AC 2007-1960: THE USE OF DIRECT AND INDIRECT EVIDENCE TO ASSESS UNIVERSITY, PROGRAM, AND COURSE LEVEL OBJECTIVES AND STUDENT COMPETENCIES IN CHEMICAL ENGINEERING

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The Use of Direct and Indirect Evidence to Assess University, Program, and Course Level Objectives and Student Competencies

Abstract

The Chemical Engineering Department at Brigham Young University (BYU) has partnered with BYU's Institutional Assessment and Analysis unit to implement a number of assessment tools. These tools involve both direct and indirect evidence measures to assess university, program, and course level objectives and student competencies. Direct measurement tools include a mandatory-pass senior competency exam, instructor end-of-course proficiency evaluations, composite assessment of communication skills across several courses, and the California Critical Thinking Skills Test. Indirect tools include student end-of-course proficiency surveys, in-course minute paper surveys, the National Survey of Student Engagement, and university-conducted surveys of seniors, alumni, and employers.

This paper discusses a suite of direct and indirect assessment tools and their use to facilitate a comprehensive evaluation of student learning and of the learning environment necessary for a continuously improving educational process.

Literature Review

Assessment has the dual purpose of providing evidence that learning objectives are being met and providing feedback to guide the improvement of educational activities. A good assessment program utilizes a variety of tools to facilitate breadth and depth of analysis yet is efficient so that the time and effort spent on assessment is optimized.

In 2003 the Middle States Commission on Higher Education published a valuable guide on assessment entitled, *Student Learning Assessment: Options and Resources*.[1] This guide discusses a variety of direct and indirect assessment tools, their strengths and limitations, and provides insight for the development of assessment programs.

Direct assessment measures are those which provide *direct* evidence that a learning objective has been met. Such evidence demonstrates the degree to which a student has mastered a particular subject, has acquired a specific skill, or developed a certain characteristic. These measures are most commonly applied at the course or program level, but can also be applied at the institution level. Examinations are by far the most common tools for direct assessment. Also valuable are portfolios of sample work such as writing samples and evaluations of oral presentations. Direct assessments are a necessary part of an assessment program, but they do not of themselves give a complete analysis. Direct assessments can show *what* was learned, but fail to show *how* or *why* the learning took place. Indirect measures are better suited to this task and are indispensable means of providing insight into the learning environment in order to improve the learning process.

Indirect measures typically focus on predictors that are correlated to learning, but do not measure learning itself. The most common indirect assessment tools are surveys which solicit input from students, alumni, employers, graduate schools, or other constituencies. These surveys provide particular insight into the questions of *how* and *why* learning takes place through questions about such topics as student engagement and the effectiveness of specific class activities. Angelo and Cross discuss the essential insight gained as students engage in self reflection in these surveys.[2] Because of the focus on the *how* and *why* of learning, indirect measures are essential in our efforts to improve the educational environment. They can help us evaluate the effectiveness of lectures, reading assignments, homework, or any other pedagogical activity, and thus guide our improvement efforts. At the course level the most commonly used indirect measures are course and instructor evaluations completed by students at the end of a semester or term. These often include a quantitative section, which facilitates statistical analysis and comparisons, and a narrative section which gives students an opportunity to provide more in-depth feedback. Such surveys need not be reserved for the end of term, but instruments such as minute papers can provide formative feedback with which an instructor can adjust a course midstream.

Most measures, both direct and indirect, fail to demonstrate value-added, i.e., whether the learning occurred in the particular course or as a result of a specific pedagogical activity. It can generally be assumed that technical learning, e.g., solution thermodynamics, occurred in the course where that material is taught, since this material is very unlikely to be learned elsewhere. Other learning objectives, such as critical thinking or communication skills are developed across the curriculum and even beyond the curriculum. Pre-test/post-test methods are the most obvious means of ascertaining value-added for this type of objective, but there are other valuable methods which may be more easily implemented. These include comparing populations which have different exposures, or using national norm standard exams. However, as Banta and Pike have reminded us,[3] standard exams that measure general intelligence are poor measures of value added. Of greater value are exams that measure specific generic skills such as critical thinking. Many accrediting organizations are not emphasizing value-added analysis, largely because of the difficulty involved and the possibility that such efforts will divert attention from the more important issue of whether or not learning objectives have been met.[1, 4] Perhaps value-added is best pursued within individual courses as instructors seek to determine the effectiveness of specific activities through minute papers or other surveys.

Keys to the success of an assessment program include ensuring that there is close correspondence between learning objectives and the items included in the assessment tool. Course examinations whose questions are transparently linked to learning objectives provide clear and quantitative data about how well these objectives are met. Carefully constructed rubrics, which are criterion-based rating scales, often used to evaluate written and oral communication skills, also provide clear connections to learning objectives.[5]

Assessment tools need to be demonstrably "valid" and "reliable."[1, 6] There are several facets of validity that should be considered in selecting and designing assessment tools. A tool has *content* validity if the tool measures what it purports to measure. Related to content validity is *face* validity which is simply whether or not the tool measures what it *appears* to measure. *Concurrent* validity means that the tool will give consistent results with other tools designed to measure the same outcome. Psychological concepts such as creativity or intelligence are not directly observable, but can be inferred on the basis of their impact on behavior. Hypothetical constructs connect these concepts with behavior and an assessment tool is said to have *construct* validity if it provides faithful evidence of the psychological concepts in question. Also important is reliability which refers to the repeatability or consistency of the tool, i.e., if applied twice to the same person similar results should be obtained.

Assessment, Evaluation and Continuous Improvement in the Department of Chemical Engineering

Criteria 2 and 3 of ABET's requirements specify that accredited institutions will have detailed program objectives and student learning outcomes that incorporate constituency needs, and will have processes in place that ensure that these objectives and outcomes are achieved.[7] The two criteria components of outcomes and objectives require assessment, evaluation, and feedback. In our program, we have defined a list of specific competencies that correspond to each outcome. Hence, our educational plan uses the terms objectives, outcomes, and competencies, where the competencies represent a third level of detail to our program objectives.

We have described elsewhere our experience with the development of an outcomes-based educational plan to satisfy accreditation requirements.[8] Critical aspects of our plan include: definition of program objectives; the method used to define student outcomes and competencies; definition of mastery levels that reflect the relative importance of individual competencies; definition of a core set of competencies targeted for mastery by all of our students; feedback from our constituencies; a variety of assessment tools including both direct and indirect instruments; and methods for continuous evaluation and improvement of our curriculum, teaching pedagogy, and the assessment plan itself. Assessment of student proficiency is performed at the competency level in order to provide detailed feedback necessary to facilitate evaluation and improvement of student learning.

We have selected a variety of direct and indirect methods (see Figure 1) to provide a comprehensive assessment of student outcomes. These methods address developed proficiency (*what* is being learned) and the effectiveness of the learning environment (*how* and *why* learning is occurring). The direct tools include end-of-course proficiency evaluations, a mandatory-pass senior competency exam, assessment of communication skills, and a nationally-normed critical thinking test. The indirect tools include student end-of-course proficiency surveys, in-course minute paper surveys, the National Survey of Student Engagement, and university-conducted surveys of seniors, alumni, and employers.

Assessment Tools — Direct Instruments

Instructor End-of-Course Proficiency Evaluation. The instructor end-of-course evaluation is administered at the end of each chemical engineering course by the instructor. The evaluation assesses student proficiency (on a 0-5 scale) in course competencies and links the proficiency rating to direct evidence from exams, homework, projects, or other measures of performance. For example, a given rating may come directly from the average score on a combination of problems from midterm exams, quizzes, and the final exam that deal specifically with that competency. This specific information is included in the evaluation form. Since instructors focus on specific competencies when preparing in class assessment tools, such as exam and quiz questions, these end-of-course evaluations provide specific and valid (both *face* and *content*) measures of student proficiency on specific competencies. Table 1 contains a portion of an instructor evaluation form.

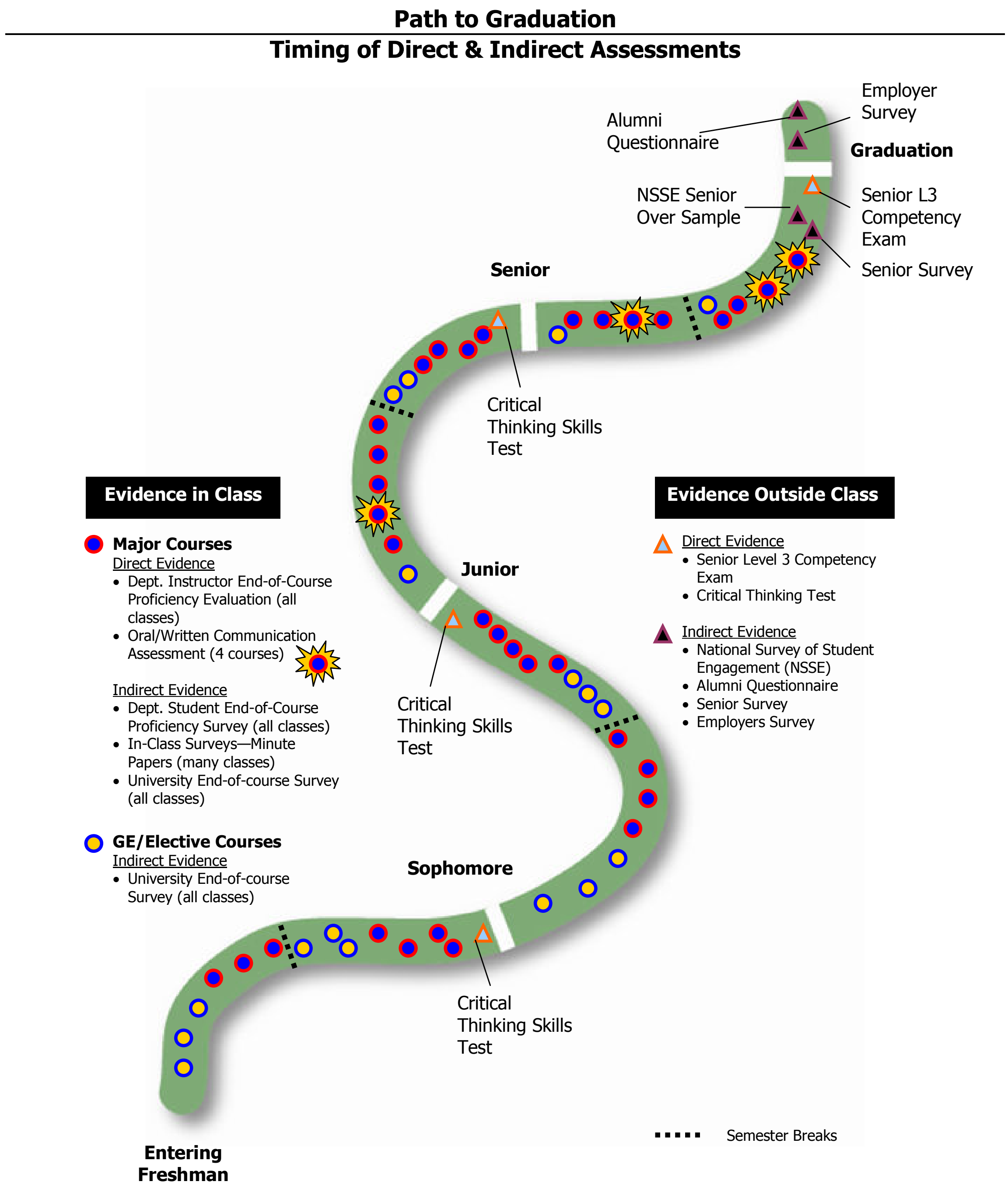

Figure 1. Direct and Indirect Assessment Tools Used Along the Path to Graduation.

Faculty have been assessing learning for as long as there have been schools, and their efforts and expertise in evaluating student learning through exams, quizzes, and assignments should retain a significant role in the renewed emphasis on outcomes-based education. Course grades are the traditional summation of in-course assessments; however, these grades smooth and smear across course competencies and therefore lose the focus on individual competencies. This course-end evaluation tool relies on the assessment expertise of faculty, but reestablishes the focus on individual competencies.

Through this tool we have discovered weaknesses in a variety of competencies including an inability to perform flash calculations in the thermodynamics course and an inability to perform transient mass and energy balances in several courses. With this information and a feedback loop to the curriculum, modifications in course activities have been made and improvements have been realized and documented.

This feedback and documentation is strengthened with a form that accompanies the end-of-course evaluation, shown in Table 2. The form includes questions concerning how thoroughly the competencies were addressed in the course and solicits comments and recommendations for improvements in treating course competencies and for modifying the competencies themselves. The department undergraduate committee reviews all of the course evaluations annually (as well as data from the other assessment tools that are currently in use). Concerns, deficiencies and/or recommendations for curriculum or course modifications are brought to the full department faculty for discussion. Recommendations are given to the instructor before the next offering of the course, and a reporting of how these recommendations were addressed in the course is included as part of the end-of-semester course evaluation.

Mandatory-Pass Senior Competency Exam. This exam is given during the senior year and assesses mastery of specific program competencies. In each program course, competencies are designated as Level 1 (exposed but not tested), Level 2 (competent with access to resources), and Level 3 (mastered without access to resources). The Senior Competency Exam tests students on the mastery of Level 3 competencies. The exam, also called the Level 3 or L3 exam, consists of 24 problems covering 24 Level 3 competencies. Level 3 competencies are the kernel concepts of chemical engineering science upon which application, design, and synthesis build. Students pass the L3 exam when not more than one question is answered incorrectly. Students may repeat the exam (for just the missed competencies) two times. If a competency is still missed, students must complete assignments regarding the competency prior to graduation. The students take the exam on-line via a program that generates a unique set of problems for each student from a database of problems. The program scores the exam and provides immediate feedback to the students on any missed competencies as soon as they have completed the exam. This allows the students, in case they have not passed the exam, to study the appropriate competencies for the next taking of the exam. The computer remembers a particular student's missed competencies and generates a new exam with only problems from the missed competencies.

Through the administration of this exam, we have become aware of weaknesses in student grasp of several of these kernel concepts. The most pronounced weaknesses have been in the areas of thermodynamics, reaction engineering, and heat transfer. This information has been fed back into the core courses dealing with these subjects and through improved classroom activities improvement has been noted. An additional benefit from the focus on these kernel concepts has been an improved structure in student learning in which they more clearly see the variety of applications building on these fundamental kernel concepts.

Oral and Written Communication Assessment. The instructors in chemical engineering courses which utilize extensive oral and/or written communication skills (primarily seminar and laboratory courses) are asked to evaluate individual student's abilities in these areas by providing a single composite score ranging from 1 (not proficient) to 4 (proficient). The composite score is based on direct assessments obtained from rubrics or other quantifiable measures. The rubric used in the senior laboratory course has 39 components from which a written report is graded. Similarly, an oral communication rubric has 27 components. This extensive rubric provides detailed feedback to each student. These scores are combined across the several classes involved to provide a composite measure of proficiency for each student.

The written and communication "soft" skills are often hard to track unless a grading rubric or some other comprehensive measure is used. One method currently used in the senior laboratory course is to have each student complete one section of a report (e.g., Materials and Methods Section), grade this written section using the above mentioned rubric (this preliminary score is not included in student grades for the course), require each student to rewrite the section based upon the graded rubric, and then re-grade the rewritten section again using the rubric. This method has been very valuable—students have done very well after having some feedback with an opportunity to rewrite. It's important to note that students were not told what to rewrite during the initial rubric grading, rather they were told what components of the writing were missing or not appropriately addressed.

Critical Thinking Test. The California Critical Thinking Skills Test (CCTST) has been used nationally and internationally for learning outcomes assessment, performance funding, program evaluation, professional development, training, and as an element in application, admissions, and personnel evaluation processes. The CCTST is designed for college students and adults. It has been most widely used with traditional aged college and university undergraduate students.

The CCTST is based on the conceptualization of critical thinking articulated in the Expert Consensus Statement on College Level Critical Thinking (1990) known as The Delphi Report.[9] This concept was supported by an independent replication research study of policy-makers, employers, and academics which was conducted at Penn State University, sponsored by the U.S. Department of Education.

The CCTST Total Score targets the strength or weakness of one's skill in making reflective, reasoned judgments about what to believe or what to do. The CCTST generates several scores relating to critical thinking including a) Overall critical thinking skills total score and *Norm-group Percentile*, b) Sub-scale scores by the classical categories of *Inductive Reasoning* and *Deductive Reasoning*, and c) Sub-scale scores by the contemporary categories of *Analysis, Inference, and Evaluation.*

The CCTST was administered for the first time at BYU in the Fall of 2006. Chemical Engineering sophomores, juniors, and seniors were included in the program. Due to student scheduling conflicts, this first administration was only to about half of the chemical engineering students. Overall, our students scored at the 94th percentile. However, we observed that students scored significantly higher in the constructs of inference (93rd percentile) and evaluation (91st percentile) than they did in analysis (71st percentile). We will follow this with subsequent administrations and plan content and pedagogical changes to address the analysis construct.

Critical thinking is a targeted learning outcome for most university degree programs, but is a difficult outcome to quantify because it is indirectly addressed in many courses and hopefully develops over time as students progress through a curriculum. As such it is desirable to have a standard to which to compare and to be able to ascertain improvement over time (value added). The nationally normed CCTST has practical utility for any university program for measuring this outcome.

Assessment Tools — Indirect Instruments

Department Student End-of-Course Proficiency Survey. The student end-of-course survey is administered at the end of each chemical engineering course to the students by department personnel. This survey asks students to rate the course based on its contribution to developing proficiency in course competencies and to rate individual student proficiency in these competencies. (See Table 3.) As an indirect measure this survey does not measure learning directly; however, student perceptions about their proficiency and about what they learned in the course are strongly correlated with learning. This survey also provides insight into the learning environment. Low ratings are reliable indicators of areas that need attention. For example, these surveys pointed out a weakness in statistics abilities in students taking the chemical engineering Unit Operations classes. This weakness has been addressed with some improved instruction.

In-Class Surveys (Minute Papers). Understanding the effectiveness of classroom activities is an essential component to understanding the *how* and *why* of student learning, and to improving the learning environment. Brief survey tools, such as minute papers, can provide real-time insight about specific activities. Questions can target the effectiveness of reading assignments, lectures, handouts, in-class activities, or any aspect of the course on student learning. Typical surveys include a list of activities and ask students to provide a numerical rating on each activity's effectiveness. Comments and recommendations are also solicited. These surveys are being used with increased frequency in our program and have led to changes in textbooks, modifications of reading assignments, and improvement in class activities. The frequency of assigning minute papers varies with instructor from a few per semester to as frequently as one per week. These surveys are a powerful and easy tool to help optimize the learning environment.

National Survey of Student Engagement. The university has participated annually in this national assessment since its inception in 2000. The survey is viewed as an excellent process measure of the learning environment and assists in providing multifaceted measurement of institutional performance regarding the university's mission, aims, and objectives. Questions focus on areas of student engagement which empirical research has shown to be predictive of success in achieving important learning outcomes. Student engagement is at the heart of *how* and *why* students learn and is a good indicator of *what* is being learned.

This survey has provided encouraging evidence of success from some of our efforts, such as the fact that 71% of BYU chemical engineering seniors have been involved in a faculty-mentored research experience. We are working toward 100%. The survey has also indicated some aspects of student engagement that need improvement. For example, less than half of our students frequently participate in class discussions and less than half complete reading assignments. To remedy these deficiencies efforts are being made to involve more students in classroom discussions, including the use of automated student-response systems, and reading questions are being assigned more frequently to encourage and guide students in completing assigned reading. As a result of these changes student engagement is increasing and better learning will likely result.

Currently many national rankings put out by such entities as *U.S. News and World Report* are criticized for being too dependent on resources and dollars expended and not looking at what matters most—what students are learning. As such rankings have been criticized, the NSSE has been applauded for focusing on how much students are learning, and their engagement in learning at their respective institutions. Nationally, the NSSE has been used widely and its constructs and national comparisons map to a large degree to the targeted learning outcomes of virtually any institution or degree program. Participation in this project not only adds some insight into targeted learning objectives, but produces university and national counterpart comparisons.

University Student End-of-Course Survey. In addition to the student end-of-course survey written and administered by the department, the university administers a separate end-of course survey to students. This survey allows for more open-ended responses and provides insight into the effectiveness of teaching. Students have an opportunity to respond to the effectiveness of learning activities, fairness of grading procedures, explanation of concepts, usefulness of feedback, degree of student involvement, time spent on homework and reading assignments, etc. Students may also include free-form comments about the course.

These surveys have brought to light many issues over the years that have required attention. For example, some courses have had an unreasonably heavy workload, requiring too much time for students to complete homework. This issue has negatively impacted student attitudes, learning in the course, and learning in other courses. Slowness in the grading process in some courses has also negatively impacted student learning. We are striving to ensure that work loads are consistent with course credit hours, and that students get prompt feedback on their work. Because issues like these require constant vigilance, end-of-course surveys have been a valuable resource for helping us track our performance and thereby improve the learning environment.

Surveys that elicit written responses allows for assessment details that are often missing from numerical surveys. These responses can provide a deeper understanding of factors that impact (either positively or negatively) learning. Individual student perceptions and needs, which are lost in averaged numerical ratings, can be recognized in these responses.

Senior Survey. The Senior Survey was developed by a faculty led committee within BYU and measures the extent to which seniors feel their university experience fulfilled the university's stated mission, aims, and objectives in their lives. The survey is aligned to 24 constructs which operationalize these stated goals. Many of these constructs map to specific program and degree goals. Issues of student engagement such as student-faculty interaction, and active learning experiences, which are closely tied to student learning, are a prominent part of the survey. Other items ask seniors to estimate the impact of their overall experience and specific facets of their undergraduate experience on their spiritual, character and intellectual development. This survey provides a comparison between chemical engineering seniors and all BYU seniors on issues of student engagement and achieving institutional objectives, and indicates that chemical engineering students generally compare favorably with their counterparts across campus.

In the survey responses, 87% of Chemical Engineering seniors reported that they participated in a major course in which the instructor engaged them in critical reflection, integration, application, or other forms of "critical thinking" as compared to 89% of all seniors. However, in a follow-up question, 53% of Chemical Engineering seniors reported that this was very typical in most or all of their major courses while only 20% of their university counterparts indicated that this was very typical. These results suggest that while our department courses compare favorably with other university programs, there is still room for improvement in engaging students in these critical thinking applications.

Senior surveys are widely used by most institutions. The value of a senior survey is that students still have things fresh on their minds. Their responses can be more formative in nature.

Alumni Questionnaire. The alumni questionnaire (AQ) is a descriptive instrument that also maps to the 24 constructs incorporated into the Senior Survey that operationalize the university's stated goals and objectives. Many of these constructs have direct linkage to program goals and intended learning objectives (e.g., communication skills, thinking habits/skills, technological skills, etc.) This questionnaire is administered to alumni three years after graduation and has been administered each year since 2000. The AQ asks alumni to rate themselves on specific, concrete self-descriptive statements and questions derived from official statements of university aims. Other items solicit alumni perceptions of the impact of their undergraduate experiences in terms of their spiritual, character and intellectual development. Academic units also have the latitude to include a limited number of department-specific questions to the base instrument. Free-response items ask alumni to describe significant experiences with faculty members, key learning experiences and areas in which the university can improve.

Results of the questionnaire indicate that our students are overwhelmingly satisfied with their overall education experience (95% rated their experience as good or excellent) and that they feel that they have been well prepared for life after graduation. Faculty accessibility, which we believe to be an important component in a good learning environment, was also rated very high.

Alumni instruments like senior surveys are widely used by most institutions. As graduates are the "product" of the educational process, their feedback is invaluable in assessing in both a formative and summative manner their experience and capabilities. Most regional and specialized accrediting organizations recommend an alumni survey to their constituents. Alumni surveys, wherein respondents are three years removed from graduation, allow for the impact of a college education to settle in and so provide valuable perspective about the quality of preparation derived from the university experience.

Employers Survey. The university has also developed and incorporated into its suite of institutional instruments a survey that assesses the perceptions held by employers of the university's graduates. Specific majors have not been differentiated in the results due to the complexity of many employers hiring from multiple disciplines. The reported level of analysis is at the university level overall, however findings are generalizable at the academic program level.

The results of these employer surveys have reconfirmed that the business world values the same attributes that are emphasized in our program, namely, a strong work ethic, problem solving skills, critical thinking skills, and ability to work on teams. Employers tell us that our students fair very well compared to graduates from other institutions. Improvements in our program could be achieved through providing more opportunities for internships and other real work experiences, and helping graduates to be more open-minded and tolerant of others.

One reason students pursue higher education to prepare themselves for future employment. Employer surveys provide an independent evaluation of the product of the educational process. These instruments are recommended as useful paths to indirect evidence by accrediting groups.

Closing the Loop and Continuous Improvement

Once a good suite of direct and indirect assessment tools has been implemented and data are being gathered, these data must be analyzed and interpreted. The loop is closed by feeding the results of this analysis back into the learning process. This feedback guides changes in learning activities and in the learning environment. The assessment process will then measure the impact of these changes. This cycle continues and as a result learning continually improves. The assessment process itself must also be continuously evaluated for thoroughness and efficiency. Assessment tools should be continuously evaluated and improved, or perhaps even replaced with more effective or efficient tools.

An emphasis on learning outcomes has led to many improvements in our learning process and in our product. An initial analysis of our program and the development of a set of student competencies led to two new courses to address areas of deficiency. These courses addressed student competencies in the areas of safety, environmental protection, resume writing, oral communication, and life-long learning. During several years of implementation, process improvements have included improved focus on fundamental (kernel) concepts, improved pedagogy through increased use of active- and cooperative-learning principles, better assessment through broad use of such tools as minute papers, new assessment tools including the critical thinking skills test, and the improvement of existing assessment tools, including fine tuning of the senior competency exam and a better set of rubrics for assessing student writing. Product improvements (i.e. improvements in student outcomes) are evident in improved written communication skills, including resume preparation and report writing, improved student understanding of some specific level-three competencies in the areas of thermodynamics, reaction engineering, and heat transfer, and improved student knowledge in safety and environmental issues.

Summary and Conclusions

The assessment program we have adopted relies on a combination of direct and indirect measurement tools and provides a comprehensive view of student learning. The direct tools measure *what* is being learned by focusing on kernel concepts of our discipline, proficiency in each of our technical courses, communication skills that cross course boundaries, and critical thinking. The indirect tools provide supporting data concerning learning specifics, but also focus on *how* and *why* learning is taking place. The effectiveness of learning activities, the degree of student engagement, and the impact of various aspects of the learning environment are effectively investigated with these tools. Both types of tools are needed in a successful assessment program.

The data gleaned from these tools provide evidence that our students are achieving our learning objectives and are facilitating our efforts to continually improve our educational process. Just as our educational process is continually improving, so is our assessment process. We are working to more effectively use all of the information provided by our assessment tools and to improve the efficiency of data acquisition, analysis, and feedback into the learning process. At the same time we are continually evaluating other assessment tools for possible adoption into our program. Assessment and continuous improvement will always be works in progress.

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Table 1. Instructor End-of-Course Proficiency Evaluation.

<table>
<tr><td colspan="4">Faculty Evaluation</td></tr>
<tr><td>ChEn 374</td><td colspan="2">Instructor:</td><td>Semester:</td></tr>
<tr><td colspan="2">Instructions: In the column marked “Proficiency” rate the students’ proficiency in the expectation corresponding to each competency using the scale shown at the right. Then identify the assessment method used to evaluate their proficiency. You may use H=homework, E=midterm exam, F=final, Q=quiz, and P=paper</td><td colspan="2">0-none 3-good
1-poor 4-very good
2-fair 5-excellent</td></tr>
<tr><td>Competency/Level</td><td>Expectation</td><td>Proficiency</td><td>Assessment Method</td></tr>
<tr><td>3.2.4/2</td><td>Students will understand mechanical behavior of materials including elastic, viscous, surface, and stress phenomena as it pertains to fluid flow applications.</td><td></td><td></td></tr>
<tr><td>3.3.1/3</td><td>Students will be able to use the mechanical energy balance equation to solve fluid flow problems both with and without friction.</td><td></td><td></td></tr>
</table>

Table 2. Instructor Course Assessment Form.

<table>
<tr><td colspan="2">Chemical Engineering Course Assessment Form</td></tr>
<tr><td colspan="2">Instructor: Course: Semester:</td></tr>
<tr><td colspan="2">Y N 1. Were student competencies included in the course syllabus?</td></tr>
<tr><td colspan="2">Y N 2. Were all competencies addressed? Please add explanation if “No”.</td></tr>
<tr><td colspan="2">Y N 3. Is there a need to update, revise, or add to the competencies? Please explain if “Yes”.</td></tr>
<tr><td colspan="2">Y N 4. Are there competencies in which students are particularly weak? Please explain if “Yes”.</td></tr>
<tr><td colspan="2">Y N 5. Are there competencies in which students are particularly strong? Please explain if “Yes”.</td></tr>
<tr><td colspan="2">The following comments and recommendations were provided following last year’s course. Please write your comments on the back page.
1. Please state what you did to address the recommendations and provide an assessment (preferably direct) that shows the impact of the addressed recommendations.
2. Please identify plans/recommendations for modifying this course (or prerequisite courses/curriculum) to better address student competencies.</td></tr>
<tr><td>Comments</td><td>Recommendations</td></tr>
<tr><td>1.</td><td>1.</td></tr>
<tr><td>2.</td><td>2.</td></tr>
</table>

Table 3. Student End-of-Course Proficiency Survey.

Student Evaluation			
ChEn 374			
Student Instructions: In the column marked "Course" rate the course on its contribution to developing the expectation shown for the listed competency. Then in the column marked "Self" rate your proficiency in the skill or expectation. Use the scale shown at the right.		0-none 3-good 1-poor 4-very good 2-fair 5-excellent	
Competency/Level	**Expectation**	**Course**	**Self**
3.2.4/2	Students will understand mechanical behavior of materials including elastic, viscous, surface, and stress phenomena as it pertains to fluid flow applications.		
3.3.1/3	Students will be able to use the mechanical energy balance equation to solve fluid flow problems both with and without friction.		