OUTCOMES ASSESSMENT METHODS

JOSEPH A. SHAEIWITZ
West Virginia University • Morgantown, WV 26506-6102

All chemical engineering departments are now, or soon will be, developing and implementing outcomes assessment plans in order to satisfy ABET Engineering Criteria 2000 (EC 2000). For many departments, this will require a paradigm shift in the administration of the undergraduate curriculum. Among the aspects that may disappear are impersonal lectures delivered by aloof faculty who teach their course in isolation from the rest of the curriculum. Among the aspects that may appear are faculty who regularly communicate with each other about course content, the goals of the undergraduate curriculum, whether these goals are being achieved, and what needs to be done to be certain that the goals continue to be achieved.

Outcomes assessment is a method for determining whether students are learning and retaining the information and skills they need for success in their chosen field. To perform outcomes assessment, measures of this information and these skills are needed. In the traditional curriculum, illustrated in Figure 1, the output of the educational process is assumed based upon the content of the curriculum and the "quality" of the faculty. With no measures of the output, this is analogous to feed-forward control, in which the output is dependent on the accuracy of the model used to predict it, in this case, the curriculum and faculty teaching ability. In the curriculum with a strong assessment component, illustrated in Figure 2, the output of the educational process is measured and compared to the set point (goals), and deviations from the set point are corrected via feedback to the curriculum. This is analogous to feedback control. As shown in Figure 2, there may be multiple measurement and feedback points, analogous to cascade control.

Joseph A. Shaeiwitz *received his degrees in Chemical Engineering from the University of Delaware (BS, 1974) and Carnegie Mellon University (MS, 1976; PhD, 1978). He is currently Associate Professor of Chemical Engineering at West Virginia University. His research interests are in design, design education, and outcomes assessment. He is coauthor of the text* Analysis, Synthesis, and Design of Chemical Processes, *published in 1998 by Prentice Hall.*

[Outcomes] assessment is usually a formal process and consists of documentation showing that students completing degree programs have the knowledge and/or skills required of their degree program in addition to a global set of skills expected of all college graduates.

Assessment may be summative or formative. Summative assessment (usually just called assessment) is conducted for the purpose of making a final (summative) judgment about the effectiveness of the educational process. It may be used by an institution to make decisions about global learning outcomes, resource allocation, and accountability.[1] Such assessment is usually a formal process and consists of documentation showing that students completing degree programs have the knowledge and/or skills required of their degree program in addition to a global set of skills expected of all college graduates. The audience for summative assessment is usually external to the department or university.

Formative assessment (often called classroom assessment) is conducted for the specific process of improving (forming or re-forming) the educational process and usually begins before the educational process is completed. It may involve continuous, often informal, assessment of student learning with the expressed purpose of improving teaching and learning within a specific course or curriculum.[1] The audience for formative assessment is usually within a department or is the instructor in a specific class. The elements of classroom assessment are described in more detail elsewhere.[2] Effective assessment plans have both summative and formative aspects, so external constituencies can be satisfied while continuously improving the educational process.

This paper is an introduction to the process of developing

an outcomes assessment plan. There are numerous citations to functioning assessment plans. A more detailed background on outcomes assessment, the details of one assessment plan, and a more extensive bibliography are available,[3] and a more detailed guide to developing an assessment plan is also available.[4]

An outcomes assessment plan consists of three components:

1. *Goals, which define what is expected of students (the set point)*
2. *Measures of achievement of these goals, multiple measures being best (comparison of outputs to the set point)*
3. *Feedback to correct and to improve the educational process (the feedback loop)*

These three components are discussed in sequence below.

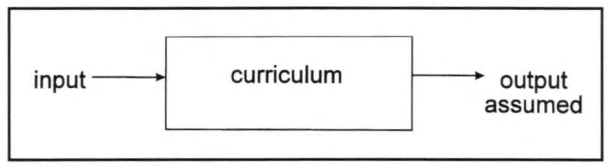

Figure 1. *Feed-forward model for traditional curriculum. Output is assumed based on curriculum model with no measurement of output.*

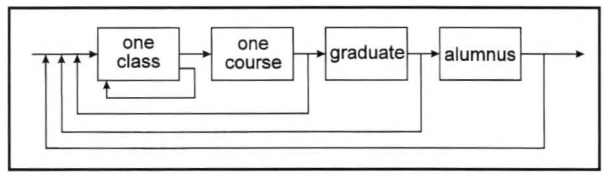

Figure 2. *Levels of feedback characteristic of a curriculum with a strong assessment component.*

GOALS

To develop an assessment plan, educational goals must be defined. It is necessary to elucidate the knowledge and skills students should possess upon completion of a degree program. EC 2000 suggests eleven goals;[5] however, many of them leave ample room for interpretation. The result may be a different set of acceptable goals for departments with different objectives (*i.e.,* preparation for academic career, preparation for industrial career). The goals for the Department of Chemical Engineering at West Virginia University, developed prior to the EC 2000 goals, are one example of goals developed by faculty consensus.[3]

Definition of goals may be a difficult process for faculty members unaccustomed to discussing undergraduate educational issues. It is likely that individual faculty members have very different ideas. For example, a course in fluid mechanics can differ considerably when taught by different instructors. In one case, the course may be mostly theory; in another case, it may be mostly practical; and in a third case, it can be a mixture of theory and practice. The differences stem from the variant opinions faculty have of the goals of the undergraduate educational process. There are no easy solutions to this problem. Faculty must be prepared for a vigorous dialog, they must recognize that there are opposing opinions, and they should be ready to compromise. The EC 2000 goals are a good fall-back position for departments unable to achieve consensus on more specific goals.

MEASURES

There are several proven assessment measures, but it is likely that as more departments develop assessment plans, new measures will be developed. Seven established assessment measures are discussed here.

Testing • This is the simplest measure and is completely summative. Standardized assessment tests have been developed for many non-engineering curricula. In engineering, the FE exam can be used, as could the GRE engineering test. With recent changes making half of the FE exam discipline specific, it is now a better measure of discipline-specific knowledge than the GRE. An advantage of testing is that outcomes can be compared to national norms, which is often what legislatures and boards of trustees want. A disadvantage of testing is that feedback is difficult to obtain from the FE exam. Students taking it in the spring do not get results until after they graduate, and information on what topics students demonstrated strength or weakness is not easily obtainable. If testing is to be used, it should be one of several measures rather than the only measure, since feedback is an essential component of a quality outcomes-assessment plan. The University of Tennessee system[6,7] uses the FE exam as the basis for an assessment plan, and the University of Missouri, Rolla, uses the FE exam as a component of an assessment plan.[8]

Portfolios • The Colorado School of Mines has used a portfolio-based assessment plan for over a decade.[9] Longitudinal records for a statistically significant random sample of students are maintained. These records are similar to ABET portfolios for a class except that they are for an individual student and cover the student's entire tenure at the university. The idea is that student accomplishments in assignments and projects demonstrate achievement of goals (much like an artist's, model's, or photographer's portfolio). In every class, coursework that demonstrates students' abilities pertinent to the stated educational goals is identified and added to the portfolio. Some advantages of a portfolio-based assessment plan are that it does not intrude on routine classroom activities and multiple examples of a student's work that demonstrate skill development and/or improvement are included. Some difficulties are the need for correct analytical methods to identify a statistically significant sample of students and the need to remind all instructors of selected students to collect appropriate portfolio material.

Capstone Experiences • Since all chemical engineering

programs have a capstone experience that draws on material learned earlier in the curriculum, they are a rich opportunity for outcomes assessment. For example, in our department, students are required to do a series of individual projects and to defend their work in front of two faculty members.[3,10] (This requirement has existed in our department for over twenty years). They must work alone, although they may "purchase" consulting time from the instructor for a small, time-dependent grade deduction. This requires well-formulated questions that can be asked and answered quickly (the questions are recorded because they also provide assessment information). The defense serves multiple purposes: it is both an assessment mechanism and a tutorial for the student. Issues common to a significant number of students are brought to the attention of the faculty and are emphasized in the project review in class. Our students have a love-hate relationship with these projects; they hate the pressure, but they recognize the quality of the learning experience. Given the faculty time involved and the potential for student revolution if they were added to a curriculum without a culture supporting them, these individual projects are not recommended as an assessment measure. However, aspects of the projects can be borrowed.

The key advantage of the individual projects is that the work presented by the students and their responses to questions allow the faculty to understand the student's thought patterns and to identify any concepts that are not fully understood. This can also be accomplished in other ways. What is needed is all of the information students are told to omit from final reports: what they tried that did not work and/or what misconceptions they corrected while doing the project. One method is for groups of students to do a series of projects similar to the individual projects described above, with faculty directing questions to specific students.

Students could also be asked to keep a diary of what they did, alternatives they considered, and dead-ends they encountered (diaries are a well-known classroom assessment method[2]). This diary could be submitted weekly or periodically during the semester for evaluation by the instructor from an assessment perspective (not for a grade). The purpose of keeping the diary should be explained to the students so they will take the assignment seriously.

The nature and scope of questions asked during a capstone experience can also yield valuable assessment information. We keep track of the questions asked during "consulting" on the individual projects. For a group project, a periodic, formalized question-and-answer session for each group should yield useful information about the level of student understanding and on their misconceptions. An interim presentation (or two) or periodic meetings with a mentor and/or a TA, in which the interaction was documented in detail, could yield the same information. If some form of individual assessment were desired, students could be required to work on the project for a week or two, outlining a solution strategy and generating questions. Then, after these preliminary strategies and questions were assessed, the group project could begin.

There are no doubt other ways in which capstone experiences can be adapted as assessment measures. When confronted with developing an assessment plan, the first place to consider should be the current curriculum and how it can be adapted to become part of an assessment plan. Since all curricula have a capstone design experience, it is a good place to start an assessment plan.

Questionnaires • Questionnaires are a common assessment measure. Typically, they are sent to employers and to alumni a few years after graduation. They have also been used at the end of each academic year.[3] Questionnaires to alumni give us feedback on their preparation for employment, and questionnaires to employers provide feedback from their perspective. Questionnaires for students in the curriculum are useful for improving the quality of student "life" within the curriculum.

In all cases, student and alumni beliefs about what they learned is being measured. Asking the right questions is important. We ask alumni and employers about global skills such as the ability to communicate and to work in teams, for self-education, etc. We also ask students at all levels what they believe to be the most important thing they learned (the answers may be surprising to some because they tend to focus on communication skills, time management, etc., while fluid mechanics, thermodynamics, or separations are rarely cited!).

One advantage of questionnaires is that it is an anonymous method of obtaining feedback. There are several disadvantages, however. The return rate of alumni questionnaires tends to be low, between 25-33%. Having the questionnaires completed by phone would increase the rate of return, but might be annoying to alumni. Our return rate on employer questionnaires has dropped to zero in the five years we have been using them, with privacy issues (even though the questionnaire does not identify the student) most often cited. Since EC 2000 suggests employer feedback as an important measure, this issue will have to be addressed in the future.

Interviews • Another assessment measure is student interviews, both individual and group. Our chairman interviews each class as a group at the end of each academic year, and random groups of students meet with our Industrial Visiting Committee. Since some students do not like to speak up in a group, individual interviews with randomly selected students could also be used. The information obtained from these interviews is very similar to that obtained from the questionnaires in that the quality of the students' life, and their self-evaluation about

what they have learned is what is measured.

Job Placement • Records of job placement are a valid assessment tool since they measure the demand for graduates from a program, and high demand usually means high-quality graduates. Most departments should have easy access to this information through their career services or placement offices. In recent years, many of our students have obtained positions without going through our career services center, so the department also maintains placement records. A disadvantage of job-placement records as an assessment measure is that employment opportunities can be affected by economic conditions unrelated to the quality or success of an undergraduate program. Therefore, while job-placement information is one outcomes measure, it is a good example of why multiple outcomes measures are needed.

Classroom Assessment • In classroom assessment, an instructor measures student learning more frequently than by traditional testing, often on an informal basis. The goal is to determine whether a particular lecture or exercise was successful. Classroom assessment is not new, and the definitive work on the subject contains fifty classroom assessment techniques.[2] They include methods for assessing critical-thinking skills, problem-solving skills, synthesis and creativity skills, and student attitudes. Perhaps the most widely known classroom assessment technique is the "minute paper" where students take the last minute of a lecture to write down what they learned in that class; the instructor then uses this informal feedback to assess the success of that lecture period. A variation of this is the "muddiest point," where students write down the item they found the most confusing in a given lecture.

Outcomes assessment is a method for determining whether students are learning and retaining the information and skills they need for success in their chosen field. To perform outcomes assessment, measures of this information and these skills are needed.

Classroom assessment is purely formative. Alone, it will not satisfy an external constituency, although it should be a part of an assessment plan that improves student learning. Examples of classroom assessment techniques that I have used successfully are presented elsewhere.[11]

The seven assessment measures above are among those most commonly used. Clearly, they are imprecise measures of learning outcomes. The lesson is that a valid assessment plan must include more than one or two of these measures; however, all seven need not be included to have a quality assessment plan.

FEEDBACK

One purpose for outcomes assessment is continuous program improvement. Feedback is absolutely essential to the process. As shown in Figure 2, a quality assessment plan has many nested feedback loops. Feedback is taken from alumni, graduates, students in the program, and students in a class, and it occurs at multiple points within the curriculum. In our curriculum, a report is generated from the results of each individual design project and is circulated to all faculty, who take it quite seriously. The results are discussed at a faculty meeting if it is deemed necessary.

Completing the feedback loop requires the same paradigm shift in faculty attitudes as does development of program goals. For there to be continuous program improvement, faculty must be willing to accept feedback. No one likes to hear that students have a significant knowledge gap in material covered in their class, but when it occurs, what is the response? Does the instructor ignore the feedback? Does the instructor attack the assessment process? Does the instructor examine how the class is taught, trying to determine why there are knowledge gaps and attempting to rectify the situation? When feedback from alumni suggests that oral and written communication skills need improvement, are faculty willing to modify the curriculum to include more communication exercises?

DISCUSSION

It is clear that implementation of an outcomes assessment plan requires more attention to be focused on the results of the teaching and learning processes instead of solely on curriculum content. How this plays out is yet to be determined. It is unclear what will occur if it is determined that outcomes assessment requires devoting a little more time to undergraduate teaching and a little less time to research. Perhaps some departments will decide they need to employ a full-time educator to coordinate assessment, to oversee evaluation of the curriculum as a whole, and to ensure desirable outcomes.

It takes several years to implement an assessment plan. Trying to implement an assessment plan over the same one-year time scale needed to prepare for an ABET visit under the old guidelines will yield unsatisfactory results. There is a hidden challenge with EC 2000. On the surface, it may create the illusion of being easier to satisfy than the Engineering Topics Criteria because the specific course requirements are less proscribed. But this is *just* an illusion. It is much easier to create a feed-forward model (as in Figure 1) to satisfy the Engineering Topics Criteria than to create a feedback model (as in Figure 2) to satisfy EC 2000. This is partly due to the non-quantitative aspects of outcomes assessment. Even though the old requirements were criticized for their "bean-counting" aspects, many may ultimately pre-

Continued on page 145.

sure the solid mean temperature?

- *Have they determined if the initial weight of the naphthalene ball influences the interphase mass transfer coefficient?*
- *Were the students able to carry out the simulation and modeling of the mass transfer process?*

We think that these questions give the teacher a real chance to evaluate the students and to know if they are really using the theoretical knowledge related to this type of unstructured research experiment.

CONCLUSIONS

We have found that the study of the naphthalene ball adds interest to the mass transfer experiment. The technique is safe, inexpensive, rapid, and capable of yielding meaningful results. The experimental data were also used for follow-up work, such as the creation of a mathematical model.

We think there is a place for this type of laboratory experiment in the undergraduate program.

ACKNOWLEDGMENTS

We wish to thank Margaret Irving Wright for help given in the preparation of this manuscript.

NOMENCLATURE

A	external surface of particle (m)
C_s	concentration on the particle surface (kg/m^3)
C_g	concentration inside the approaching air (kg/m^3)
d_p	diameter of particle (m)
K_{sg}	solid-gas mass transfer coefficient (m/s)
M	molecular weight (kg/mol)
$\dot{m}^*$	sublimation rate (kg/s)
p_s	vapour pressure of the pure substance at saturation (N/m^2)
R	gas law constant (J/mol K)
r	radius of particle (m)
T_s	temperature on surface of the particle (°C or K)
t	time (s)
W_o	initial mass of particle (kg)
ρ_s	particle density (kg/m^3)

REFERENCES

1. Macias-Machin, A., G. Zhang, and O. Levenspiel, "The Unstructured Student-Designed Type of Laboratory," *Chem. Eng. Ed.*, **24**(2), 78 (1990)
2. Sensel, M.E., and K.J. Myers, "Add Some Flavor to Your Agitation Experiment," *Chem. Eng. Ed.*, **26**(3), 156 (1992)
3. Joulié, R., M. Barkat, and G.M. Rios, "Effect of Particle Density on Heat and Mass Transfer During Fluidized Bed Sublimation," *Powder Technol.*, **90,** 79 (1997) ❐

Outcomes Assessment Methods

Continued from page 131.

fer the well-defined requirements of the Engineering Topics Criteria when struggling to implement an outcomes assessment plan.

For chemical engineers, it is likely that determining curriculum goals will not be the most significant obstacle, especially since EC 2000 provides a suggested list of program goals.[5] The outcomes assessment measures described above are examples that have been used successfully, but they are by no means exhaustive. The two lessons learned from these outcomes assessment measures are 1) that multiple measures are essential, and 2) that we must look at what is already being done to identify potential outcomes measures. Probably the most difficult part of an assessment plan to implement is the feedback. Faculty unaccustomed to discussing curricular issues and individual student outcomes, or to receiving feedback will have to change their attitudes.

CONCLUSIONS

Outcomes assessment is a reality looming on the horizon. Within the next five years or so, all chemical engineering programs will have a functioning assessment plan. The methods described in this paper present a framework for developing an assessment plan. The goal is to develop a plan that benefits everyone involved. The result is a win-win-win situation in which students learn more, faculty become better teachers, and employers are more satisfied with their employees.

REFERENCES

1. Davis, B.G., "Demystifying Assessment: Learning from the Field of Evaluation," in *Achieving Assessment Goals Using Evaluation Techniques,* P.J. Gray, ed., New Directions for Higher Education, No. 67, Jossey-Bass, San Francisco, p.5 (1989)
2. Angelo, T.A., and K.P. Cross, *Classroom Assessment Techniques: A Handbook for College Teachers,* 2nd ed., Jossey-Bass, San Francisco, CA (1993)
3. Shaeiwitz, J.A., "Outcomes Assessment in Engineering Education," *J. Eng. Ed.*, **85**, 239 (1996)
4. Rogers, Gloria M., and Jean K. Sando, "Stepping Ahead: An Assessment Plan Development Guide," Rose-Hulman Institute of Technology (1996) (contact gloria.rogers@rose-hulman.edu)
5. *Criteria for Accrediting Programs in Engineering in the United States,* ABET, Inc., Baltimore, MD, 29, December (1996)
6. Hutchings, P., and T. Marchese, "Watching Assessment: Questions, Stories, Prospects," *Change,* **22**(4), 12 (1990)
7. Tolbert, R., and N. Tolbert, "Outcomes Assessment: The Tennessee Model," *1994 ASEE Annual Conf. Proc.,* 515
8. Patterson, G.K., Department of Chemical Engineering, University of Missouri,Rolla; personal communication (see also http://www.umr.edu/~assess/umrassess/umrasses.html)
9. Olds, B.M., and M.J. Pavelich, "A Portfolio-Based Assessment Program," *1996 ASEE Annual Conf. Proc.,* Session 2313
10. Shaeiwitz, J.A., W.B. Whiting, R. Turton, and R.C. Bailie, "The Holistic Curriculum," *J. Eng. Ed.*, **83**, 343 (1994)
11. Shaeiwitz, J.A., "Classroom Assessment," *J. Eng. Ed., in* press (1998) ❐