Outcomes Assessment Measures

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Most engineering departments are now or soon will be required to have a working assessment plan as part of their ABET accreditation. In this paper, the principles of assessment are summarized. The assessment plan in the Department of Chemical Engineering at West Virginia University is used as an example of how a plan can be developed and implemented. Suggestions for how to implement an assessment plan are also presented.

Principles of Assessment

The term assessment is generally used in two contexts. Summative assessment (usually just called assessment) is what an institution may use to make decisions about global learning outcomes, resource allocation, and accountability. The assessment is usually a formal process and consists of documentation that students completing degree programs have the knowledge and/or skills required of their degree program. The audience for summative assessment is usually external to the department or university. Formative assessment (often called classroom assessment) involves continuous, often informal, assessment of student learning with the expressed purpose of improving teaching and learning within a specific course or curriculum. The audience for formative assessment is usually within a department or the instructor in a specific class. The elements of classroom assessment are described in detail elsewhere.

A well-founded assessment plan has three components. The first is a statement of educational goals. It is necessary to define exactly what is expected of students. The second is a valid set of measures of achievement of these goals. As in any good experimental design, multiple measures are best. The third, and perhaps the most important and difficult component, is use of the information gathered in order to correct and improve the educational process.

In order to develop an assessment plan, educational goals must be defined. It is necessary to define what knowledge and skills students should be possessed by students completing a degree program.

Next, and more difficult, is developing valid measures of the goals. A single measure is neither sufficient nor desirable. One possible measure is a standardized test like the FE Exam. For example, the cornerstone of the assessment plan in the University of Tennessee system is testing. Another measure of learning outcomes could be senior, capstone experiences or professional field experience. By carefully designing and monitoring these experiences, student learning as well as the ability to apply knowledge in a new context can be assessed. Yet another assessment method is appropriately designed questionnaires. These could be post-graduate, follow-up questionnaires, sent to graduates (and possibly employers) two to three years after graduation. The questionnaires focus on the graduate’s preparation for the challenges of a
“real” job, both from their own and from their employer’s perspectives. Other measures of learning outcomes can include records of job/graduate school/professional school placement and portfolios of student work. General methods for designing and implementing an assessment plan are discussed elsewhere⁶-¹⁰. Assessment plans at a variety of universities have also been summarized.

If it is agreed that the main purpose of assessment is improvement, then the final element of an assessment plan is use of the information obtained. For example, in the University of Tennessee plan, a portion of state finding is tied to performance on the assessment tests⁴.⁵. Another way to use assessment information is to feed back to parts of the curriculum to which the information is pertinent. In many ways, use of the results of an assessment plan maybe more difficult than developing the plan itself. Faculty must be flexible. They must interact with each other on teaching issues and be willing to respond to information provided by the assessment process. If a deficiency is found, faculty must be willing to correct it. Similarly, if a particular method of learning is found to be most effective, faculty must seriously consider implementing it. It is neither possible to develop an assessment plan to satisfy administrative requirements nor feasible to develop one to improve education that does not contain feedback. Without feedback elements, no improvement in student learning should be expected.

Chemical Engineering Assessment Plan at West Virginia University

Goals

To prepare students to become practicing chemical engineers, consistent with the expectations of the College of Engineering and the West Virginia University Undergraduate Program Goals.

- students will understand and be able to analyze entire chemical processes
- students will be proficient in the oral and written communication of their work and ideas
- students will be proficient in computer programming and in the use of computer software
- students will have the ability to learn independently, but also be able to participate effectively in groups of their peers
- students will be able to design and perform laboratory experiments to gather data and test theories
- students will understand the safety and environmental consequences of their work as chemical engineers
- students will be prepared for a lifetime of continuing education
- students will conduct themselves in accordance with the highest professional and ethical standards

Measures

interviews with students

These interviews are conducted annually or as often as the committees convene. The Academy (distinguished alumni) reports to the Department Chair who provides a written summary of their comments.
The Visiting Committee (industrial advisory board) provides a written summary of their meeting with students and verbal feedback to all faculty during their visit to campus. The Department Chair meets with students annually prepares a written document summarizing his interviews with students. All groups are provided with the assessment plan and questionnaires so that they are informed regarding the goals of the program.

questionnaires

All students are required to complete questionnaires annually. Alumni are requested to complete questionnaires regarding the quality and quantity of their WVU educational experience about two years after graduation. A questionnaire is also provided for employers. Samples of questions contained in the questionnaires are presented in Table 1.

Majors

The Majors are design projects which students must complete individually and defend in front of at least two faculty. They provide a unique assessment opportunity as well as an opportunity for individual remedial instruction. The one-hour defense amounts to a one-hour, individual tutorial by two faculty members. There are three Majors of increasing scope and difficulty during the academic year. They have been described in more detail elsewhere 1,12, The Majors date back to the PRIDE program13, became a part of our curriculum before the national assessment movement began, and predate the arrival of all of the present faculty. Now, as part of the formal assessment plan, the faculty teaching design provide a summary report after each major summarizing specific student strengths and weaknesses. If weaknesses are found, recommendations regarding remedial action and suggested course improvements are included.

records of job placement

This provides information regarding the attractiveness of our graduates to companies hiring chemical engineers.

Use of Assessment Information

In the Chemical Engineering Department at West Virginia University, assessment results are used in several ways. They are used to satisfy the Board of Trustees requirement for an assessment plan, they were used to satisfy the North Central Accreditation requirement of a working assessment, and they will be used to satisfy the forthcoming ABET requirement of a working assessment plan. However, the most important use of assessment results are within the Department.

The results of the questionnaires returned by graduates and their employers usually emphasizes the same points. Students and employers are very positive about the communication skills and teamwork skills learned in our curriculum12, which is consistent with several of the goals stated above. The results of the questionnaires completed by students in or just finishing our program can yield different information. Seniors usually cite the same global skills such as communication, teamwork, and time management, and also tend to comment in detail on the senior year. However, sophomores and juniors usually respond in more detail to specific classes. There is some redundancy between the results obtained from these questionnaires and the interviews; however, since the interviews are conducted in large groups, the questionnaires provide an anonymous means of communication, which often results in more specific comments.

By far, the most useful assessment information is obtained through the Majors. Even though the students work on these assignments independently, there are always a few common errors or misconceptions. A report of common errors and fundamental misconceptions observed from multiple students is prepared and
Table 1
Sample Questions on Assessment Questionnaires

Respondents are asked to rate the quality of these experiences or performance on a scale of 1-5. Space is left for comments. Many items appearing only once here actually appear on all questionnaires.

<table>
<thead>
<tr>
<th>Seniors</th>
<th>Alumni</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral communication</td>
<td>fundamentals of chemical engineering</td>
</tr>
<tr>
<td>written communication</td>
<td>oral communication</td>
</tr>
<tr>
<td>laboratory experience</td>
<td>written communication</td>
</tr>
<tr>
<td>ChE Advising</td>
<td>group dynamics</td>
</tr>
<tr>
<td>computer usage</td>
<td>majors</td>
</tr>
<tr>
<td>ethics</td>
<td>senior group design</td>
</tr>
<tr>
<td>environmental/safety considerations</td>
<td>sophomore and junior designs</td>
</tr>
<tr>
<td>If you have had a summer job in engineering or science please rate your preparation as follows:</td>
<td>ability/desire for self-learning/continuing education</td>
</tr>
<tr>
<td>overall preparation for job</td>
<td>How would you rate your preparation for employment in comparison with your?</td>
</tr>
<tr>
<td>preparation relative to peers</td>
<td>What do you believe to be the most important thing you learned while a student at WVU?</td>
</tr>
<tr>
<td>What do you believe to be the most important thing that you learned this year?</td>
<td>Do you have any specific examples/anecdotes (good or bad) regarding your preparation for employment relative to your peers?</td>
</tr>
<tr>
<td>What do you believe to be the most important thing that you learned while a student at WVU?</td>
<td>Do you have any specific comments regarding your education at WVU? (i.e., content, a specific course or instructor, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employers</th>
<th>Briefly describe your current job. Are you in charge of a particular process? Do you supervise other professionals? Describe any awards, recognition, or promotions you have received since beginning employment with your current employer.</th>
</tr>
</thead>
<tbody>
<tr>
<td>knowledge of fundamentals of chemical engineering</td>
<td>How would you rate this individual’s preparation for employment in comparison with his/her peers? Do you have any specific examples/anecdotes regarding this individual’s preparation for employment relative to his/her peers?</td>
</tr>
<tr>
<td>oral communication skills</td>
<td></td>
</tr>
<tr>
<td>written communication skills</td>
<td></td>
</tr>
<tr>
<td>computer skills</td>
<td></td>
</tr>
<tr>
<td>“hands-on” laboratory skills</td>
<td></td>
</tr>
<tr>
<td>ability to work in a group</td>
<td></td>
</tr>
<tr>
<td>ability to work independently</td>
<td></td>
</tr>
<tr>
<td>knowledge of safety/environmental concerns</td>
<td></td>
</tr>
<tr>
<td>ability/desire for self-learning/continuing education</td>
<td></td>
</tr>
<tr>
<td>How would you rate this individual’s preparation for employment in comparison with his/her peers?</td>
<td></td>
</tr>
<tr>
<td>Do you have any specific examples/anecdotes regarding this individual’s preparation for employment relative to his/her peers?</td>
<td></td>
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</table>

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circulated to faculty, and the report is discussed at a faculty meeting if a timely one can be scheduled. While the faculty teaching the design class in which the Majors are assigned are in charge of the oral presentation and subsequent question and answer period, other faculty are encouraged to and do attend some of these presentations. They receive first-hand feedback on student performance, and are expected to take steps so that subsequent classes will not have the same problems. In the design class, there is always question and answer session just after the assignment is distributed, which itself is an assessment exercise. The scope and content of the questions reveal the level of students’ understanding of the material contained in the problem. After the assignment is completed, there is a debriefing session in which at least one student presents his or her solution, and common problems are discussed in detail. If appropriate, a reinforcing problem assignment follows.

Classroom Assessment Methods

Classroom assessment methods are designed to give the instructor feedback on how well students are learning more frequently and without resorting to testing. One example of classroom assessment is an exercise done in the first week of our two-semester, senior, capstone design class. Students are asked to compile a list of the topics they feel are important to chemical engineering. This assessment technique is related to the techniques known as the Memory Matrix, the Categorizing Grid, and the Defining Features Matrix\(^4\). This exercise often starts slowly, with the first few suggestions being course titles. However, once the students realize what is being requested, a comprehensive list is generated quite rapidly. Students are then asked to target several items for review. The faculty try to get students to explain what they do not understand about targeted topics, and as many as possible are reviewed before the first Major. Faculty use their judgment in choosing among the suggested review topics. This exercise demonstrates whether our seniors know what they are supposed to know to be chemical engineers, and whether they are mature enough to admit what they do not know, which makes it easier to identify topics in need of review and reinforcement.

An example of the result of this assessment exercise involves catalysts. In the fall of 1993, the class asked for more instruction on catalysts. After some questioning, it was determined that they mistakenly thought a well-defined method existed that they had not yet mastered for choosing catalysts for a chemical reaction. This misunderstanding was cleared up. Without the assessment exercise, the faculty would have had no way of identifying this misconception.

There are numerous classroom assessment exercises available which have been proven effective. The goal of these techniques is to get students to think in more depth about what they have learned and for the instructor to get feedback on what students do and do not understand more often and in other ways than by formal testing. This author has had success with the following method. Instead of going over an example on the board, students are given the problem and told to work on it for 5-10 minutes. Group work is encouraged. The instructor goes around the room and sees how students approach the problem. Students making errors get immediate feedback and individual attention. The instructor gets an idea of what concepts students are having difficulty applying or what items covered in a lecture were not fully understood. This author has used this method successfully in classes up to 45 students. By integrating classroom assessment with normal teaching, it is possible to obtain continuous feedback in a less stressful setting than examinations.

Implementation of an Assessment Plan

It is neither necessary nor advisable to use individual projects like our Majors as assessment measures. We believe if it were not for the long history of these individual projects, that students would revolt if these...
were implemented today. Questionnaires are a useful assessment measure and should be part of an assessment plan; however, our experience is that the fraction actually returned is not sufficient for them to be the basis of a good assessment plan. There are other excellent methods of assessment available. In fact, most departments are probably already doing things that can, with only minor modifications and formalization, form the basis of an excellent assessment plan. Two examples are portfolios of student work and well-designed and evaluated capstone experiences.

Portfolios are a documentation of experiences that demonstrate that students are achieving stated goals. They are similar to what is required for each course for an ABET visit, except that they are usually organized by student rather than by course.

Most capstone experiences are untapped assessment measures. The desired information is how students proceed from the assignment to the final product. This is the information we always tell students to omit from the final report; it is the history of how the final product was obtained. Two possible ways to gather this information are as follows. Students could be asked to keep a diary of what they did, alternatives they considered, and dead-ends they encountered. This diary would be submitted weekly or periodically during the semester and evaluated by the instructor from an assessment perspective (not for a grade). As stated previously, we have observed that the nature and scope of questions asked during a capstone experience can yield valuable assessment information. Therefore, a periodic, formalized question and answer session for each design group during their capstone project, with someone like a TA taking detailed notes, should yield useful information on the level of student understanding and on their misconceptions. An interim presentation (or two) 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.

Finally, for an assessment plan to have maximum success in the long term, beyond merely satisfying the requirements of external constituencies, a culture supporting the importance of assessment should be developed within a department. This takes time, but it must start somewhere. The survival of the Majors in our department is due to the existence of this type of culture. All faculty should be involved in development and implementation of an assessment plan. The shared ownership can be the first step toward evolving the desired culture. Faculty should communicate with each other about their expectations for course content and students’ performance, and about the resulting outcomes. Faculty must be willing to provide feedback, to accept feedback, and to adjust their teaching and course content in response to the feedback. While this may require a paradigm shift in faculty behavior, the result will be a better product (students).

Conclusions

Assessment plans will be required of all engineering departments. While implementation of a formal assessment plan takes some time (at least one year), it is likely that the elements of a sound assessment plan already exist in most departments. If it is done properly, development of an assessment plan will result in improved student learning and production of a better graduate.
References


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 research interests are in design and design education. Of particular interest are the use of performance problems to complement design problems, the integration of design experiences throughout the curriculum, and assessment of learning outcomes.