Assessing Chemical Engineering Education as it is Delivered

Joseph A. Shaeiwitz
West Virginia University

Introduction

Is the typical response to the need to develop an outcomes assessment plan to leave the curriculum and routine teaching activities fundamentally unchanged and to implement alumni questionnaires, exit interviews and questionnaires, and perhaps some type of portfolio assessment? These are mostly summative assessment instruments that are added on to the existing curriculum. Feedback from this type of assessment plan has a significant time lag since most of the assessment is done at the end of or beyond the curriculum. An alternative assessment plan would include many of the above summative instruments plus ongoing formative assessment activities where the time lag for feedback is much shorter. This latter alternative is the subject of this paper. Some may consider the ideas presented below to be a fantasy, especially at research-oriented universities. However, if EC 2000 is to be successful and if those who publicly claim that their universities will focus more on undergraduate education are serious, the ideas presented in this paper may become more of a reality than a fantasy.

According to Boyer, curricula are disjointed, fractured, and unstructured.[1] Courses in the curriculum do not always have a relationship to the goals of the curriculum, if such goals actually exist.[2] The AAHE basic assessment principles include:[3]

- Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated, and revealed in performance over time
- Assessment requires attention to outcomes, but also and equally to the experiences that lead to these outcomes
- Assessment works best when it is ongoing.

Application of these three basic assessment principles are viewed as a major step in addressing the problems of a disjointed curriculum with content unrelated to curriculum goals. The idea is to assess education as it is delivered, to integrate assessment with teaching and make assessment part of an instructors every day activities.

The ideas presented below are a few that might be used to assess education as it is delivered. The examples are by no means exhaustive. What is most important is the concept that successful assessment occurs continuously. Successful assessment is part of the ongoing instructional activity, not an add-on to an unaltered curriculum.

Examples of Integrating Assessment with Teaching

Teaching Goals Inventory. One idea for the integration of assessment activities into the curriculum would be for faculty to do a self-evaluation of their instructional goals. This teaching goals inventory[4] can help instructors become more aware of what they want to achieve in their classes and can help them identify opportunities for classroom assessment, possibly a new idea to most engineering instructors.

Course Content Matrix. A second idea would be for faculty to prepare a matrix showing how the content of their courses maps into the goals of the curriculum. Subjects not demonstrating a clear relationship to curriculum goals might be candidates for elimination in favor of either subjects not already in the course or more time devoted to subjects that have a direct relationship to the curriculum goals. Faculty would repeat this process each semester for each course taught. Given the difficulty in including all of the desired content in an already crowded curriculum, this activity is intended to optimize curriculum content relative to curriculum goals. Instead of course content as usual, the result would be course content directed specifically at the curriculum goals.

Course Competency Matrix. Another idea would will be for faculty to develop a course competency matrix.[5] In the course competency matrix, desired outcomes are mapped into learning levels, such as Bloom's Taxonomy (cognitive objectives).[6] This method is an updated and more structured version of the idea that careful definition of educational objectives improves teaching.[7] The desired outcomes would be those already determined to be directly related to the curriculum goals. Faculty would evaluate this matrix for the class as a whole. Sample problems from assignments and exams would be evaluated using a rubric that would need to be developed. Individual students selected at random, would use the matrix for self-evaluation, and submit portfolio material to support their self-evaluation. Self-evaluation is a well-established assessment measure. Its advantages include involving students in the assessment process, allowing faculty to determine if educational processes are working, and the time students spend on it involves learning.[8] Its only real weakness is that instructors often get surprising responses, which can actually be an advantage if instructors are really interested in how students view their education.[8] What is described above has been termed "course-embedded" assessment.[9] Instead of teaching the curriculum as usual, faculty would be certain to be teaching higher-order cognitive skills. Instead of being on the receiving end of teaching, often passively, students would be more actively involved in learning and assessment.

Skills Development over Time. The Chemical Engineering Department at West Virginia University was one of the first to implement vertical integration of design through the curriculum. We first implemented use of a single design project for all courses taken in the sophomore and junior years in 1988.[10,11] Since students move through our curriculum together and we only offer courses once per year, it is easy for students to work on one progressively more complex project over four semesters. The project counts as part of the grade for all courses taken in the same semester. Students do these projects in groups of three or four, written reports are required each semester, and oral presentations are required for the second through fourth semesters. In the senior year, students must do three individual projects which involve a written report and an oral defense in front of at least two faculty.[11,12] Also for the entire senior year, they work on a comprehensive design project under the leadership of a student chief engineer, in which the class is organized like a design team in a company.[13] There are group leaders, group members, a faculty member playing the role of the students' supervisor, and a different faculty member playing the role of the client. Simultaneously, in the senior laboratory, students work in pairs, and they must prepare written reports and oral presentations for each experiment. These projects and labs are an example of how students have the opportunity to develop skills over the entire curriculum. They develop their oral and written communications skills, the ability to work in teams of different sizes, the ability to work independently, the ability to learn things on their own not covered in class, and the ability to attack comprehensive problems involving analysis of entire chemical processes. Students receive feedback on each project, which allows them to improve their skills in these areas as they proceed through the curriculum.

Historically, most of these projects and labs have only been evaluated for grading purposes. Only the individual projects have been used for assessment purposes.[14] For these individual projects, faculty are able to ask questions and follow-up questions. Oral "examinations" like this are rare, but they are acknowledged as an excellent method for probing breadth and depth of student knowledge.[15,16] The faculty coordinating the senior design class in which these individual projects are done prepare an assessment report. This report identifies areas in which students demonstrated strength and weakness. Suggestions for improving student weaknesses are made. Faculty are expected to implement these suggestions. Additionally, project reviews and follow-up assignments address student weaknesses, providing them with rapid feedback.

The parts of the design and lab component described above other than the individual projects are a rich source of assessment information that can be cultivated. The writing in all reports is evaluated using an assessment rubric developed specifically for that purpose. A similar rubric was developed for oral presentations. Oral presentations are often videotaped to assist in the evaluation process, and, as part of the feedback process, students are required to watch the videotapes of their presentations. There are also rubrics for peer group evaluation available that can be adapted for this purpose.[17,18]

<u>Classroom Assessment</u>. Yet another component of the assessment embedded curriculum is classroom assessment. Classroom assessment is a well-documented activity.[19] It is perhaps the most difficult to implement because it usually requires faculty to change the lecture-oriented delivery style they learned from in school, copied when they became professors, and have become comfortable with over their careers. Among the different learning styles discussed by Felder and Silverman[20] (which is an adaptation of the Myers-Briggs type indicators to engineering and science), no one along the spectrum of active vs. reflective learners is served by the lecture format, since taking notes, which is little more than stenography, neither lets active learners be active nor reflective learners reflect. Examples of classroom assessment activities have been presented.[21] Classroom assessment is usually for the benefit of the instructor; it lets the instructor know whether students have learned or what students have learned from lectures or other classroom experiences. However, it could also be possible to use classroom assessment results to help other instructors understand students' weak areas or what topics students have trouble learning either in other classes or prior to teaching the same class.

As an example, one of the most successful classroom assessment activities I have used is to assign example problems for the class to work on before showing the solution on the board. I then circulate around the classroom coaching the students. Students receive immediate feedback, and the instructor immediately learns if there is a concept that most students have not yet grasped. Since this activity takes more class time than simply doing examples on the board, examples must be chosen very carefully. The instructor must be flexible enough to spend more time on a problem students are finding difficult at the expense of another problem that cannot be discussed, which may be one reason why instructors stay with the lecture format. In the lecture format, coverage of the syllabus is maximized. When using classroom assessment, the instructor may cover fewer topics, but they take the time to ensure that these topics are learned at a high level.

Conclusion

The ideas presented above are just a few that can be used to embed assessment activities into the curriculum and to assess learning as it occurs. Are these ideas a fantasy? That is up to the reader to decide. However, I am sure most everyone would agree that implementation of these or similar activities would result in improved teaching and learning, which is one goal of outcomes assessment.

Bibliography

1. Boyer, E. L., *College: The Undergraduate Experience in America*, Harper Collins, New York, 1987.
2. Diamond, R. M., *Designing and Assessing Courses and Curricula. A Practical Guide*, Jossey-Bass, San Francisco, 1998, pp. 2-3.
3. American Association of Higher Education. "Basic Assessment Principles." *How Do You Measure Success? Designing Effective Processes for Assessing Engineering Education.* ASEE Professional Books, Washington, DC, 1998, p. 45.
4. Angelo, T. A. and K. P. Cross, *Classroom Assessment Techniques. A Handbook for College Teachers (2nd ed.)*, Jossey-Bass, San Francisco, 1993, pp. 13-23.
5. McNeill, B. and L. Bellamy, "The Articulation Matrix. A Tool for Defining and Assessing a Course," *Chemical Engineering Education*, vol. 33, 1999, pp. 122-127.
6. Bloom, B., ed., *Taxonomy of Educational Objectives. Book 1. Cognitive Domain*, Addison Wesley Longman, Reading, MA, 1956.
7. Stice, J., "A First Step Toward Improving Teaching," *Engineering Education*, vol. 66, 1976, pp. 394-398.
8. Banta T. W., *Making a Difference. Outcomes of a Decade of Assessment in Higher Education*, Jossey-Bass, San Francisco, 1993, Ch. 16.
9. Palomba, C. A. and T. W. Banta, *Assessment Essentials. Planning, Implementing, and Improving Assessment in Higher Education*, Jossey-Bass, San Francisco, 1999, pp. 13-14.
10. Bailie, R. C., J. A. Shaeiwitz and W. B. Whiting, "An Integrated Design Sequence. Sophomore and Junior Years," *Chemical Engineering Education*, vol. 28, 1994, pp. 52-57.
11. Shaeiwitz, J. A., W. B. Whiting, R. Turton and R. C. Bailie, "The Holistic Curriculum," *Journal of Engineering Education*, vol. 83, 1994, pp. 343-348.
12. Turton, R. and R. C. Bailie, "Chemical Engineering Design Problem-Solving Strategy," *Chemical Engineering Education*, vol 26, 1992, pp. 44-49.
13. Shaeiwitz, J. A., W. B. Whiting and D. Velegol, "A Large-Group Senior Design Experience: Teaching Responsibility and Life-Long Learning," *Chemical Engineering Education*, vol. 30, 1996, pp. 70-75.
14. Shaeiwitz, J. A. and R. Turton, "Acetone Production from Isopropyl Alcohol: An Example Debottlenecking Problem and Outcomes Assessment Tool," *Chemical Engineering Education*, vol. 33, 1999, pp. 210-215.

15. Banta T. W., *Making a Difference. Outcomes of a Decade of Assessment in Higher Education*, Jossey-Bass, San Francisco, 1996, p. 157.
16. Prus, J. and R. Johnson, "A Critical Review of Student Assessment Options," in *Assessment and Testing: Myths and Realities (T. H. Bers and M. L. Miller, eds.)*, New Directions for Community Colleges, no. 88, Jossey-Bass, San Francisco, 1994, pp. 69-83.
17. Walker, C. and T. Angelo, "A Collective Effort Classroom Assessment Technique: Promoting High Performance in Student Teams," in *Classroom Assessment and Research: An Update on Uses, Approaches, and Research Findings (T. Angelo, ed.)*, New Directions for Teaching and Learning, no. 75, Jossey-Bass, San Francisco, 1998, pp. 101-112.
18. Diamond, R. M., *Designing and Assessing Courses and Curricula. A Practical Guide*, Jossey-Bass, San Francisco, 1998, p. 144.
19. Angelo, T. A. and K. P. Cross, *Classroom Assessment Techniques. A Handbook for College Teachers (2nd ed.)*, Jossey-Bass, San Francisco, 1993.
20. Felder, R. M. and L. K. Silverman, "Learning and Teaching Styles in Engineering Education," *Engineering Education*, vol. 78, 1988, pp. 674-681.
21. Shaeiwitz, J. A., "Classroom Assessment," *Journal of Engineering Education*, vol. 87, 1998, pp. 179-183.

JOSEPH A. SHAEIWITZ
Joseph A. Shaeiwitz received his B.S. degree from the University of Delaware and his M.S. and Ph.D. degrees from Carnegie Mellon University. His professional interests are in design, design education, and outcomes assessment. He is co-author of the text *Analysis, Synthesis, and Design of Chemical Processes,* published by Prentice Hall in 1998.