# AC 2012-4388: A NEW ASSESSMENT METHOD TO EASILY IDENTIFY AREAS NEEDING IMPROVEMENT IN COURSE-LEVEL LEARNING OUTCOMES

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Thomas Knotts became a faculty member in the Department of Chemical Engineering at Brigham Young University in 2006 after receiving his Ph.D. from the University of Wisconsin, Madison. He teaches a variety of courses, including thermodynamics, computer tools, unit operations lab, and molecular modeling. He enjoys teaching and discovering ways to improve student learning through problem-based and inductive learning strategies. With his research group, Knotts seeks to understand the physics of proteins and DNA at the molecular level with particular emphasis on the behavior of these molecules in "non-native" environments such as those often found in biotechnology. His research efforts have earned him the NSF CAREER Award and the Young Faculty Award from the Defense Advanced Research Projects Agency (DARPA). As part of his research efforts, Knotts creates outreach programs to help teachers improve K-12 STEM education.

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William G. Pitt received a Ph.D. in chemical engineering in 1987 from the University of Wisconsin, Madison. He obtained a faculty position at Brigham Young University in the Chemical Engineering Department, where he has served since 1987. He is currently the Pope Professor of chemical engineering at BYU, and is an Adjunct Research Professor in the Bioengineering Department of the University of Utah. During his 24 years at BYU, his teaching has been in the areas of materials, polymers, and transport phenomena. His research has spanned many disciplines, ranging from biomedical material surfaces and composite materials to his current work in controlled drug and gene delivery. With colleagues and students at BYU and other institutions, he has more than 110 peer-reviewed journal publications.

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# A New Assessment Method to Easily Identify Areas Needing Improvement in Course-level Learning Outcomes

## Introduction

Assessment of student proficiency in expected outcomes, whether on the course or program level, is an important aspect of curriculum development in engineering programs. The reasons for such assessment range from desires to improve student learning to fulfilling requirements of various accreditation bodies. But regardless of the reasons, the challenge is to develop suitable metrics that can clearly identify areas that need improvement.

In order to assess student learning, the Department of Chemical Engineering at Brigham Young University has outlined multiple objectives, termed *competencies*, for each required course in the curriculum. Each competency was designed to correspond to a specific Program Outcome such that assessment of mastery of the course competencies demonstrates achievement of the Program Outcomes. For several years, mastery of the competencies has been measured using surveys of both faculty and students. The student surveys required each pupil to assess his or her mastery of each competency on a scale of 1-5. Though this approach has provided a numerical evaluation of the students' perceived abilities of each class as a whole, and has ensured minimum standards are kept, it has proven difficult to glean opportunities for specific improvement from these data, and changes to the curriculum have been largely prompted by the faculty surveys.

In an effort to improve the student surveys, a pilot study was completed in which changes were made to the evaluation procedure for two courses in the curriculum: Chemical Engineering Thermodynamics and Plant Design. The numerical rating was removed and replaced with a simple yes/no question asking if the student felt proficient in each competency. In addition, the students were asked to select two of the competencies in which they felt weakest and explain the reason for the weakness.

These simple adjustments greatly increased the effectiveness of the student surveys with no additional overhead cost. The data readily identify competencies that are problematic for students *and* (more importantly) the reasons for the struggles. This allows precise plans to be made to improve student learning the next time the course is taught.

This paper will explain this new assessment process in detail. To illustrate the value of the new procedures, the results of the new method will be compared with those of the traditional method (numerical 1-5 scale). Emphasis will be placed on showing how the new method not only provides better data, but does so in a time-efficient manner and makes "closing-the-loop" easier.

The remainder of this paper is organized as follows. First, the traditional method of assessment of the competencies will be explained in more detail and the historical results will be presented. This will be followed by an explanation of the changes that were made for the Winter 2011 semester and the results. Taken as a whole, the results show significant promise in improving the assessment process.

**Explanation of course competencies**

Each course in the chemical engineering curriculum is designed to teach students specific competencies which are directly related to program outcomes. For example, Program Outcome #3 states students will have "An ability to apply knowledge of chemical engineering fundamentals." Multiple courses and multiple competencies contribute this is outcome. For example, Competency 3.1.5—"Students will be able to read mixture phase diagrams (solid solubility, liquid-liquid, VLE) and construct mass balances from them using the lever rule, tie lines, etc."—is found in four different courses: Mass and Energy Balances (sophomore), Material Science (junior), Thermodynamics (junior), and Heat and Mass Transfer (junior). Competency 3.6.1—"Students will understand fundamentals of kinetics including definitions of rate and forms of rate expressions."—is found in three different courses: Introduction to Chemical Engineering (freshman), Chemical Reaction Engineering (junior), and Unit Operations Lab (senior). The competencies are numbered such that the first numeral identifies the related Program Outcome. Over 140 competencies are found in the curriculum to cover the 12 Program Outcomes.

**Traditional assessment method**

Assessment of student proficiency in each competency is done in each course every semester/term by both students and faculty. The faculty portion consists of two parts and the first part (Figure 1) has two sections. The first section contains a few simple questions for an instructor to consider as he/she assesses how well the competencies were addressed and helps identify areas for concern. The second section asks the instructor to give recommendations to improve the course and requires a description of specific actions taken in response to items identified from previous assessment/evaluation. This is done to ensure that the assessment, evaluation, action, reassessment loop is complete and functioning properly.

Instructor: ___________________ Course: __________________ Semester: __________

**Chemical Engineering Course Assessment Form**

Y N 1. Were student competencies included in the course syllabus?

Y N 2. Were all competencies addressed? Please add explanation if "No".

Y N 3. Is there a need to update, revise, or add to the competencies? Please explain if "Yes".

Y N 4. Are there competencies in which students are particularly weak? Explain if "Yes".

Y N 5. Are there competencies in which students are particularly strong? Explain if "Yes".

___________________________Additional Input _______________________________

A. You were provided a list of action items based on review of last year's assessment. Please comment (and provide assessment details if appropriate) on your response/action to each item assigned to you. Action items are listed under course AND curriculum sections.

B. Please identify future recommendations for the course and/or recommendations for the curriculum that will help strengthen the course competencies.

Updated 11/07

**Figure 1** Summary Faculty Evaluation Form Part 1

The second part of the course assessment form for faculty asks the instructor to evaluate the students in regard to each of the competencies for a given course. A blank copy of this part of the form for ChEn 373, Chemical Engineering Thermodynamics, is shown in Figure 2 and Figure 3. The faculty member is asked to rate the student mastery of each of the course competencies on a 5-point scale and to specify the method of assessment (e.g. homework, quiz, final exam, etc.) One purpose of this form is to provide a direct assessment of each competency. Thus, instructors are also asked to give numerical evidence for their raking. In general, a score of 90% and above on an assessment activity is considered "excellent," 80%-90% is considered "very good" etc. So if the first question of the second exam in the semester focused on competency 3.1.2, and the class average on that problem was 87%, an instructor would likely give a ranking on the order of 4.

**Faculty Evaluation**

**ChEn 373** **Instructor:** ________________ **Semester:** ________________

*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.*

| | |
|---|---|
| 0-none | 3-good |
| 1-poor | 4-very good |
| 2-fair | 5-excellent |

| Competency | Expectation | Proficiency | Assessment Method |
|---|---|---|---|
| 3/ 1.2/ | Students will be able to solve steady-state, overall, material and energy balances for systems which include one or more of the following: recycle, multiple units, chemical reactions. | | |
| 3/ 1.5/ | Students will be able to read mixture phase diagrams (Mollier diagram, liquid-liquid, VLE, pressure-enthalpy diagram) and construct mass and energy balances from them using the lever rule, tie lines, etc. | | |
| 3/ 1.6/ | Students will be able to set up and solve simple transient energy balances. | | |
| 3/ 2.1/ | Students will understand the phase behavior of pure substances in relationship to the variables T, P, and density (including vapor pressure, critical point, freezing line, triple point, etc.) | | |
| 3/ 7.1/ | Students will be able to apply the first law of thermodynamics to closed and open systems (including energy, work, and heat transformations in process units such as tanks, turbines, compressors, valves, etc.). | | |
| 3/ 7.2/ | Students will be able to apply solution thermodynamics fundamentals to solve VLE, LLE, SLE, and GLE problems including bubble point, dew point and flash calculations. | | |
| 3/ 7.3/ | Students will understand the fundamental principles of chemical reaction equilibria including extent of reaction, equilibrium constant and its temperature-dependence, equilibrium conversion. | | |
| 3/ 7.4/ | Students will be able to use equations of state and corresponding states correlations in the determination of properties. | | |
| 3/ 7.5/ | Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation. | | |
| 3/ 7.6/ | Students will understand the concept of entropy and the second law of thermodynamics and be able to apply the second law to closed and open systems. | | |

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**Figure 2** Page 1 of Faculty Evaluation Form Part 2 for ChEn 373 (Thermodynamics).

**Faculty Evaluation**

**ChEn 373** **Instructor:** ______________ **Semester:** ______________

*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.*

| | |
|---|---|
| 0-none | 3-good |
| 1-poor | 4-very good |
| 2-fair | 5-excellent |

| Competency | Expectation | Proficiency | Assessment Method |
|---|---|---|---|
| 3/ 7.7/ | Students will understand the fundamental concepts of solution thermodynamics including chemical potential, fugacity, activity, partial molar properties, ideal solutions, and excess properties. | | |
| 5/ 5./ | Students will be able to use modern property databases to assist in problem solving. | | |
| 6/ 1./ | Students will demonstrate an ability to solve engineering problems. | | |
| 6/ 4./ | Students will exhibit critical and creative thinking skills for analysis and evaluation of problems and cause-effect relationships. | | |
| 6/ 6./ | Students will be able to rationalize units, make order of magnitude estimates, assess reasonableness of solutions, and select appropriate levels of solution sophistication. | | |
| 7/ 2./ | Students will understand and have a basic knowledge of how safety considerations are incorporated into engineering problem solving. | | |
| 7/ 4./ | Students will understand and have a basic knowledge of how environmental considerations are incorporated into engineering problem solving. | | |
| 10/ 4.2/ | Students will be able to set up and solve single-stage flash calculations. | | |
| 10/ 6.1/ | Students will be able to perform design (sizing) calculations for turbines and compressors (e.g., involving delta H, delta S, work, heat, efficiencies). | | |
| 10/ 6.2/ | Students will be able to perform energy conversion calculations for Rankine power and compression refrigeration cycles. | | |

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**Figure 3** Page 2 of Faculty Evaluation Form Part 2 for ChEn 373 (Thermodynamics).

The student portion of the assessment is very similar to the second part of the instructor assessment. The rating form (Figure 4 and Figure 5) asks them to do a self assessment and rate their mastery in each of the competencies. The student form may sometimes differ slightly from the instructor form in the exact competencies assessed because the student forms only focus on core competencies for the course and not those that may be review or introductory. The students are also asked to rate how well that particular *course* has helped develop their proficiency.

## Student Evaluation

## ChEn 373

*Instructions: In the column marked "Course" rate the course on its contribution to developing the expectation shown for the listed comptency. 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 | Expectation | Course | Self |
|---|---|---|---|
| 3/ 1.2/ | Students will be able to solve steady-state, overall, material and energy balances for systems which include one or more of the following: recycle, multiple units, chemical reactions. | | |
| 3/ 1.5/ | Students will be able to read mixture phase diagrams (Mollier diagram, liquid-liquid, VLE, pressure-enthalpy diagram) and construct mass and energy balances from them using the lever rule, tie lines, etc. | | |
| 3/ 1.6/ | Students will be able to set up and solve simple transient energy balances. | | |
| 3/ 2.1/ | Students will understand the phase behavior of pure substances in relationship to the variables T, P, and density (including vapor pressure, critical point, freezing line, triple point, etc.) | | |
| 3/ 7.1/ | Students will be able to apply the first law of thermodynamics to closed and open systems (including energy, work, and heat transformations in process units such as tanks, turbines, compressors, valves, etc.). | | |
| 3/ 7.2/ | Students will be able to apply solution thermodynamics fundamentals to solve VLE, LLE, SLE, and GLE problems including bubble point, dew point and flash calculations. | | |
| 3/ 7.3/ | Students will understand the fundamental principles of chemical reaction equilibria including extent of reaction, equilibrium constant and its temperature-dependence, equilibrium conversion. | | |
| 3/ 7.4/ | Students will be able to use equations of state and corresponding states correlations in the determination of properties. | | |
| 3/ 7.5/ | Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation. | | |
| 3/ 7.6/ | Students will understand the concept of entropy and the second law of thermodynamics and be able to apply the second law to closed and open systems. | | |

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**Figure 4** Page 1 of Student Evaluation Form for ChEn 373 (Thermodynamics).

**Student Evaluation**

**ChEn 373**

*Instructions: In the column marked "Course" rate the course on its contribution to developing the expectation shown for the listed comptency. 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 | Expectation | Course | Self |
|---|---|---|---|
| 3/ 7.7/ | Students will understand the fundamental concepts of solution thermodynamics including chemical potential, fugacity, activity, partial molar properties, ideal solutions, and excess properties. | | |
| 10/ 4.2/ | Students will be able to set up and solve single-stage flash calculations. | | |
| 10/ 6.1/ | Students will be able to perform design (sizing) calculations for turbines and compressors (e.g., involving delta H, delta S, work, heat, efficiencies). | | |
| 10/ 6.2/ | Students will be able to perform energy conversion calculations for Rankine power and compression refrigeration cycles. | | |

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**Figure 5** Page 2 of Student Evaluation Form for ChEn 373 (Thermodynamics).

At the end of each semester, all the assessments for every course are gathered, entered into a database, and evaluated by the department Undergraduate Committee. The numerical assessments by both the faculty and the students are placed in a table to facilitate the evaluation. Table 1 depicts this sheet for the course assessment for Fall 2007. The first part of the semester evaluation is to identify any competencies with an average rating of less than 3 (good). Reasons for the low ratings are discussed and any corrective actions are determined. Second, the Undergraduate Committee reads and discusses any comments returned on Part 1 of the Instructor evaluation form (see Figure 1). Third, the assignments for improvement made from the previous evaluation are reviewed and discussed to determine if further action is needed. The result is a list of action items for each course based upon student ratings, instructor ratings, instructor comments, and previous evaluations. These action items are then distributed to each faculty member for implementation when the course is next taught.

**Table 1** Summary of numerical assessment of competencies for courses taught in the Fall 2007 semester.

## Fall 2007 Assessment

| | Course | Self | Professor |
|---|---|---|---|
| **ChEn 170 Rasband** | | | |
| 1/1/3/M | 3.83 | 3.51 | 4.00 |
| 1/2/2/P | | | 3.00 |
| 3/1.1//3/M | 4.18 | 3.79 | 3.00 |
| 3/1.2/3/M | 4.33 | 3.85 | 4.00 |
| 3/3.1/3/M | 4.04 | 3.48 | 3.00 |
| 3/4.1/3/I | | | 4.00 |
| 3/6.1/3/I | | | 3.00 |
| 3/7.1/3/I | | | 3.00 |
| 3/8.1/2/I | | | 4.00 |
| 5/2/2/I | | | 5.00 |
| 6/1/3/P | | | 4.00 |
| 6/2/2/M | 3.71 | 3.38 | 4.00 |
| 6/4/2/P | | | 3.00 |
| 6/6/2/P | | | 3.00 |
| 7/2/2/M | 3.57 | 3.30 | 3.00 |
| 7/5/2/M | 3.15 | 3.27 | 3.00 |
| 9/1/2/M | 3.88 | 3.78 | 5.00 |
| 9/2/2/M | 4.00 | 3.86 | 5.00 |
| 10/1.1/3/I | | | 3.00 |
| 10/2.1/3/M | 3.77 | 3.43 | 4.00 |
| 10/3.1/3/I | | | 3.00 |
| 10/7.3/2/I | | | 2.00 |
| 10/8.2/2/I | | | 3.00 |
| 11/4/2/I | | | 5.00 |
| **ChEn 263 TAK** | | | |
| 2/1/2/M | 4.18 | 3.98 | 4.50 |
| 3/1.1/3/M | 4.66 | 4.47 | 5.00 |
| 5/2/2/M | 4.21 | 3.81 | 4.00 |
| 5/3/2/M | 4.56 | 4.19 | 5.00 |
| 5/4/2/M | 3.82 | 3.23 | 4.00 |
| 6/1/3/P | | | 5.00 |
| 6/2/2/M | 3.76 | 3.31 | 4.00 |
| 6/6/2/M | 3.82 | 3.63 | 3.50 |
| **ChEn 374 KAS** | | | |
| 3/2.4/2/M | 4.25 | 3.79 | 3.00 |
| 3/3.1/3/M | 4.92 | 4.69 | 3.90 |
| 3/3.2/3/M | 4.69 | 4.31 | 4.00 |
| 3/3.3/2/M | 4.69 | 4.46 | 4.00 |
| 3/3.4/2/M | 4.21 | 3.81 | 3.50 |
| 3/3.8/2/M | 4.29 | 3.87 | 4.10 |
| 6/1/3/P | | | 4.00 |
| 6/4/2/P | | | 3.50 |
| 6/6/2/P | | | 3.00 |
| 7/2/2/R | | | 3.00 |
| 7/5/2/M | 3.73 | 3.73 | 4.10 |
| 10/3.1/3/M | 4.46 | 4.12 | 4.30 |
| 10/3.2/2/M | 4.19 | 3.71 | 4.30 |
| 10/3.3/2/M | 3.81 | 3.33 | 4.60 |
| **ChEn 291 KAS** | | | |
| 1/1/3/P | | | 4.00 |
| 12/1/2/P | | | 3.00 |
| 12/2/2/P | | | 3.50 |
| **ChEn 378 WGP** | | | |
| 3/1.5/2/M | 4.40 | 4.57 | 5.00 |
| 3/2.2/2/M | 3.73 | 3.57 | 4.00 |
| 3/2.3/2/M | 4.30 | 3.93 | 4.00 |
| 3/2.4/2/M | 4.17 | 3.93 | 4.00 |
| 3/2.5/2/M | 4.03 | 3.77 | 4.00 |
| 3/2.7/2/M | 3.60 | 3.30 | 5.00 |
| 6/1/3/P | | | 4.00 |
| 6/4/5/P | | | 3.00 |
| 6/6/2/P | | | 4.00 |
| **ChEn 391 THF** | | | |
| 1/2/2/M | 3.81 | 3.88 | 4.00 |
| 8/1/2/M | 4.75 | 4.56 | 5.00 |
| 8/2/2/M | 4.81 | 4.75 | 4.00 |
| 11/4/2/P | | | 4.00 |
| 12/2/2/M | 4.63 | 4.69 | 4.00 |
| **ChEn 391 HBH** | | | |
| 1/2/2/M | 4.00 | 3.71 | 4.00 |
| 8/1/2/M | 4.43 | 4.14 | 5.00 |
| 8/2/2/M | 4.43 | 4.36 | 5.00 |
| 11/4/2/P | | | 4.00 |
| 12/2/2/M | 4.29 | 4.36 | 5.00 |
| **ChEn 391 DRW** | | | |
| 1/2/2/M | 3.82 | 3.45 | 4.00 |
| 8/1/2/M | 4.64 | 4.00 | 5.00 |
| 8/2/2/M | 4.45 | 4.00 | 4.00 |
| 11/4/2/P | | | 4.00 |
| 12/2/2/M | 4.09 | 4.27 | 3.00 |
| **ChEn 436 RLR** | | | |
| 1/2/2/P | | | 3.50 |
| 3/1.3/2/M | 4.39 | 4.33 | 4.50 |
| 3/1.6/2/M | 4.26 | 3.98 | 4.20 |
| 3/8.1/2/M | 4.46 | 4.07 | 4.50 |
| 3/8.2/2/M | 4.26 | 3.91 | 4.00 |
| 3/8.3/2/M | 4.26 | 4.11 | 5.00 |
| 3/8.4/2/M | 4.47 | 4.19 | 4.00 |
| 3/8.5/2/M | 4.16 | 3.88 | 3.50 |
| 3/8.6/2/M | 4.32 | 4.05 | 3.50 |
| 3/8.7/2/M | 4.37 | 4.04 | 4.80 |
| 4/1./2/M | 3.56 | 3.42 | 3.00 |
| 4/4/2/M | 3.65 | 3.51 | 3.50 |
| 5/1.4/2/M | 4.07 | 3.93 | 4.00 |
| 6/1/3/P | | | 3.80 |
| 6/4/2/P | | | 3.50 |
| 6/6/2/P | | | 3.00 |
| 7/2/2/P | | | 4.00 |
| 10/3.2/2/M | 3.60 | 3.23 | 3.80 |
| 10/5.1/3/M | 4.35 | 4.25 | 4.00 |
| 10/5.2/2/M | 4.32 | 4.14 | 4.00 |
| 10/5.3/2/M | 3.46 | 3.08 | 3.00 |
| **ChEn 311 WCH** | | | |
| 6/4/2/P | | | 3.00 |
| 6/6/2/P | | | 4.00 |
| 7/1/3/M | 4.23 | 4.44 | 5.00 |
| 7/2/2/M | 4.02 | 4.31 | 4.00 |
| 7/4/2/M | 3.85 | 3.92 | 4.00 |
| 7/5/2/M | 3.60 | 3.83 | 4.00 |
| 9/1/2/M | 3.65 | 4.19 | 4.00 |
| 9/2/2/M | 3.83 | 4.25 | 4.00 |
| 10/7.2/2/M | 3.77 | 3.79 | 4.00 |
| 11/1/3/P | | | 5.00 |
| 11/2/2/M | 4.33 | 4.40 | 5.00 |
| 11/3/2/P | | | 4.00 |
| 11/4/2/P | | | 4.00 |
| 12/5/2/P | | | 3.00 |
| **ChEn 475 RSL** | | | |
| 1/2/2/M | 3.90 | 4.14 | 5.00 |
| 3/3.2/3/R | | | 5.00 |
| 3/4.1/3/R | | | 4.00 |
| 3/4.2/3/R | | | 4.00 |
| 3/4.3/3/M | 4.10 | 4.10 | 4.00 |
| 4/1/2/M | 4.38 | 4.14 | 5.00 |
| 4/2/2/M | 3.86 | 4.00 | 5.00 |
| 4/3/2/M | 3.43 | 4.05 | 4.50 |
| 4/4/2/R | | | 5.00 |
| 4/7/2/M | 2.76 | 2.86 | |
| 6/1/3/P | | | 4.00 |
| 6/3/2/M | 4.29 | 4.19 | 5.00 |
| 6/4/2/P | | | 5.00 |
| 6/5/2/P | | | 4.50 |
| 6/6/2/P | | | 5.00 |
| 7/1/3/M | 3.81 | 4.29 | 5.00 |
| 8/1/2/R | | | 5.00 |
| 8/2/2/M | 3.86 | 4.00 | 4.50 |
| 9/2/2/M | 4.00 | 4.43 | 5.00 |
| 10/3.1/3/R | | | 5.00 |
| **ChEn 475 Giles** | | | |
| 1/2/2/M | 4.04 | 3.61 | 4.00 |
| 3/3.2/3/R | | | 4.00 |
| 3/4.1/3/R | | | 4.00 |
| 3/4.2/3/R | | | 4.00 |
| 3/4.3/3/M | 3.91 | 3.87 | 4.00 |
| 4/1/2/M | 4.39 | 4.13 | 5.00 |
| 4/2/2/M | 4.13 | 4.26 | 4.00 |
| 4/3/2/M | 3.91 | 3.65 | 4.00 |
| 4/4/2/R | | | 4.00 |
| 4/7/2/M | 3.26 | 2.52 | 3.00 |
| 6/1/3/P | | | 4.00 |
| 6/3/2/M | 4.48 | 4.22 | 5.00 |
| 6/4/2/P | | | 4.00 |
| 6/5/2/P | | | 4.00 |
| 6/6/2/P | | | 3.00 |
| 7/1/3/M | 3.35 | 3.91 | 4.00 |
| 8/1/2/R | | | 5.00 |
| 8/2/2/M | | | 4.00 |
| 9/2/2/M | 4.17 | 4.13 | 4.00 |
| 10/3.1/3/R | 4.22 | 4.04 | 4.00 |
| **ChEn 476 WVW** | | | |
| 3/1.2/3/M | 4.23 | 3.88 | 4.43 |
| 3/1.5/2/M | 4.32 | 4.39 | 4.87 |
| 3/5.2/3/M | 3.54 | 3.20 | 3.99 |
| 3/7.2/3/M | 4.18 | 3.88 | 4.00 |
| 3/7.7/2/R | | | 3.77 |
| 5/1.2/2/M | 3.30 | 3.14 | 3.50 |
| 6/1/3/P | | | 4.25 |
| 6/3/2/M | | | 3.50 |
| 6/4/2/P | | | 3.90 |
| 6/6/2/P | | | 3.50 |
| 7/2/2/R | | | 4.00 |
| 10/4.1/2/M | 4.29 | 3.88 | 4.54 |
| 10/4.2/3/M | 4.18 | 3.96 | 4.54 |
| 10/4.3/2/M | 4.07 | 3.68 | 3.91 |
| 10/4.4/2/M | 3.68 | 3.11 | 3.56 |
| 10/4.7/2/M | 4.29 | 3.96 | 3.94 |

Figure 6 displays a sample of the document that was distributed to the faculty following the evaluation of Fall 2007 assessments. One notable feature that Figure 6 demonstrates is the "closing the loop" nature of our education and assessment plan. The cycle of assessment, evaluation, action, reassessment, reevaluation, additional action is built right into the plan resulting in real and documented improvement.

**Fall 2007 Course and Curriculum Assessment Review**
**March 2008**

*Curriculum:*

1. Feedback Loop: Coordinated TA's in CAEDM lab with ChEn 170, 436, and 476 based on last year's assessment. The faculty were not enthusiastic. Students did not appear to benefit from this coordination since they used other facilities (such as the UO Lab). It is recommended that this coordination is no longer needed.
2. Feedback loop: Interviewing trips. It was reported in Fall 2006 assessments that ChEn 436 students were distracted from interviewing trips- coursework stopped. Pile-up of projects at end of semester for multiple classes was also noted. Projects and exams were better coordinated this past year among classes. ChEn 436 introduced more flexibility. There were still problems with one section of ChEn 475 but not with another section. Project and exam coordination will continue. **Responsible faculty: [Name removed]**

*ChEn 170:*

1. Unit conversions are still a problem. This was observed in the previous year's assessment. The instructor plans on developing practice problems to help. Please follow up with assessment.

*ChEn 263:*

1. Feedback loop: VBA instruction. As suggested from last year, a reduced amount of time was spent on Excel and two lectures of VBA were added (along with a project). Students were more capable this year (92% was average score on project). Continue with the added VBA lectures
2. There was some concern that programming may not be needed and that we should re-evaluate the computer tools used. Students frequently complain that they don't use the programming in this class during later classes. [Name removed] will form a committee to address this issue. [Name removed] will chair the committee.

*ChEn 378:*

**Figure 6** Sample Summary Sheet From Fall 2007 Course Assessments for Evaluation

**Analysis of the historical method of assessment**

The assessment procedures outlined in the previous sections have provided hundreds of opportunities to improve the chemical engineering program at Brigham Young University over the last several years; however, a recent review of the process by the Undergraduate Committee revealed that not all parts of the assessment were equally useful in this regard. Specifically, the numerical ratings by both the faculty and the students, as summarized in Table 1, are a rather blunt instrument for assessment and do not yield many insights into student learning.

The data in Figure 7 - Figure 12 help illustrate the reasons for this lack of effectiveness of the numerical data. Depicted are the historical performances for six different competencies as rated by the instructor and by the students (for both *Course* and *Self*) since 2001. Only one section of the courses represented in Figure 7 through Figure 10 is taught in a Fall/Winter sequence. Multiple sections (taught by different instructors) of the course depicted in Figure 12 are taught in a Fall/Winter sequence and data for each section are shown. To facilitate understanding of these data, the sections belonging to the same semester are shaded, and the shading is alternated each year in Figure 12.

One of the features readily apparent from the data is that the students rarely report poor performance for any competency. This same trend is true for all competencies in the curriculum including those not depicted for sake of conciseness. The average rating for both the *Self* and the *Course* evaluations falls above and below 4 but rarely dips below 3. Since 2001, fewer than 10 competencies in total (from all courses in all semesters) received an average rating of less than 3. Because the criterion for identifying problems based upon these data is a rating of less than 3, the numerical portion of the assessment process has rarely prompted any improvements to the curriculum or student learning.

Figure 8 shows another reason why the numerical results are a blunt instrument for assessment. Notice the step-change in performance on Competency 10.2.1. During the first three years (2001 – 2003), the *Self* and *Course* ratings by the students hovered below 4. From 2004 on, these ratings were consistently above 4. It would be advantageous, from "closing-the-loop" and student-learning perspectives, to determine what prompted this increase in understanding. However, the data do not provide this insight.

Another feature of the data, that is hard to interpret or use for continuous improvement is the difference between the student and instructor ratings. This discrepancy is present multiple times in the data shown, but is distinctly found in Figure 11 (Competency 10.7.3). For this competency—which concerns understanding the influence of environmental, social, political, ethical, health and safety, manufacturability, and sustainability constraints on engineering solutions—the student rating is approximately 3 while the instructor rating is almost 4.5 in the Winter 2003 semester. While the degree of separation diminishes in subsequent semesters, the student ratings continue to be lower than the instructor ratings up to the present time. Such discrepancies are also observed in Figure 7 around 2003 and 2004, Figure 8 around 2006, and in

Figure 12 in 2005 and 2009. These instances reveal that student and instructor perceptions of student learning are often different, but they do not provide the insights into the reason for such differences or how to correct them.

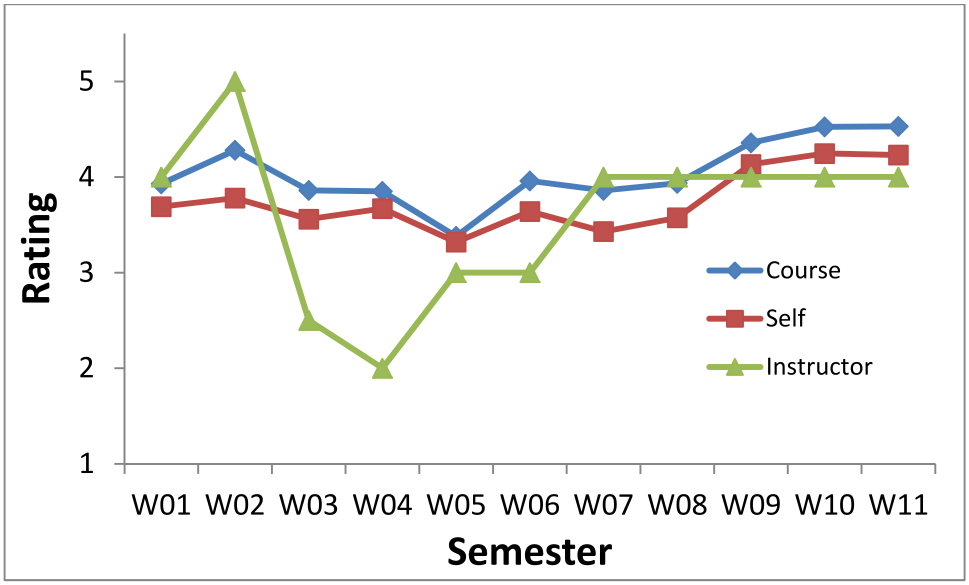


**Figure 7** Historical Performance of Competency 3.1.5—*Students will be able to read pure component and mixture phase diagrams (e.g. psychrometric chart, Mollier diagram, solid solubility, liquid-liquid, VLE, pressure-enthalpy diagram) and construct mass and energy balances from them using the lever rule, tie lines, etc.*

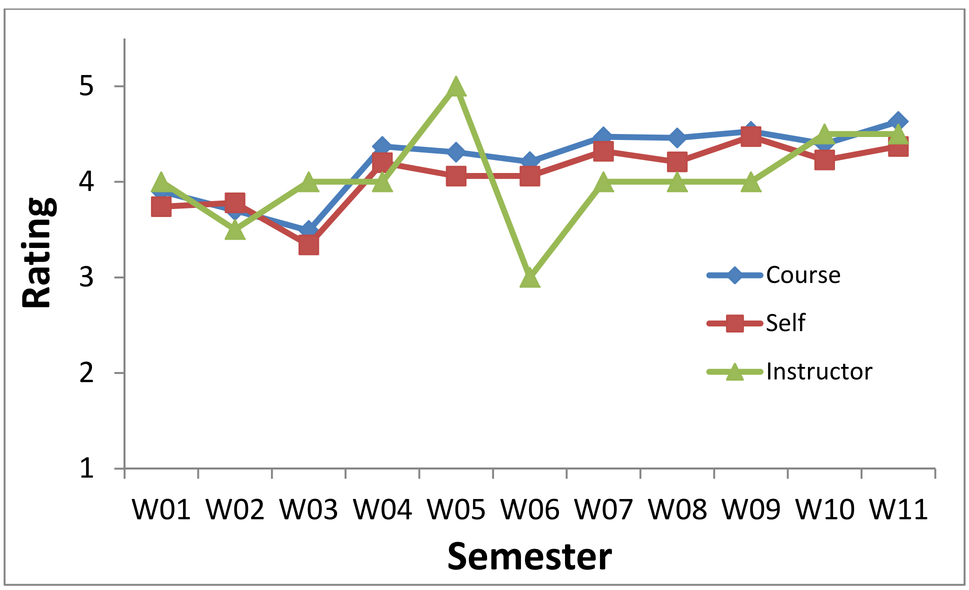


**Figure 8** Historical Performance of Competency 10.2.1—*Students will be able to do preliminary size calculations on shell-and-tube heat exchangers using the log-mean-temperature-difference (LMTD) method.*

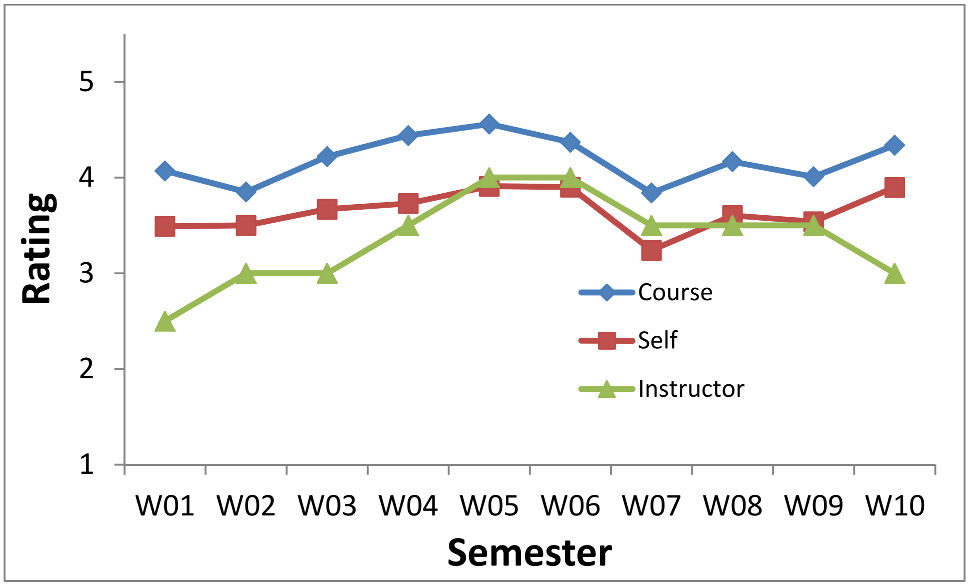


**Figure 9** Historical Performance of Competency 10.2.1—*Students will understand the concept of entropy and the second law of thermodynamics and be able to apply the second law to closed and open systems.*

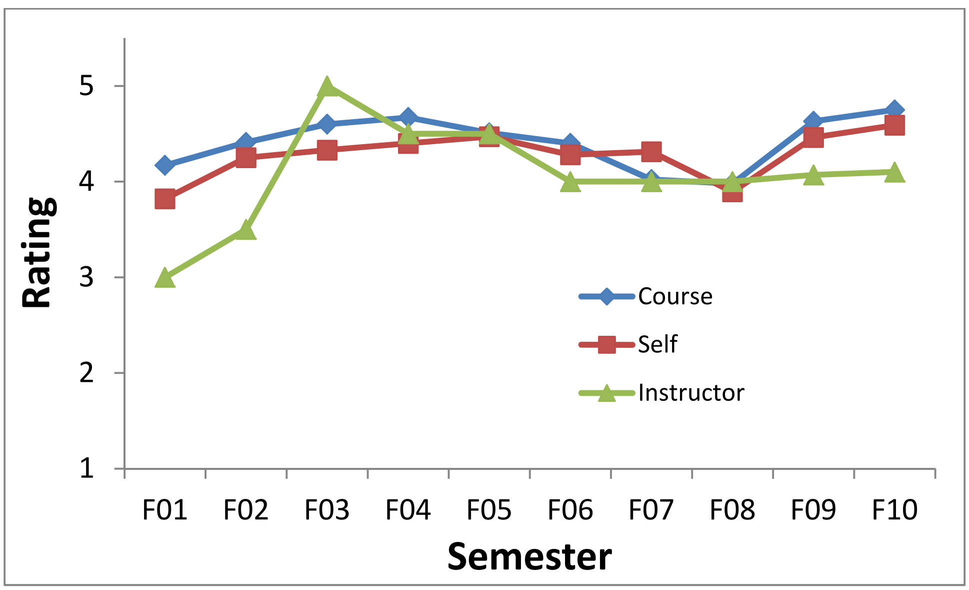


**Figure 10** Historical Performance of Competency 7.2—*Students will be dedicated to safe engineering practices; demonstrate knowledge of pertinent safety laws and regulations; understand and have a basic knowledge of how safety considerations are incorporated into engineering problem solving.*

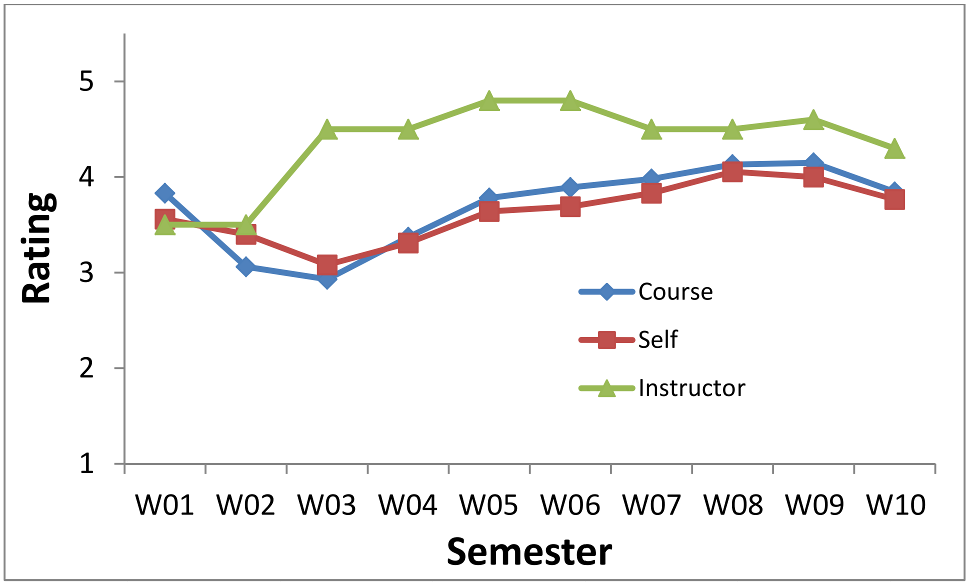


**Figure 11** Historical Performance of Competency 10.7.3—*Students will understand environmental, social, political, ethical, health and safety, manufacturability, and sustainability constraints and be able to incorporate these into process synthesis.*

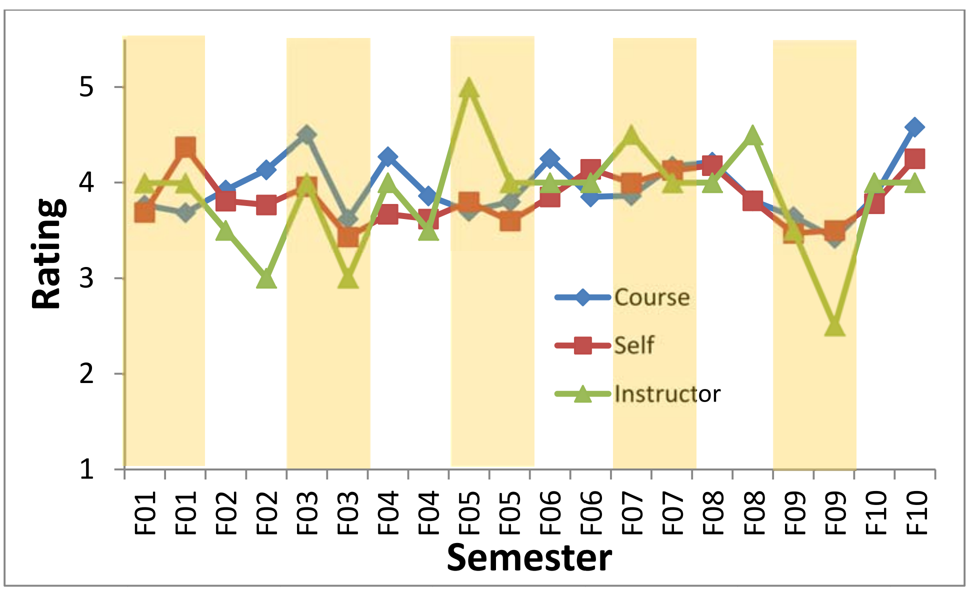


**Figure 12** Historical Performance of Competency 8.2—*Students will be able to write effective, well organized technical reports, including formal engineering reports and short letter reports.*

As mentioned previously, there have been times when the numerical assessments have proven useful at identifying problem areas (competencies with an average rating below 3). This usually occurs during semesters when a new instructor is assigned to the course. In this manner, numerical data are effective at ensuring that minimum standards are met and at proscribing a remedy before the problem becomes too great. However, because the data do not reveal “why” the competency was rated poorly, the Undergraduate Committee is severely limited in its ability to analyze the data. Due to this deficiency, the recommendation from the committee is usually a general statement requesting the instructor to emphasize the competency in question the next time the course is taught, rather than specific ideas for improvement.

**The new assessment method**

Last year, the Undergraduate Committee initiated an effort to evaluate if this weakness in the assessment process could be strengthened. Upon reflection, almost all curricular changes suggested and undertaken in the department, in regard to course enhancements, were recognized to come from Part 1 of the instructor assessment (See Figure 1) rather than the numerical ratings obtained from the student assessments or Part 2 of the instructor assessment. Part 1 is filled out by the instructor, where a portion of this form requires the instructor to identify strengths and weaknesses of the students based upon direct assessment. Requiring each instructor to evaluate the performance of each course each semester generates a tremendous amount of ideas to improve the curriculum in a manner that the numerical data, from either the instructor or the students, never does.

The reason why Part 1 generates so many specific recommendations is that the numerical instructor ratings (Part 2) are placed in context by the written comments (Part 1). This provides significant advantages over the student ratings. Specifically, Part 1 of the form requires the instructor to provide the *reasons* for any competencies deemed weak. This, by construction, includes any competency rated <3, but it also allows the instructor to list weaknesses that might not be rated below “good,” but could still be improved upon. The written comments allow flexibility not offered by the numerical data and allow the instructor to take ownership of the course and look for ways to improve student learning. The numerical student ratings do not include a portion that allows the students to explain the reasons for any competency marked as weak. Thus, interpretation of these data is difficult.

Upon recognizing the deficiency in the student portion of the course assessments, the Undergraduate Committee sought to change the assessment process to capture the advantages found in the instructor assessment. The solution was to create a “two-part” student assessment process. Because of time constraints, the student version could not simply mimic the instructor process. The students need to be able to complete the forms in a few minutes during one of the last days of the class. The instructors have the luxury of taking time and analyzing the performance of the class when giving their assessment. Therefore, a new approach was taken.

First, the numerical form was simplified. Rather than requiring the students to rate *Self* and *Course* on a scale of 1-5, the students were given one simple question asking if he/she felt proficient in each competency. The students are only allowed to answer yes or no. Removing a 5-point scale and replacing it with a yes/no evaluation eliminates much of the source of the variableness in the assessment. There is still a judgment-call that must be made, but the degree of judgment is reduced for the yes/no case compared with the numerical scale case. Figure 1 shows the first page of the new form for ChEn 373 (Thermodynamics).

**Student Evaluation**
**ChEn 373**
*Instructions: Indicate below whether you feel proficient in each competency*

| Competency | Expectation | Yes | No |
|---|---|---|---|
| 3/ 1.2/ 3/ M | Students will be able to solve steady-state, overall, material and energy balances for systems which include one or more of the following: recycle, multiple units, chemical reactions. | | |
| 3/ 1.5/ 2/ M | Students will be able to read mixture phase diagrams (Mollier diagram, liquid-liquid, VLE, pressure-enthalpy diagram) and construct mass and energy balances from them using the lever rule, tie lines, etc. | | |
| 3/ 1.6/ 2/ M | Students will be able to set up and solve simple transient energy balances. | | |
| 3/ 2.1/ 3/ M | Students will understand the phase behavior of pure substances in relationship to the variables T, P, and density (including vapor pressure, critical point, freezing line, triple point, etc.) | | |
| 3/ 7.1/ 3/ M | Students will be able to apply the first law of thermodynamics to closed and open systems (including energy, work, and heat transformations in process units such as tanks, turbines, compressors, valves, etc.). | | |
| 3/ 7.2/ 3/ M | Students will be able to apply solution thermodynamics fundamentals to solve VLE, LLE, SLE, and GLE problems including bubble point, dew point and flash calculations. | | |
| 3/ 7.3/ 3/ M | Students will understand the fundamental principles of chemical reaction equilibria including extent of reaction, equilibrium constant and its temperature-dependence, equilibrium conversion. | | |
| 3/ 7.4/ 2/ M | Students will be able to use equations of state and corresponding states correlations in the determination of properties. | | |
| 3/ 7.5/ 2/ M | Students will understand and be able to apply the concepts of heat capacity, latent heat, heat of reaction, heat of combustion, and heat of formation. | | |
| 3/ 7.6/ 2/ M | Students will understand the concept of entropy and the second law of thermodynamics and be able to apply the second law to closed and open systems. | | |

*Thursday, January 05, 2012* *Page 1 of 2*

**Figure 13** Page 1 of Part 1 of the New Student Evaluation Form for ChEn 373 (Thermodynamics).

To augment the yes/no responses received by the students, and to help interpret the data, a second section was added to the assessment. In this part, depicted in Figure 14, the students were asked the following questions:

1. List two of the course competencies in which you feel particularly strong.
2. List two competencies in which you feel weakest and explain how the course could improve the instruction in this area. (These are likely competencies in which you indicated that you were not proficient on the accompanying form.)

Instructor: ___________________ Course: __________________ Semester: __________

**Chemical Engineering Course Assessment Form**
***This form is to be completed by the Student***
***at the end of each semester.***

1. List two of the competencies in which you feel particularly strong.

2. List two competencies in which you feel weakest and explain how the course can improve the instruction in this area. (These are likely competencies in which you indicated that you were not proficient on the accompanying form.)

Updated 5 January 2012

**Figure 14** Part 2 of the New Student Evaluation Form for ChEn 373 (Thermodynamics).

The main purpose of this new section of the student assessment was to allow the students to explain why a certain competency was marked as weak. As mentioned above, this information could not be obtained from the numerical data alone, which made interpretation difficult. As is described in the next section, this simple change, allowing the students to briefly explain their responses, proved to be a significant improvement in our assessment process by making it very easy to prescribe corrective actions.

**Results of the new assessment method**

The new assessment method was piloted in two courses during the Winter 2011 semester. The first course was Chemical Engineering Thermodynamics (ChEn 373), which is a junior-level course that covers the First and Second Laws of Thermodynamics and their applications as well as the thermodynamics of mixtures and reactions. The second course was Plant Design (ChEn 451), which is a senior-level, capstone course.

Table 2 contains the numerical results of the assessment for ChEn 451. Two types of data are found in this table. The first are the total number of Yes and No responses for each competency which came from Part 1 of the new assessment (see Figure 13). These two numbers add up to 67—the total number of students who took the assessment. The other data listed are the number of times each competency was listed as *strong* and *weak* by the students in response to Questions 1 and 2, respectively, of Part 2 of the assessment (see Figure 14).

The Yes/No data contained in the table show one of the strengths of this assessment method. Notice that it is very easy to see which competencies the students have a problem with. More than 10 "No" values were reported for Comptencies 7.4, 7.5, and 10.7.3. These seem to be much higher than the other competencies. The power of these data is that they allow the faculty to immediately identify two or three areas where improvements should be made the next time the course it taught. The previous assessment method did not provide such a clean demarcation.

The second set of numbers in Table 2, the Strong vs. Weak data, also help give the instructor additional insight into the thinking of the students. Notice that the number of weak responses is not necessarily correlated to whether the student felt *proficient* in each competency. For example, all the students reported feeling proficient in competencies 5.1.1 and 5.1.2, but in each case, 5 students still reported these as being one of their two weakest competencies. Alternatively, those competencies which the Yes/No data revealed were problematic to students were also reported as being among the weakest by the students. While this latter point might seem extraneous or repetitive, it helps place some of the data into better perspective. For example, competencies 5.1.3 and 7.3 had 9 and 5 "No" votes, respectively. These numbers alone—when compared with the 11, 12, and 17 for Competencies 7.4, 7.5, and 10.7.3, respectively—are probably too low to initiate action to improve the instruction in these areas.

However, over 10 people in each case reported these competencies as being among the weakest, which may prompt the instructor to consider these competencies as candidates for improvement in addition to those identified previously.

**Table 2** Numerical results of new assessment method in ChEn 451 during the Winter 2011 Semester.

| Competency | Yes | No | | Strong | Weak |
|---|---|---|---|---|---|
| 5.1.1 | 67 | 0 | | 7 | 5 |
| 5.1.2 | 67 | 0 | | 11 | 5 |
| 5.1.3 | 58 | 9 | | 7 | 14 |
| 6.3 | 67 | 0 | | 16 | 1 |
| 7.2 | 62 | 5 | | 5 | 6 |
| 7.3 | 62 | 5 | | 4 | 10 |
| 7.4 | 55 | 12 | | 3 | 15 |
| 7.5 | 50 | 17 | | 1 | 16 |
| 9.1 | 67 | 0 | | 16 | 2 |
| 10.2.4 | 61 | 6 | | 6 | 17 |
| 10.7.1 | 63 | 4 | | 5 | 4 |
| 10.7.3 | 56 | 11 | | 0 | 11 |
| 10.7.4 | 63 | 4 | | 6 | 9 |
| 10.8.1 | 67 | 0 | | 21 | 1 |
| 10.8.2 | 67 | 0 | | 6 | 1 |
| 10.8.3 | 66 | 1 | | 11 | 2 |
| 10.8.4 | 66 | 1 | | 3 | 5 |

In the end, the instructor is left with very clear data as to the top three weakest competencies and fairly clear data about the next two. He or she can then decide whether to focus improvements on the top three or all five. But regardless of the number of improvements made during the next time the course is taught, the important point is that the choice of 3 or 5 even exists. The previous method of assessment did not yield such clear data. In fact, none of the competencies in ChEn 451 were rated less than three in any of the last several semesters the course was taught. As such, the previous data never identified any needs or prompted any improvements in these competencies.

Part 2 of the new assessment form further helps the instructor by providing the reasons why students marked certain competencies as weak. In some cases, it even gives specific ideas for improvement. For example, Competency 7.4 for ChEn 451 states “Students will be dedicated to environmentally responsible engineering; demonstrate knowledge of pertinent environmental laws and regulations; understand and have a basic knowledge of how environmental considerations, including green engineering strategies, are incorporated into engineering problem solving.” This competency received 12 “No” ratings and was marked as one of the two weakest by 15 people (See Table 2). One difficulty with understanding these low ratings is that so much is included in this competency. Are students weak in "being environmentally responsible," "laws and regulations," or one of the other concepts mentioned? This is where Part 2 of the assessment helps in the improvement process.

Table 3 contains the responses provided by the students in regard to Competency 7.4 on Part 2 of the assessment for ChEn 451. A quick reading of the comments yields interesting patterns. Multiple students commented that 1) they did not know where to go to find environmental regulations and 2) they recalled being taught environmental issues in a junior-level course (ChEn 311) but these were not covered in this course. These two themes provide the instructor a much better idea on what to improve when the class is taught next time. Spending time showing the students where to find environmental requirements would appear to help address the weakness reported for this competency.

**Table 3** Comments provided by students for Competency 7.4 on Part 2 of the new assessment process for ChEn 451 during the Winter 2011 semester.

| # | Comment |
|---|---|
| 1 | We didn't cover these, really. Maybe if each project was assigned to a location then research could be done on specific laws, etc. |
| 2 | I felt that I focused all of my time completing the project and not trying to estimate environmental impacts. |
| 3 | We didn't deal a whole lot with laws and green engineering. Maybe spend a little time on that. |
| 4 | Talk more about environmental regulations. |
| 5 | We see some of them in 311 but a couple classes for these subjects will be useful. |
| 6 | More constraints on emissions for project, etc. |
| 7 | We could probably go over how to find environmental laws better. |
| 8 | I feel like these environmental/social concerns were covered well in 311, but not much in this class. |
| 9 | I felt like we didn't talk about environmental concerns very much. |
| 10 | I struggled to find EPA regulations for emissions. |

The efficacy of Part 2 of the assessment was not limited to just Competency 7.4. Rather, all of the competencies marked as weak had useful comments. Competency 10.2.4 received 6 "No" ratings (not enough to be deemed poor by Part 1 of the assessment) but 17 "Weak" on Part 2. This competency states "Students will be able to size and estimate the capital costs of heat exchangers." Table 4 contains the comments provided by the students outlining the reasons for the "Weak" rating given on this competency. A quick reading of these comments again reveals a common theme. Students could calculate the heat duty required by a heat exchanger, but many could not translate this into the surface area required to accomplish this heat transfer, nor could they take this heat surface area and estimate the capital costs. Thus, Part 2 of the new assessment process provides two things that can quickly be changed the next time the course is taught. Spending 10-20 minutes reviewing how to translate a heat duty into a required surface area and then into a capital costs will likely improve performance on this competency and, more importantly, result in better trained engineers.

**Table 4** Comments provided by students for Competency 10.2.4 on Part 2 of the new assessment process for ChEn 451 during the Winter 2011 semester.

| # | Comment |
|---|---|
| 1 | I was unsure on how to calculate surface area from heat duties; A 10 minutes review would help. |
| 2 | Weak, but able, taught well, my fault and application. |
| 3 | I can find the area required but I don't know how to translate that into an actual piece of equipment. |
| 4 | I can't say the course needs to do better, but it just takes me more time to learn some things really well. |
| 5 | I had only limited exposure to working on the heat exchangers and don't feel as proficient at it. |
| 6 | Better learning in heat and mass. |
| 7 | I found it difficult to know how to size and cost heat exchangers. Spend some time specifically on this. |
| 8 | My group couldn't figure out how to find the heat exchanger surface area. |
| 9 | I wish there were detailed instructions on how to size the reactor. |
| 10 | Need review of manually estimating ahead. |
| 11 | Review how to do this without CapCost. |
| 12 | Only had 1 opportunity to do this in final project and another group member did most of it. |

The new assessment method was also implemented in another course—Chemical Engineering Thermodynamics (ChEn 373). As with the results just described for ChEn 451, the new process easily identified problem areas. However, an additional benefit is seen in this case. To further illustrate the advantages of the new method, consider the data presented in Table 5. This table contains the Part 1 results of the student assessments of this class. The data quickly reveal the two most problematic competencies: 3.1.6 and 3.7.7. These competencies state:

- **Competency 3.1.6:** Students will be able to set up and solve simple transient energy balances.

- **Competency 3.7.7:** Students will understand the fundamental concepts of solution thermodynamics including chemical potential, fugacity, activity, partial molar properties, ideal solutions, and excess properties.

Both of these competencies also received high "Weak" ratings.

**Table 5** Numerical results of new assessment method in ChEn 373 during the Winter 2011 Semester.

| Competency | Yes | No | | Strong | Weak |
|---|---|---|---|---|---|
| 3.1.2 | 72 | 3 | | 3 | 3 |
| 3.1.5 | 74 | 1 | | 16 | 5 |
| 3.1.6 | 59 | 16 | | 3 | 26 |
| 3.2.1 | 74 | 1 | | 5 | 0 |
| 3.7.1 | 75 | 0 | | 31 | 4 |
| 3.7.2 | 67 | 8 | | 10 | 15 |
| 3.7.3 | 75 | 0 | | 19 | 2 |
| 3.7.4 | 71 | 4 | | 5 | 4 |
| 3.7.5 | 70 | 5 | | 6 | 4 |
| 3.7.6 | 69 | 6 | | 6 | 11 |
| 3.7.7 | 61 | 14 | | 2 | 21 |
| 10.4.2 | 68 | 7 | | 5 | 8 |
| 10.6.1 | 72 | 2 | | 4 | 8 |
| 10.6.2 | 72 | 3 | | 18 | 6 |

The comments, provided on Part 2 of the assessment, provide useful information about the reasons why the students felt weak in these two competencies. As an example, Table 6 contains these responses for competency 3.1.6. A quick reading of the comments reveals two main themes (aside from the fact that the topic is simply challenging): 1) students would like more examples and 2) too little time was spent on this subject throughout the semester. Both of these are likely related to each other. Only one 50-minute class period and its accompanying homework assignment are spent on this topic in the current setup of the course. Moreover, the instruction occurs very early in the semester before more advanced topics—such as the mathematics of thermodynamics with advanced equations of state, unit operation sizing based upon applications of the first and second laws of thermodynamics, and thermodynamics of mixtures (which include partial properties, fugacities, and phase equilibrium)—are covered. As such, the explanations provided by the students accurately describe the situation.

Discussions about this particular competency in the Undergraduate Committee were interesting in that multiple issues were brought up. The main question is whether more time should be devoted in ChEn 373 to transient energy balances, when that topic is stressed more in later courses. This discussion continues, but the present preference is to keep the topic in the course, still spend more time on the subject, but solve easier problems so that the students grasp the basic concepts. The more advanced application of transient energy balances will then occur in subsequent course. The exact action that will be taken is not important for the present purposes. What is important is the fact that this discussion is happening at all. Prior to the new assessment, Competency 3.1.6 was always rated above 3 and possible improvements were never discussed. The new assessment prompted a discussion that will have a meaningful impact on student learning.

**Table 6** Comments provided by students for Competency 3.1.6 on Part 2 of the new assessment process for ChEn 373 during the Winter 2011 semester.

| # | Comment |
|---|---|
| 1 | Maybe spend a little more time on this. |
| 2 | Use more examples, both simple and difficult. |
| 3 | One of the assigned transient homework problems used a lot of tricks we didn't talk about in lecture. This problem could use a hint or two to help us see "the forest through the trees". |
| 4 | More practice. |
| 5 | I don't remember this topic. |
| 6 | More examples? |
| 7 | Just a little more clarity on the difference in the math in different problems, what assumptions to make, etc. |
| 8 | Somewhat difficult to wrap mind around, maybe spend a little more time on it. |
| 9 | I need a little more math review. |
| 10 | The setup and notation was confusing. |
| 11 | Although explained well, probably another homework later in the semester for a refresh might be beneficial. |
| 12 | Examples were VERY few and limited. |
| 13 | Perhaps more practice, or maybe it's just been too long so I need to review. |
| 14 | I've forgotten this by now. |
| 15 | I just didn't feel like I had a grasp on this topic. |

The student assessments for ChEn 373 reveal one other interesting advantage of the new method. Notice that Competency 3.7.2 received 8 “No” responses and 15 “Weak” responses. Though the “No” responses alone might not have prompted discussion of this topic, the addition of the 15 “Weak” responses brought the competency to the attention of the instructor. Competency 3.7.2 states “Students will be able to apply solution thermodynamics fundamentals to solve VLE, LLE, SLE, and GLE problems including bubble point, dew point and flash calculations.”

When the instructor of the course first saw this numerical data, he was astonished. A significant amount of time is spent on bubble, dew, and flash calculations for Vapor/Liquid Equilibrium because it is so important in the field of chemical engineering. The time spent specifically on these calculations is so extensive that it takes almost three weeks of time in the course. At the end of these three weeks, the students have completed a substantial team project on the subject. The fact that many students reported this as weak was thus a big surprise to the instructor and rather disheartening.

However, the comments for this competency, found in Table 7, helped the instructor understand why the competency was rated poorly and that VLE was not the problem. Notice that most of the comments focused on the fact that not enough time is spent on Liquid/Liquid Equilibrium (LLE), Solid/Liquid Equilibrium (SLE), Solid/Vapor Equilibrium (SVE), and Gas/Liquid Equilibrium (GLE) and *not* Vapor/Liquid Equilibrium (VLE). VLE is the most important topic among those listed and is the one that is taught for over three weeks. The other topics receive only one day of instruction each. Moreover, in order to provide time outside of class for the students to work on the major project about VLE, the instructor did not assign homework on SVE or SLE and very little on LLE and GLE . This imbalance of time and homework is intentional because of the aforementioned importance of VLE in chemical engineering as well as the fact that once VLE is mastered, the others topics can be learned fairly quickly should the need arise.

The instructor was relieved that it was not VLE, but the other topics that students felt weak in. This particular point deserves emphasis. The instructor for this course is one of the authors of this paper. As mentioned above, when he received the numerical results from Part 1 of the new assessment process, he was amazed that any student would rate Competency 3.7.2 as “Weak” or “No.” He could not imagine how any student would not feel proficient in VLE calculations when so much time was spent on the subject. Moreover, he immediately began to make plans to cut even more content from other topics in order to give the students more time to practice VLE. After a few minutes of quiet frustration and meditation on the subject, he then read the comments provided in Part 2 of the assessment form. To his relief, he realized that VLE was not the problem and set aside the content-cutting plan.

Herein is found an additional value of the new assessment process. To the instructor, the VLE part of the competency was so important that the other topics were negligible when evaluating proficiency on the competency. Apparently, the students focused not on VLE but on all of the topics when providing their assessments. Had the instructor not had Part 2 of the assessment, this difference in perception would have led to changes that further reduced the time spent on the other topics *making the matter worse*. The new assessment method, specifically the student comments, identified this “false positive” by placing the numbers in context and not requiring the instructor to assume the reason for the numbers.

**Table 7** Comments provided by students for Competency 3.7.2 on Part 2 of the new assessment process for ChEn 373 during the Winter 2011 semester.

| # | Comment |
|---|---|
| 1 | We didn't have homework on these to give us time for the project. Going into the test I thought I understood SVE, going out I realized I did not. |
| 2 | Have a homework assignment on each of these (VLE, LLE, SVE, SLE, GLE). |
| 3 | Assign a less intense project and give homework on solid equilibrium. |
| 4 | We just didn't spend enough time on these concepts. |
| 5 | Homework on SVE. |
| 6 | Mostly SLE and GLE problems are confusing. |
| 7 | I zoned out for about a month, so that's foggy. It was well taught though. |
| 8 | I would have liked to understand these conceptually better and not only focus on calculations. |
| 9 | I'm a little weak with LLE and SLE. |
| 10 | I thought I understood but not having done homework on them made it difficult to remember for the test. But I think we needed that break to do the project so I don't know how to fix this. |

**Summary and conclusions**

One of the main purposes of the assessment process is to ensure continual improvement occurs in engineering programs. An analysis of the assessment process in the Department of Chemical Engineering at Brigham Young University revealed that the traditional method for assessing student learning from the student perspective never led to any such improvements. This portion of the assessment process consisted of the students rating, on a scale of 1-5, the course and themselves on each course learning outcome (termed competencies). The problem with this method, due to differences in the personal interpretations of the meaning of each number (e.g. 3 vs. 4) and the averaging of the data, was that the numerical data rarely indicated that problems existed. Moreover, no mechanism existed to uncover the reasons for the few instances where the rating was low.

To improve the student portion of the assessment process, changes were made to 1) remove the numerical scale and replace it with a Yes/No question and 2) create a mechanism to determine the reasons for any low ratings. The former was done to help remove the numerical averaging of the data and reduce the variableness in individual interpretation of the meaning of the numbers in the 1-5 scale. The latter was done to help place the ratings in the proper context. The new assessment method consisted of two parts. Part 1 required the students to state whether or not they were proficient in each course competency (Yes/No). Part 2 required the students to briefly explain why competencies perceived as weak were so rated.

The new assessment process was piloted in two courses during the Winter 2011 semester. The results easily identified problem areas in a manner not seen previously and did so without a significant increase in the class time needed to fill out the forms. Not only were weak competencies clearly distinguished from strong competencies, the reasons for the difficulties were also learned. Together, these two pieces of information proved to be a powerful combination in that they allowed the instructors to almost effortlessly identify specific changes that could be made to the course to improve student learning. The efficiency of the process is such that the faculty in the department recently approved a motion to adopt the new method across the entire curriculum.