OUTCOMES ASSESSMENT
An Unstable Process?

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The new outcomes-based world of higher education and accreditation may be scary to some, annoying to others, fun to a few, but certainly challenging to all of us. We are faced with examining our educational process in new ways, optimizing a complex ill-defined process, and presenting it clearly and coherently to our accreditation agency. The goals of this paper are to outline the basics of outcomes assessment, describe a format useful for assessment preparation, summarize some lessons learned from the 1996 pilot visit conducted at Worcester Polytechnic Institute (WPI), and discuss some consequences of outcomes assessment.

Let's start with the question, "Why do assessment?" A number of responses come to mind, such as "I do it to assign grades," "...to make accreditation agencies happy," "...to make grant funders happy," "...to know that what I do as an instructor is meaningful," "...to know that students are learning what I set out to teach them."[1] If we care at all about our teaching, we each embrace one or more of these during any course we teach. But how many of us examine the complete curriculum or spend significant time with colleagues (and not just our chemical engineering colleagues) discussing and *doing something constructive* about these issues? Until recently, I suspect, such faculty and departments were in the small minority.

So, is there a problem? We have been successfully educating competent engineers for decades. Why change? I like the simple answer—we can always do better and are ethically obligated to strive for the best. There are many ways to improve teaching and learning, and outcomes assessment is one of them. Others may prefer the more involved response that links rapidly changing technological market forces to needed changes in our graduates' abilities.[2] Either way, future graduates must function effectively in multidisciplinary teams, communicate well, understand global and societal issues related to engineering, and of course, master engineering and scientific fundamentals. A rigorous, well-designed assessment process can make that happen, allow new flexibility in the curriculum, and result in continuous improvement. I am hard pressed to find a reason why we should not do it. We should be aware there are costs associated with doing it right, however.

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ASSESSMENT BASICS

Assessment basics are relatively simple: define objectives, determine if students are meeting them, and improve the educational process if they are not. An excellent primer is provided by Rogers and Sando,[3] and other articles in this issue expand on these principles. The assessment process usually includes

- Setting educational objectives
- Determining performance criteria
- Defining practices
- Defining assessment methods
- Evaluating the assessment data
- Feeding back the results to improve the curriculum

Measurable outcomes are linked to objectives, and the whole process drives continuous improvement of the educational system. Sounds straightforward, right? Well, maybe not. Goal setting and determining performance levels for chemical engineering topics may not sound too bad, but what about these "assessment methods"? Experts tell us we need methodologies that are both formative and summative.

Formative methods are those that take place periodically during a course or curriculum and answer the question, "Is it working?" For example, a mid-course survey might tell a professor some on-line course adjustments are needed. Summative methods take place at the end and answer the question, "Did it work?" A comprehensive final exam tells the professor what fraction of the students mastered the material at specified comprehension levels.

Either method might involve qualitative or quantitative tools. Simply put, quantitative tools involve numbers such as exam scores, survey results, and database analysis. Qualitative tools involve textual or verbal information, including open-ended survey responses, videotape data, and interview transcripts. The same experts tell us that we should use both types for formative and summative evaluations, and that triangulation, redundant measurements with multiple independent tools, is very important.

Most of us are comfortable with quantitative data, but many engineers are uncomfortable with qualitative data. We may not know how to collect it or analyze it properly, and too often it is regarded with disdain. Any mention of "discourse analysis" may set off the touchy-feely alarm in many engineers. But some of the richest and most meaningful data from an educational experience are sometimes obtained only through qualitative analysis. Several of the items in ABET EC 2000 Criterion 3 are quite well suited to measurement using qualitative techniques.

Process Control Analogy

The best assessment processes include a mix of methods and tools. The process is also closed-loop since it contains an essential feedback step that forces us to correct the curriculum when we detect problems in the outcomes. It is hard to ignore the analogy to process control, and other authors have used block diagrams to help simplify the description.[4] I believe the analogy and diagrams are also useful to make a different point.[5]

Figure 1 presents one general view of assessment. The primary loop is shown in bold. The "process" is the curriculum into which students enter. They exit possessing desired abilities or outcomes. The output is measured by having students demonstrate these abilities through defined practices. Feedback is achieved by comparing measured outcomes against the "set point" or performance criteria for each outcome. The controller is the assessment analysis that dictates changes in the curriculum when outcomes don't meet performance criteria. Unfortunately, this is a multivariable, multiloop system with difficult measurements. If we wanted all students to graduate with red hair, then measurement, feedback and correction would be easy. Our goals include some tough-to-measure qualities, however, such as lifelong learning and understanding of ethics and social issues.[4]

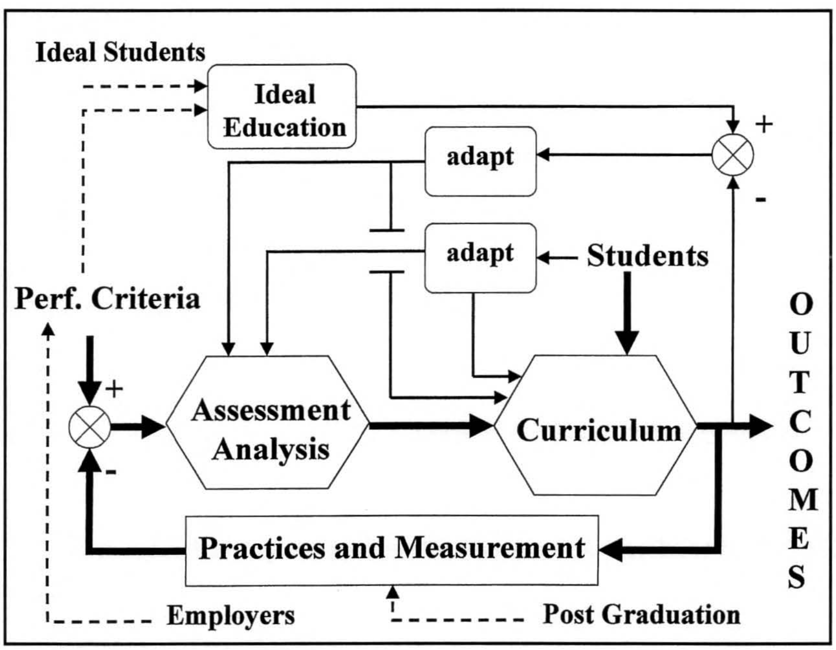

Figure 1. *The assessment process as a multiloop feedback control system.*

We also need to consider some measurements taken well after graduation. They tell us something about the connection between our curriculum and job performance. Such measurements must also enter our feedback loop, even though there is a significant time lag. Our constituencies include our students' employers. Since most students take industrial positions, industry involvement in determining objectives and performance criteria is important. This results in set-point disturbances.

The characteristics of students entering college change with time. Why wait until students are well into the curriculum (when it may be too late) to make corrections? Any good control-system designer would try solving this problem with a feedforward loop. Such a loop might include adapting the process and the controller.

Finally, a major goal is "continuous improvement," or optimization. Model-reference adaptive control is one possible scheme. Changing set points/performance criteria are input to an ideal educational model. The theoretical output is compared to our actual outcomes and an adaptation algorithm modifies both the controller and the curriculum appropriately so that the system moves continuously toward the optimum. Maybe such an analogy is a bit unrealistic, but some time-optimal control strategy is needed.

At this point, we have a multivariable, feedback-feedforward, time-optimal control system to design and operate. It is potentially unstable. Variable measurement is difficult, and we have ignored the sampling problem: how often and how many students will be sampled? If we are serious about assessment, then the only conclusion is that this is not an easy problem.[5] It is complex, with many possible solutions—none of which are simple. Recall that multiple types of evaluation tools should be applied at several levels of the curriculum and across appropriate time periods. Assuming none of us have achieved the ideal educational system, we must realize that even the simplest design will include changes in the curriculum. Force fitting of an existing static and inflexible education system to EC 2000 will probably not work.

But chemical engineers are good at attacking and solving difficult, ill-defined, complicated problems. After all, isn't that what we want our students to do? This problem will require some effort to do right, but it can be done, and the results should be well worth our efforts.

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THE WPI VISIT

The Chemical Engineering Department at WPI was accredited under the new EC 2000 during the first pilot evaluation in 1996. We faced the problems described above and are still working on solutions. Our specific preparation and timetable were unique to that pilot experience, but some elements of preparation and presentation might be useful to others.

Visit Preparation

Visit preparation cannot begin early enough, and two years is an absolute minimum for the first visit. Four or five years would be better. It should be clear that departments can no longer wait until the year before a visit to begin preparations. Outcomes assessment is continuous, and data collection and analysis must occur constantly. The educational process has a four-year time constant, so early formative data collection is highly recommended. Also consider that alumni and employer survey data might have little meaning unless collected at the proper time intervals.

Educational objectives must be defined first. Presumably there will be institutional ones and discipline-specific departmental ones. A common mistake is to launch into discussions about assessment methods without clear objectives. It is best that faculty and staff avoid many hours in committee meetings discussing the content and logistics of student portfolios before they understand exactly how portfolios link to objectives. When clear, measurable objectives are in place, the specification of performance criteria and the choice of assessment tools derive logically. This may seem obvious, but experience shows that we tend to digress quickly into discussion of assessment methodologies prior to understanding how we really want to use them.

A committed (compensated) department coordinator can help facilitate the process, but all faculty must be involved. A time commitment level of at least 25% is needed for the coordinator.[6] There is no secret formula for engaging all faculty in the process, but one potentially useful argument is that outcomes-based assessment is being required in more and more research proposals. Proposals with decent assessment plans have the edge over others; hence, research-oriented faculty might gain useful knowledge from participation in the process.

Consultant use is highly recommended, but consultants cannot and should not write the assessment plan. They cannot substitute for the faculty. Faculty must define objectives, performance criteria, and feedback mechanisms. Consultants can help recommend methodologies and assist with data-evaluation strategies.

Documentation Using an Assessment Matrix

Presentation of a complex assessment process to a visiting team is problematic. One must clearly show how the department plan addresses the major evaluation criteria. If student portfolios are used, you cannot expect your evaluator to read through several of them looking for evidence of items under Criterion 3. The portfolio itself needs a guide, probably written by the student, and it needs evaluation, probably by faculty. Our experience, and that of others,[7] showed that the assessment matrix format is quite useful for presenting the department's plan, but much detailed additional documentation must accompany the matrix.

The assessment matrix is one way to help organize the plan. It is concise, and it serves as a guide to additional documentation. I will show how we used it to outline our assessment plan, how two years later it portrays some potential problems, and how it illustrates some consequences of outcomes assessment that are important outside of WPI.

Table 1 shows a portion of the WPI Chemical Engineering Department matrix. The column headings are the general assessment process steps. The row headings are the individual educational objectives. Our department adopted ABET EC 2000 Criterion 3 (a-k) as objectives and we show two of them for example purposes. Some definitions are necessary to follow the matrix:

IQP *The Interactive Qualifying Project. This project is a significant open-ended, non-classroom experience that equals three courses worth of credit. It is usually done during the junior year in teams with students from different majors. It must address a problem that considers the interaction of technology with society and culture. Faculty advisors may be from any discipline, and the project topics are interdisciplinary. Since we believe that the global nature of technology is important, many of our students leave campus to conduct these projects at our international project sites. The project is a degree requirement for all students.*

CDR *Completion of Degree Requirement Form. The form is signed by the faculty advisor when the final project report is completed and graded. It is proof that the student has satisfied the degree requirement and is filed with the Registrar.*

PRC *Program Review Committee. This is the department undergraduate committee that annually reviews all senior transcripts to ensure all degree requirements are met for graduation.*

So, let us go through the matrix using "an ability to function on multidisciplinary teams" for our first example. The performance criteria is that students complete a team-based IQP, and the practice is that we require all students to do these projects. Project assessment is done by the faculty advisor and is documented by a grade appearing on the CDR form. This is accomplished for nearly all students by the end of the junior year. The feedback process involves the PRC—if a student does not complete the project, then the PRC issues paperwork informing the student and the Registrar of that fact. Superficially, this might look okay. These projects are truly multidisciplinary (you will have to take my word for that), so completing one with a passing grade, or being duly informed if you did not, may seem like a reasonable assessment loop. Until recently it appeared to be so, but a critical reexamination of the matrix makes me now think otherwise.

I believe that a real assessment plan must go deeper. Completing such a project is not always a guarantee that students function effectively in teams since a dysfunctional team could still pass this degree requirement. Unless an evaluation of effective teamwork is a documented part of the advisor's grading policy, we cannot be sure about the students' abilities relative to the objective. If we believe that argument, then the grade alone is not the proper assessment method. A tool that measures teamwork effectiveness must replace it, and measurable standards of effective teaming must be defined. It logically follows that the PRC review is not adequate feedback. If our teamwork-effectiveness tool indicates that significant numbers of students do not meet our standards, then somehow we must find a way to include team-building activities into the process and formally document the procedure. Some faculty may claim that such a move threatens their academic freedom as project advisors. This issue may arise any time faculty are asked to include new course activities for outcomes assessment purposes. We, and other universities, must deal with this issue as assessment plans are developed.

Here is another example (objective "h"): "...the broad education necessary to understand the impact of engineering solutions in a global/societal context." Compare this objective to the goals of the IQP and you will see they are quite

TABLE 1
Portion of the Department Assessment Matrix

Objective	*Performance Criteria*	*Practices*	*Assessment Method*	*Frequency*	*Feedback Process*
d) an ability to function on multidisciplinary teams	-complete a multistudent IQP	-IQP opportunities are available for every student	-CDR form	-Jr. year	-PRC audit, academic advisor
h) the broad education necessary to understand the impact of engineering solutions in a global/societal context	Demonstrate an understanding or interest in the global or societal implications of engineering by: -completing an IQP abroad	WPI has extensive overseas IQP	-CDR forms	-Jr. year for IQP	-WPI IQP review

similar. What better way to satisfy this objective than to complete one of these projects outside the United States? Such an experience includes a multidisciplinary team working in a government agency, a company, or a non-profit organization in another country on a topic interfacing technology and society. Our assessment plan for this item has some of the same problems described above, but we focus here on a different aspect.

WPI has an outstanding and extensive global-projects program. We send more engineering students overseas for such projects than any other university in the country[8]—quite surprising considering our relatively small enrollment. But last year, only one-third of our students went off campus for their IQP experience. This means that two-thirds of our students did not satisfy objective (h) unless they completed some other appropriate, but as yet unknown, academic experience. Should we try to send all our students outside the U.S., or do we modify the on-campus curriculum to provide alternate paths? Both are viable options, but neither is simple. What about other schools? Should a large university initiate such an extensive global-projects program? The expertise, resources, and organization needed to run such a program are not trivial. Can this objective be equivalently addressed in a course about global engineering? Does that dilute the academic impact so much that the original intent of this objective is lost? We are currently exploring possible answers to these questions. The process is part of what EC 2000 is all about.

Clearly and efficiently linking measurable outcomes to objectives is key to preventing instability in the assessment process. Good objectives with poor evaluation tools means we have little idea if educational goals are met. Good objectives and tools with no feedback means no improvement will occur. Vague objectives, poor evaluation strategies, and excessive assessment will choke the life out of an academic system—an instability we must avoid. Chemical engineers have the skills to design and control complicated chemical processes. Although some adapting is required, we are in a good position to apply those skills creatively to good assessment design.

SUMMARY

The consequences of EC 2000 will be different for each school. The two examples from WPI's assessment plan described above illustrate two major points:

- *Designing and conducting a rigorous outcomes-based assessment process for engineering education is a complex task.*
- *We will all have to change the way we do business. This includes the way we educate and interact with students, the way learning is measured, and the way we use the data.*

If universities and ABET take this approach seriously, then we must do it right to make it meaningful.[5] It is a challenging problem that is well worth our efforts. This holistic approach to education frees us from the rigidity of past accreditation philosophies. New curriculum flexibility is possible, so long as we document its successes and use its failures for improvement. Yes, our learning curve may be steep, but if we maintain high performance standards, our students will ultimately be the main beneficiaries of these efforts.

An answer to our earlier question about why we should assess included something about putting meaning into our instruction and knowing that students learn what we want them to learn. Typically, we focus only on the technical content. The new accreditation criteria add a human element into the process. Perhaps this element coupled with good assessment plans will ensure that students go beyond our earlier answers and learn "how to learn." This certainly gets at the heart of what teaching is all about and may help guarantee that our students become lifelong learners.

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