AC 2011-493: COLLECTING PROGRAMMATIC ASSESSMENT DATA WITH NO ”EXTRA” EFFORT: CONSOLIDATED EVALUATION RUBRICS FOR CHEMICAL PLANT DESIGN

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Collecting Programmatic Assessment Data with No "Extra" Effort: Consolidated Evaluation Rubrics for Chemical Plant Design

Abstract

In order to gain accreditation, engineering programs must define goals and objectives, assess whether their graduates are meeting these objectives, and "close the loop" by using the assessment data to inform continuous improvement of the program. In ABET's jargon, program "objectives" describe capabilities that graduates are expected to possess, e.g., "Graduates of the Chemical Engineering program at Rowan University will be able to…." Thus, the true success of the program in meeting its objectives is reflected in the first few years of graduates' careers. Practically speaking a program cannot be expected to assess directly the performance of graduates with respect to these objectives, at least not in a comprehensive way. Consequently, programs are expected to define and assess measurable "outcomes" which fit within the undergraduate curriculum, and which ensure, to the best degree possible, that graduates will meet the program objectives.

A variety of assessment instruments are in common use and merits and shortcomings of each have been discussed in the open literature. For example, surveys and exit interviews are commonly used, but are subjective, rely on self-assessments and may oversimplify the questions under examination. This paper focuses on tools for direct measurement of student performance through objective evaluation of work product. Numerous authors have outlined the assessment strategy of constructing rubrics for measuring student achievement of learning outcomes and applying them to portfolios of student work. Other authors have outlined use of rubrics for evaluation and grading of individual assignments and projects. This paper will describe the use of a consolidated rubric for evaluating final reports in the capstone Chemical Plant Design course. Instead of grading each report and then having some or all of the reports evaluated through a separate process for programmatic assessment purposes, the instructor evaluates the report once using the rubric, and the same raw data is used both for grading and for programmatic assessment.

Background

Since 2000, ABET[1] has required that in order to be accredited, engineering programs must demonstrate evidence of continuous assessment and continuous improvement. Components of a good assessment strategy include:

1) Establish goals and desired educational outcomes for the degree program, which must include 11 outcomes[2] (designated "A-K") identified by ABET as essential for all engineering programs.

2) Measure whether graduates of the program are attaining the goals and outcomes. This process is required by ABET Criterion 3.

3) Use the data collected in step 2 to identify opportunities for improvement, and modify the program accordingly.

4) "Close the loop" by assessing whether the changes led to improved attainment of desired outcomes[1].

Approximately 35% of recently evaluated programs were cited with shortcomings in Criterion 3.[3] Two potential pitfalls that have been identified in recent literature are: not creating a *sustained, continuous* assessment plan, and not articulating expectations in a manner specific enough to be useful. This section expands upon these two potential problems, and the remainder of the paper describes the approach to program outcomes assessment adopted in the Chemical Engineering program at Rowan University.

Continuous Assessment and Continuous Improvement

ABET evaluations are scheduled to occur every six years. Shryock and Reed[5] note that "some programs treat the six-year time lag between visits with the following timeline:

- Year 1 – Celebrate success of previous ABET visit.
- Years 2-4 – Feel that ABET is a long time away.
- Year 5 – Begin to worry about ABET visit the following year, and survey every class imaginable to be ready for year 6 with the ABET visit."

Limiting assessment to a "snapshot" of data collection once every six years undermines the intent of the ABET criteria; continuous assessment and continuous improvement. Significantly, ABET recently separated what was Criterion 3 into two distinct accreditation criterion:[2] "Criterion 3- Program Outcomes" and "Criterion 4- Continuous Improvement." This change was presumably motivated by the need to emphasize the importance of assessment as a continuous, ongoing activity.

A more subtle point raised by Shryock and Reed's description is the strategy of "survey every class imaginable." Dr. Gloria Rogers, ABET's Managing Director of Professional Services, calls attention to the fact that collecting large amounts of data from "every class imaginable" is not merely inefficient, but likely misleading and counter-productive. Program objectives are summative in nature; they concern not the capabilities of students in specific courses, but the capabilities of *graduates.* Thus, Dr. Rogers writes, "Why do we collect data in lower level courses and average them with the data taken in upper level courses and pretend like we know what they mean? Are we really saying that all courses are equal in how they contribute to cumulative learning and that the complexity and depth/breadth at which students are to perform is the same in all courses for any given outcome? *Why not only collect 'evidence' of student learning in the course where students have a culminating experience related to the outcome*." (emphasis added)[4]

In sum, the 6-year cycle described by Shryock and Reed is contrary to the intent of the ABET criteria, for multiple reasons. Nonetheless, with all the demands that exist on faculty time, even well-intentioned departments could easily fall into the trap of approaching assessment and accreditation as Shryock and Reed describe. A sustainable assessment plan is one that makes efficient use of faculty time. This paper examines ways of conducting program assessment by leveraging activities that are already occurring and information that is already available, rather than creating new data-gathering tasks that serve no purpose beyond program assessment.

Strategies for Assessing Program Outcomes
Instruments for assessing achievement of program outcomes can broadly be subdivided into direct and indirect instruments.[5] Surveys of students, alumni and/or employers are common indirect instruments. This paper focuses on direct instruments, in which actual student work product is evaluated to make a determination of how well students met programmatic outcomes.

An outcome is a broad statement such as "The Chemical Engineering Program at Rowan University will produce graduates who demonstrate an ability to apply knowledge of mathematics, science, and engineering," which mirrors ABET outcome A[1]. According to Dr. Gloria Rogers[6] the most difficult part of the assessment process, and one which most engineering programs do not do well, is "identification of a limited number of performance indicators for each outcome." Dr. Rogers notes that programs "…tend to go from broad outcomes to data collection without articulating specifically what students need to demonstrate…"[6]

In 2003, Felder[7] outlined a strategy for bridging the gap between broad outcomes and clear, specific indicators of success. At the heart of the approach is development of assessment *rubrics.* An example of a rubric, which was published previously in *Chemical Engineering Education*[8], is shown in Table 1. For each outcome, 3-6 indicators are identified, and these are located in the leftmost column. For each indicator, precise descriptions of four different levels of achievement are provided. When reviewing a sample of work product (exam, lab report, etc.) the evaluator simply moves from left to right until he/she finds the descriptor that is accurate for the student's work. The Chemical Engineering department at Rowan University also did a study[8] which demonstrated that these rubrics provide excellent consistency for different raters evaluating a particular exam or report. This result highlights one significant merit of the indicators. Inter-rater reliability would presumably not be present if the evaluator was making a single, holistic determination of whether a particular student "demonstrates an ability to apply knowledge of mathematics, science and engineering," or if the evaluator were rating work on a scale from 1-4 with no specific description of what each number meant. Thus, a rubric like the one in Table 1 fills the need identified by Dr. Rogers; it can be used to assess how well students have achieved programmatic outcomes in an objective and quantitative way.

A drawback of using the assessment rubric shown in Table 1 is that it is time-intensive; each sample of student work must be read and individually evaluated with the rubric. A more time-efficient strategy is using information that is already available. The most obvious "direct" assessment instrument available is student grades. Assigning grades is a routine task. Tracking the fraction of students who earn A, B, and C in a course, or calculating the average score on a particular assignment, are data collection tasks that require essentially no "extra" effort on the part of faculty. However, ABET cautions against using grades as an assessment metric[9] because a grade is a holistic evaluation of whether a student has met *all* of the instructor's expectations. A class of students that has one very specific and widespread shortcoming may still earn good grades. There are several recent examples of programs[10,11,12,13] that address this concern by identifying tasks, such as individual homework problems or individual questions on exams, that are specific enough that they do reflect single outcomes, and track scores on these. Shryock and Reed call these "embedded indicators"[5] and note that "it is important for the score of the activity to directly correlate to a specific outcome."

The assessment tool described here combines assessment rubrics with embedded indicators. Recent ASEE publications include several examples of rubrics used for programmatic assessment.[14,15,16] Other recent ASEE publications include examples of rubrics used to evaluate individual student assignments, or student performance in specific aspects of a project.[17,18] This paper shows that a single rubric can be used for both. The instructor grades a student report using the rubric, and aspects of the rubric are used as embedded indicators for assessing program outcomes. Thus, essentially all of the effort required to collect program assessment data is integrated into the routine task of grading.

Overall Approach to Assessing Measurable Outcomes

Because program outcomes speak to the capabilities of *graduates*, the Rowan University Chemical Engineering department has settled on an assessment strategy that focuses on the two courses in the curriculum that best reflect real engineering practice:

- Chemical Plant Design- This is the program's capstone design experience.
- Junior/Senior Engineering Clinic- This is a multidisciplinary, project-based course in which most projects are sponsored by local industry.

These two courses clearly offer what Dr. Rogers described as a "culminating experience;" they both require students to synthesize information learned in a variety of courses and apply it to an open-ended, long term project. For each of these courses, the following tasks were completed:

1) Identify essential elements for each course
2) Prepare grading rubrics that evaluate student achievement with respect to each element
3) Map the elements of the courses to the program's outcomes; verify that each outcome is thoroughly represented
4) Evaluate student design reports and final presentations using the grading rubrics
5) Use the data obtained from the evaluation both for individual student grading and for programmatic assessment

The department's assessment program does also include senior exit interviews, student focus groups and surveys, but this paper focuses only on direct assessments of student achievement as measured by the grading rubrics. A previous paper[19] discussed how this process has evolved over the past ten years. This paper focuses on the assessment process as it is currently implemented. One section is devoted to each of the tasks summarized above. Throughout the paper, examples are primarily drawn from the Chemical Plant Design course, because the Chemical Plant Design rubric is more likely to be directly portable to other Chemical Engineering programs. However, the complete rubrics for both courses are available on request from the author.

Rationale for Selection of Courses

This section provides more detail on the Chemical Plant Design and Junior/Senior Engineering Clinic courses, and why they are considered appropriate and sufficient choices for assessment of program outcomes.

Chemical Plant Design

The capstone design course is the most straightforward venue for evaluating the abilities of graduates, since it is taken in their final semester and requires them to synthesize information learned throughout the four-year curriculum. In Chemical Plant Design, student teams are tasked with designing a complete chemical process, (e.g., design a process to manufacture 50 million pounds of methyl methacrylate per year) including economic analysis and assessment of safety and environmental impact. Plant design problems can be framed such that they draw from every required chemical engineering course in the curriculum. Further, the course at Rowan has always been team-taught by a tenure track faculty member and an adjunct faculty member with an industry background, in order to ensure that problems are genuinely reflective of engineering practice. Despite these facts, the capstone design course cannot realistically be the *sole* vehicle for assessing achievement of programmatic objectives. The two most prominent reasons are:

- One program objective is that graduates will have the ability to function effectively on multidisciplinary teams. While students work in teams of 4-5 in Chemical Plant Design, neither the teams nor the design problems can be well described as “multidisciplinary.”
- Some program objectives are related to ability to perform hands-on experimental and laboratory work. Chemical Plant Design at Rowan University makes extensive use of process simulation but has never been taught with a wet-lab component.

Junior/Senior Engineering Clinic

Rowan University has an eight-semester Engineering Clinic program intended to provide Engineering students with experience solving practical, open-ended engineering problems. The sequence culminates in the Junior/Senior Engineering Clinic, in which students work on real engineering research and design projects. Project teams work with close faculty supervision and usually consist of 3-4 students; sometimes drawn from a single discipline but generally representing more than one, depending on the needs of the particular project. Most projects are externally sponsored, either by local industry or government agencies. Consequently, the Junior/Senior Clinic provides the most genuine refection of engineering practice in the curriculum: the projects are real problems with real clients.

Every Junior/Senior Clinic project is unique, so a crucial step in the assessment process was identifying goals and attributes that are common to *all* Engineering Clinic projects. These are the "Essential Elements" detailed in the next section. While all Engineering Clinic project teams need to identify and apply relevant engineering principles synthesized from a variety of courses, there is no stipulation that any *specific* chemical engineering subject matter (e.g., heat transfer, diffusion, chemical reaction kinetics) be a substantial aspect of every project. Consequently, Junior/Senior Clinic cannot, by itself, be used to assess all chemical engineering program objectives.

In sum, the Junior/Senior Clinic provides an ideal setting for assessment of engineering skills in general (functioning on multi-disciplinary teams, collecting and interpreting data, drawing meaningful conclusions, etc.), while the capstone design course provides an ideal setting for assessment of the skills that are specific to the discipline of chemical engineering. Many program outcomes (e.g., communication skills, understanding solutions in societal/global settings) are well represented in both courses.

Task 1: Identify Essential Elements for Each Course

The specific design problem in Chemical Plant Design is different every year, and the course instructors have the freedom to frame specific instructional objectives for the course as they see fit. However, one can identify elements such as an economic analysis, an environmental impact assessment, etc., that are integral components of *any* chemical process design. Similarly, while every Junior/Senior Clinic project is unique, there are general expectations that are common to all clinic projects, such as defining objectives, executing a plan to attain them, interpreting data to form valid conclusions, etc.

The specific essential elements for these project-based courses are listed below.

Essential Elements for Chemical Plant Design projects:

- Overall Process Conceptualization
- Physical Properties of Chemicals
- Reaction Stoichiometry and Kinetics
- Separation Techniques
- Sizing & Design of Unit Operations
- Use of Modern Engineering Tools
- Estimation of Capital Costs
- Estimation of Revenues and Operating Costs
- Overall Economic Analysis
- Tier 1 Environmental Analysis
- Tier 2 Environmental Analysis

- Analysis of Process Hazards
- Conclusions and Recommendations
- Effective Written Communication
- Effective Oral Communication

Essential Elements for Junior/Senior Engineering Clinic projects:

- Meeting Deadlines
- Defining Project Goals
- Working in Teams
- Project Organization
- Record Keeping
- Safety
- Professional Conduct
- Professional Attire
- Execution of Project Plan
- Awareness of Existing Relevant Technical Literature
- Understanding and Application of Underlying Principles
- Apparatus or System Design
- Laboratory Functions
- Use of Modern Engineering Tools
- Societal/Global Perspectives
- Interpretation of Results
- Formulating Conclusions
- Making Recommendations
- Effective Written Communication
- Effective Oral Communication

Task 2- Prepare grading rubrics that evaluate student achievement of instructional objectives

The elements identified in the previous section are relatively broad. With no further guidance, gauging the performance of a specific student or team with respect to one of these (on, for example, a 1-10 scale) is quite subjective. Consequently, consistent with the strategy outlined in the Background section, detailed rubrics have been crafted for each of the elements listed in the previous section. Example rubrics are provided in Table 2. The current rubrics for both courses were drafted by the author in 2007, and were reviewed, revised and endorsed by the entire Chemical Engineering department. The rubrics were also reviewed by student focus groups in 2007 and 2008; feedback was generally positive and the reviews led to some minor revisions for clarity.

In Chemical Plant Design, there is always a final report and final presentation that are heavily weighted in the course grading, and the rubrics described in Table 2 are specifically designed for these final deliverables. Other assignments, such as progress reports and homework, can be assigned at the discretion of the instructor, but do not figure into programmatic assessment. Similarly, by College policy, all Junior/Senior Clinic projects include a mid-semester review presentation, a final written report and a final presentation. Individual faculty set deadlines and expectations for additional deliverables (e.g., progress reports, memos, etc.) to meet the needs of their specific projects, but the department's assessment plan only uses data obtained for these common assignments.

Task 3- Map the course outcomes to the programmatic outcomes; verify that each programmatic outcome is well represented

The chemical engineering program has four goals:

> Goal 1 - Develop students who understand and apply the core scientific, mathematical, and engineering principles that form the basis of chemical engineering.
>
> Goal 2 - Develop students who work individually and in diverse teams and effectively utilize advanced technology to solve complex problems.
>
> Goal 3 - Develop students who gain a perspective on the role of engineering in a global society including the importance of ethics, professional responsibility, diversity and culture, lifelong learning, safety, sustainability and the environment.
>
> Goal 4 - Develop students who communicate their ideas effectively in various formats to both technical and non-technical audiences.

There are 15 objectives related to these goals, as summarized in Appendix A. In most cases, there is a straightforward, one-to-one mapping between the program's objectives (e.g., graduates will be able to do X) and measurable outcomes (e.g., students will demonstrate during the culminating experiences in the curriculum that they are able to do X.) However, three of the instructional objectives are sub-divided into distinct outcomes for assessment purposes, making a total of 18 outcomes.

Final reports and presentations in Junior/Senior Clinic and Chemical Plant Design clearly contain evidence regarding whether or not these outcomes have been attained. This evidence is gleaned through a systematic mapping of the expectations for individual assignments to the measurable program outcomes which they reflect. An example portion of the mapping is illustrated in Table 3. If the mapping had revealed that some outcomes were not adequately assessed by the final reports and projects in these two courses, one or more additional courses would have been added to the assessment plan through the same 5-step process outlined here.

Task 4- Evaluate student design reports and final presentations using the grading rubrics

The complete grading rubrics are distributed to students in both Chemical Plant Design and Junior/Senior Engineering Clinic during the first week of class. The purpose of using a 1-10 scale and benchmarking the meanings of 10, 7 and 5 is to communicate expectations to students in familiar terms. Students recognize that the 10/10 column summarizes what they need to do to earn an A, the 7/10 column summarizes what they need to do to earn a C, etc. As previously reported,[19] average performance in Junior/Senior Engineering Clinic improved when the practice of distributing grading rubrics in the first week of class was implemented, though the improvement was not dramatic enough to be statistically significant with the relatively small sample size available (~12 teams per semester).

Each assignment (report or presentation) is evaluated by the course instructor or project manager and scored on a scale from 1-10 with respect to each element, using the rubrics as a guide. Logistically, this is done using Microsoft Excel spreadsheets. The rubrics are summarized on the sheet and ratings for each element are entered into specific cells. A screen capture of a portion of the Chemical Plant Design spreadsheet is shown in Figure 1. Some faculty, particularly in Jr/Sr Engineering Clinic, also ask their student teams to provide a self-evaluation of their own work using the rubrics and site specific evidence to defend their ratings. This input informs the faculty member's evaluation.

Task 5- Use the data obtained from the evaluation both for individual student grading and for programmatic assessment

The faculty evaluations of final reports and presentations are used to assign grades, though it is impossible to give a single specific explanation of *how* the grade is determined. The weighting of each individual element in the grading of assignments varies from course to course and project to project, and is at the discretion of the instructor. Project supervisors also have the discretion to determine that specific elements are not applicable to a particular Jr/Sr Clinic project, though this is rare.

Prior to the introduction of a common grading rubric that was agreed upon by the department, most faculty members assigned project grades by a holistic evaluation of the team's work throughout the project. Since the use of grading rubrics was first introduced, faculty members have reported feeling more confident that the grades they assign are legitimately fair reflections of student performance.[20]

The department's assessment coordinator collects the evaluations of each team in Chemical Plant Design and Junior/Senior Engineering Clinic. The mapping of elements of individual projects to program instructional objectives, which was summarized in Table 3, is programmed into the spreadsheets. Consequently, once the data is compiled into a central spreadsheet, the overall student performance with respect to each of the program's educational outcomes is automatically summarized, as illustrated in Figure 2.

Summary

ABET requires continuous assessment and continuous improvement of engineering programs. This paper outlines a strategy for direct assessment of students' achievement of programmatic outcomes. Rubrics were developed for evaluating final reports and final presentations in two project-based courses: Chemical Plant Design and Junior/Senior Engineering Clinic. A report or presentation is evaluated once using the rubric, and the data obtained from this evaluation is used both for grading the assignment and for assessment of program outcomes. Thus, instead of creating "new" activities for the purpose of assessment, programmatic assessment is integrated into the routine activity of grading student reports and presentations.

The general strategy described here should be applicable to any engineering program. More specifically, the rubrics themselves are suitable for direct use in other Chemical Engineering programs. The Chemical Plant Design rubrics could be adopted by most any Chemical Engineering program, provided the capstone design experience is a fairly traditional process design project. While the 8-semester Engineering Clinic model is specific to Rowan University, the Jr/Sr Clinic rubrics could be adapted to most any undergraduate research experience, such as a Senior Thesis.

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Table 1: Sample rubric for the outcome "The Chemical Engineering Program at Rowan University will produce graduates who demonstrate an ability to apply knowledge of mathematics, science, and engineering (ABET - A)"

Indicator	4	3	2	1
Formulates appropriate solution strategies	Can easily convert word problems to equations. Sees what must be done	Forms workable strategies, but may not be optimal. Occasional reliance on brute force	Has difficulty in planning an approach. Tends to leave some problems unsolved	Has difficulty getting beyond the given unless directly instructed
Identifies relevant principles, equations, and data	Consistently uses relevant items with little or no extraneous efforts	Ultimately identifies relevant items but may start with extraneous info	Identifies some principles but seems to have difficulty in distinguishing what is needed.	Cannot identify and assemble relevant information
Systematically executes the solution strategy	Consistently implements strategy. Gets correct answers	Implements well. Occasional minor errors may occur	Has some difficulty in solving the problem when data are assembled. Frequent errors.	Often is unable to solve a problem, even when all data are given
Applies engineering judgment to evaluate answers	Has no unrecognized implausible answers	Has no more than one if any unrecognized implausible answers. If any it is minor and obscure	Attempts to evaluate answers but has difficulty. Recognizes that numbers have meaning but cannot fully relate.	Makes little if any effort to interpret results. Numbers appear to have little meaning

Table 2: Grading rubrics for assessment of Chemical Plant Design projects.

Project Element	An "A" team (10)	A "C" team (7)	An "F" team (5)
Overall Process conceptualization	Process meets stated objectives and is thoroughly optimized	Process meets stated objectives but is not optimized. Opportunities for recycle, heat integration etc. not well explored.	Process has a fatal flaw, or does not meet stated objectives.
Physical Properties of Compounds	Physical properties and safety hazards of all species known, clearly presented, and used to inform design	Physical properties and MSDS sheets for chemicals are present, but some design decisions display lack of understanding of significance of the information	Basic information on chemicals is cursory or missing
Reaction Stoichiometry and Kinetics	Reactor models are accurate and realistic based upon available information, and reactor is thoroughly optimized. Any assumptions are clearly stated and reasonable.	Reactor models are self-consistent but may include assumptions that are unnecesary, dubious or not explicitly acknowledged. Optimization attempted but not fully achieved.	Reactor is fundamentally flawed: model is wrong, calculations are wrong, and/or desired objectives are not achieved.
Separation Train	Individual separation operations are carefully chosen, sequenced for maximum efficiency, and thoroughly optimized. Models are realistic. Assumptions are explicitly stated and reasonable.	Workable separation operations are chosen but some reasonable alternatives not explored. Desired objectives achieved but not with maximum efficiency. Some assumptions unnecessary, dubious or not explicitly acknoweldged.	The separation train is fundamentally flawed: model is wrong, calculations are wrong, and/or desired objectives are not achieved.
Sizing & Design of Unit Operations	Sizing calculations for all equipment is accurate and based upon sound engineering principles. Assumptions clearly stated and reasonable. Materials of construction chosen for clear and valid reasons.	All needed equipment is accounted for, but some sizing calculations are sub-optimal or overly simplistic. Materials of construction acceptable for application but may be unnecessarily expensive.	Equipment sizing is unrealistic and/or some needed equipment is missing. Material compatibility problems not acknowledged.
Use of Modern Engineering Tools	Process simulation software and other relevant engineering tools are used accurately and effectively. Limitations of tools are known and accounted for.	Simulation software and other relevant tools are generally used reasonably, but sometimes haphazardly (e.g., overlooks potential limitations of software.)	Relevant engineering tools are not used or are badly misused.

Table 3: Mapping of aspects of the Chemical Plant Design course to five programmatic outcomes (the Chemical Engineering Program at Rowan has 18 total outcomes).

	Ability to apply knowledge of mathematics, science, and engineering.	Acquisition and interpretation of experimental results	Design and conduct appropriate experiments	Working knowledge of chemistry principles	Working knowledge of chemical engineering principles
Deadlines					
Project Goals					
Teaming					
Project Organization			**X**		
Record Keeping		**X**			
Professional Conduct					
Professional Attire					
Safety		**X**			
Execution of Project Plan			**X**		
Technical Awareness	**X**			**X**	**X**
Underlying Principles	**X**			**X**	**X**
System or Apparatus Design	**X**				
Laboratory Functions		**X**			
Modern Engineering Tools					
Interpretation of Results	**X**	**X**			

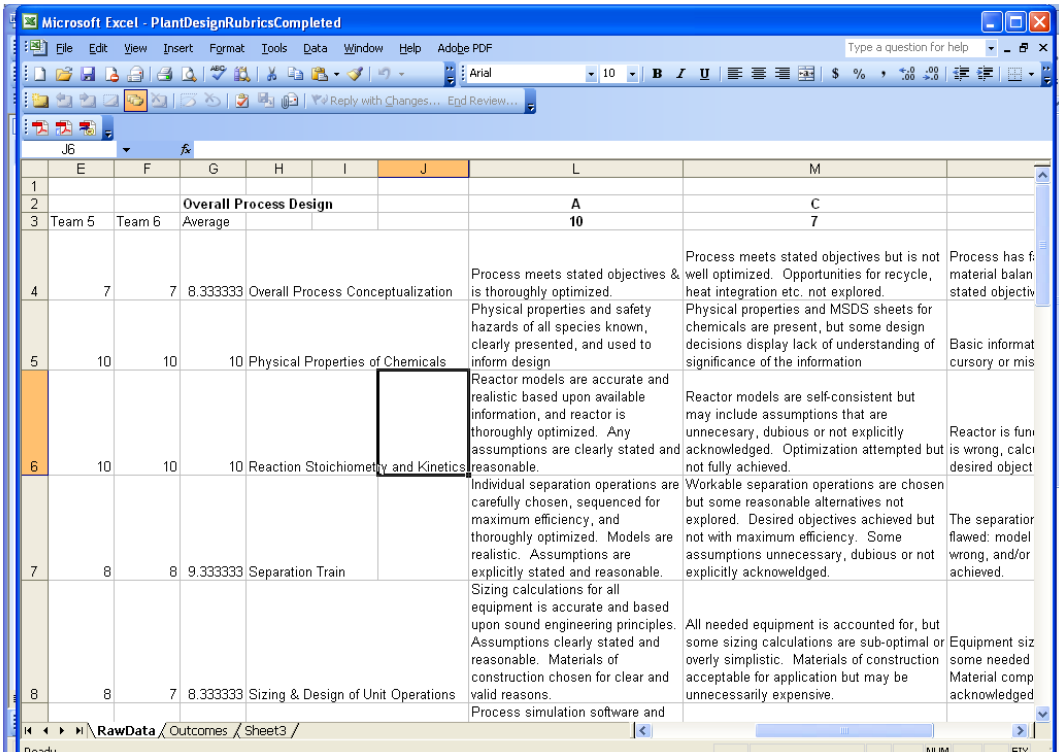

Figure 1: Screen capture of spreadsheet used for Chemical Plant Design. Faculty enter the evaluations on the "Raw Data" tab shown here.

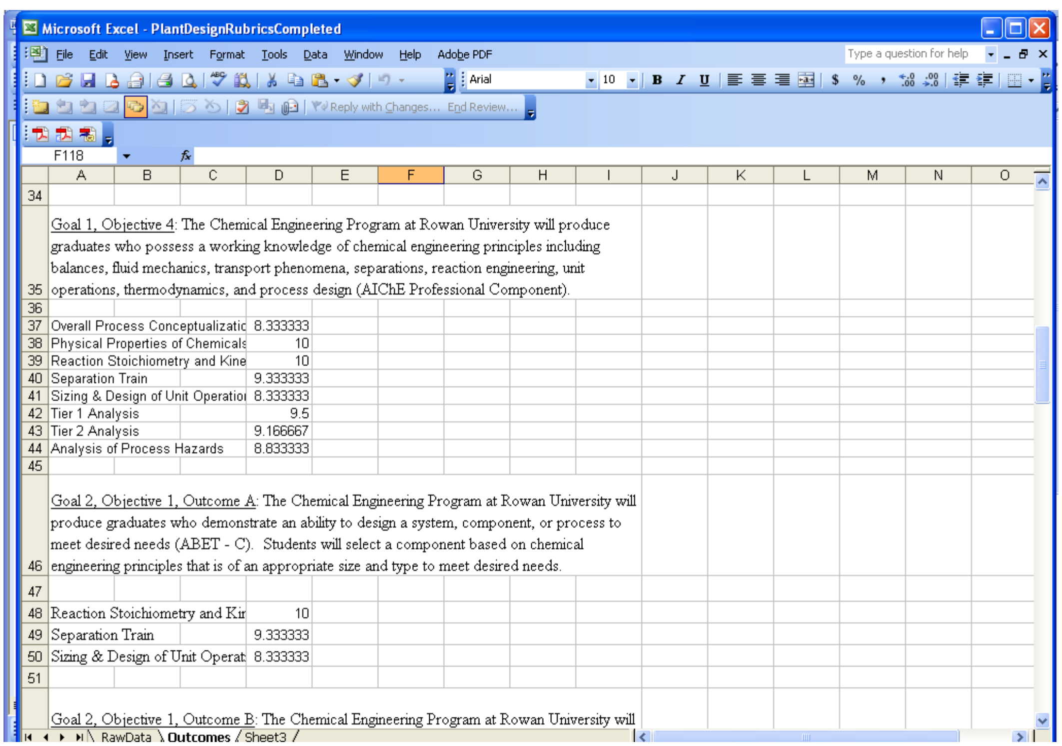

Figure 2: Screen capture of the spreadsheet used for Chemical Plant Design. On the "Outcomes" tab, student achievement with respect to each outcome is summarized.

Appendix A: Chemical Engineering Program Goals and Objectives

Goal 1 - Develop students who understand and apply the core scientific, mathematical, and engineering principles that form the basis of chemical engineering.

The four program educational objectives related to Goal 1 are:

1) The Chemical Engineering Program at Rowan University will produce graduates who demonstrate an ability to apply knowledge of mathematics, science, and engineering (ABET - A).

2) The Chemical Engineering Program at Rowan University will produce graduates who demonstrate an ability to design and conduct chemical engineering experiments as well as to analyze and interpret data (ABET - B).

This objective is sub-divided into two outcomes: “Students will approach tasks involving the acquisition and interpretation of experimental results in a logical and systematic fashion” and “Students will design and conduct appropriate experiments that effectively use limited resources to obtain the necessary information.”

3) The Chemical Engineering Program at Rowan University will produce graduates who possess a working knowledge of organic, inorganic, materials, and physical chemistry and a background in other advanced chemistry topics as selected by the individual student (AIChE Professional Component).

4) The Chemical Engineering Program at Rowan University will produce graduates who possess a working knowledge of chemical engineering principles including balances, fluid mechanics, transport phenomena, separations, kinetics and reaction engineering, unit operations, thermodynamics, and process design (AIChE Professional Component).

Goal 2 - Develop students who work individually and in diverse teams and effectively utilize advanced technology to solve complex problems.

The seven program educational objectives related to Goal 2 are:

1) The Chemical Engineering Program at Rowan University will produce graduates who demonstrate an ability to design a chemical engineering system, component, or process to meet desired needs within realistic constraints (e.g. economic, environmental, social, political, health, safety, manufacturability, sustainability) (ABET - C).

This objective is sub-divided into two outcomes: “Students will select a component based on chemical engineering principles that is of an appropriate size and type to meet desired needs” and “Students will design a process or system, consisting of components, into operations that convert raw materials into desired products.”

2) The Chemical Engineering Program at Rowan University will produce graduates who have an ability to function on multidisciplinary and/or diverse teams (ABET - D).

3) The Chemical Engineering Program at Rowan University will produce graduates who demonstrate the ability to identify, formulate and solve engineering problems (ABET - E).

4) The Chemical Engineering Program at Rowan University will produce graduates who understand contemporary issues relevant to the field of chemical engineering (ABET - J).

5) The Chemical Engineering Program at Rowan University will produce graduates who have the ability to use techniques, skills, and modern engineering tools necessary for chemical engineering practice (ABET - K).

6) The Chemical Engineering Program at Rowan University will produce graduates who have experience in undergraduate research and engineering in practice.

7) The Chemical Engineering Program at Rowan University will produce graduates who possess skills and experience in working with both bench and pilot scale hands-on chemical engineering equipment.

Goal 3 - Develop students who gain a perspective on the role of engineering in society including the importance of ethics, professional responsibility, lifelong learning, safety, sustainability and the environment.

The three program educational objectives related to Goal 3 are:

1) The Chemical Engineering Program at Rowan University will produce graduates who have an understanding of professional and ethical responsibilities (ABET - F).

2) The Chemical Engineering Program at Rowan University will produce graduates who have the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context (ABET - H).

3) The Chemical Engineering Program at Rowan University will produce graduates who recognize the need for and the ability to engage in lifelong learning (ABET - I).

Goal 4 - Develop students who communicate their ideas effectively in various formats to both technical and non-technical audiences.

A single objective exists for Goal 4. The Chemical Engineering Program at Rowan University will produce graduates who demonstrate effective oral and written communication skills (ABET - G).

For assessment purposes, “effective oral communication skills” and “effective written communication skills” are assessed as two distinct outcomes that fall within this objective.