols/min						
17		F A in	1	mols/min						
18		F gas out top	99.099099	mols/min						
19		F A out top	0.0990991	mols/min						
20		X A bot out	0.04							
21		F A bot out	0.9009009	mols/min						
22		F total liq out	22.522523	mols/min						
23		F water out	21.621622	mols/min						

Figure 3 – The solution spreadsheet from an Excel workbook that corresponds to the example examination question. The randomize button will change the order of the answers. The slider bar is linked to the original question and will change the percentage of A entering the column. The correct answers are linked to the "Ans" Spreadsheet where the responses are formatted.

The responses to the questions are computed in the corresponding workbook. Some of the incorrect responses corresponded to common conceptual mistakes. In the example above presented above the 44.1 is equal to the total liquid out + the total water out of the column. Some of the incorrect responses are somewhat random, for example the 124.0 in the above problem was 5.73 times the correct answer. Care must be taken so that when the parameters are changed in the problem that the incorrect responses are different from the correct response and different from each other.

After each question was written, a separate faculty member evaluated the question for errors and clarity. Any problems that did not seem clear were re-written before they appeared on the examination.

USE OF THE EXAMINATION:

The most difficult part of any program assessment tool is defining the feedback mechanism. Our starting point for the use of this examination is to incorporate examination results and student feedback to:

- Establish a baseline for both the aggregate and individual subject scores.

- Refine the examination.
- Compare the results of the examination to our expectations.
- Establish control limits for the results.

After baselines have been established, we will set continuous improvement goals for test scores. We will also implement statistical quality control procedures. For example, suppose after giving the examination for a few years the mean CAE score is found to be 52 ± 7 (CL = 95%, n = 35). We can then set the lower control limit on the mean test score (e.g. 45). If in a particular year we find the mean on the CAE to be below this control limit, the ChE program faculty can ask questions such as:

- Did the test scores fall more in one area (e.g. equilibrium thermodynamics) than another? If so, is there one particular problem area within the subject area that the students are not performing well on (e.g. everyone missed the question on VLE)?
- What are some possible explanations for the root cause? (e.g. this class had an adjunct professor for Thermo II.) What do the students think is the root cause?
- Did a small minority of the students cause the drop or did the drop occur across the board?
- Of the causes that are possible, which ones are under faculty control? How can we adjust the program to remedy the drop in examination scores?

This kind of discussion can be very constructive and provide the faculty with a starting point for program improvement. These types of discussions are in general absent from many departments because objective, detailed information on student performance is not available.

However, there are a couple things that we must guard against when implementing the CAE:

- Teaching to the test. The test should reflect the curriculum not the other way around. To avoid teaching to the test, the particular questions on the examination will not be used in the courses and the examination questions will only be reviewed by the faculty once per year.

- Over emphasizing the results. There may be a tendency to weight this measure of program performance more heavily than other metrics because of its quantitative nature. While we believe the examination will be a valuable measurement tool, it is a single, imperfect measure of program performance and should be treated as one element of the program assessment system.

Students will take the examination for the first time in the spring of 1999. We will have student feedback as well as preliminary results from the examination after that time.

CONCLUSIONS:

- A Curriculum Assessment Examination has been developed in the Chemical Engineering program at Tri-State University.
- The CAE was developed on curriculum based objectives and should provide valuable feedback on program performance.
- Security measures such as making the examination questions dynamic and randomizing the answers should help keep the examination secure.
- Control charts of examination performance will be made and control limits set. Continuous improvement goals will be made, and root causes for under-performance will be investigated.