Abstract – This paper describes an effective outcomes assessment approach that does not add a lot of work to already overloaded faculty members. This system was developed by the industrial and manufacturing systems engineering (IMSE) faculty at Kansas State University (K-State) in a quest to improve the direct assessment of the industrial engineering (IE) program outcomes while decreasing the overhead use of faculty time and effort to assure the quality of our programs. Though it requires a lot of faculty effort up front to define the outcomes and process, the implementation is relatively easy and not intrusive or taxing. This paper describes the development of this course-based assessment process and describes the outcomes assessment method, evaluation of results, and incorporation of this system into our program improvement process.

Index Terms – ABET, Program Outcomes, Assessment

INTRODUCTION

The industrial engineering program at K-State was on the leading edge of the implementation of the ABET 2000 criteria when we were reviewed by ABET in 1999. Though our assessment strategy was acceptable during that first visit we recognized a need to develop a better assessment process. We desired a process that gave us concrete data upon which we could base decisions to improve our program, but that did not require a lot of faculty time.

We began to realize that the assessment strategy we had developed was inadequate after some IMSE faculty members returned from an assessment workshop in which workshop leaders discussed the importance of directly assessing program outcomes. Upon their return and after sharing the information they had gained, the IMSE faculty recognized that the outcomes assessment strategy we had previously defined relied too heavily on indirect tools and methods. Consequently, we undertook a quest to define a more rigorous direct assessment process for our program outcomes.

We began to try to develop a direct assessment strategy for our program outcomes and debated the development and use of student portfolios, summary exams, course-based methods, and hybrids of these three main ideas. We talked with other engineering faculty members, and met with our industrial Advisory Council to ask for their assistance in defining a direct assessment strategy. We wrestled with the time and effort that these systems would require.

Our struggle to define simple, direct assessment methods for each of our “outcomes” drove us to seek further help. IMSE faculty members participated in assessment and ABET workshops provided locally, at professional meetings, and by assessment experts. We became aware that ABET had clarified the difference between program educational objectives and program outcomes. This awareness forced us to recognize that we had inappropriately defined our program educational objectives and program outcomes and that our original “outcomes” were actually part of our educational program objectives.

Our original definition of the IE program outcomes was a list of the things that we expected our graduates to know and be able to do in the early years of their careers and not, “statements that describe what students are expected to know or be able to do by the time of graduation from the program.” We realized that our struggle to develop an efficient direct assessment strategy was primarily due to misunderstanding program outcomes. Therefore, we redefined our program educational objectives and our program outcomes.

We established a systematic process to directly assess those outcomes and piloted the system in the spring semester of 2004. We used the results of that review to better define our assessment tools and processes. In the fall of 2004, we collected outcomes assessment data and reviewed the data both to analyze and improve our programs and to further refine our assessment process. In May 2005, we collected our assessment data from the spring semester and reviewed the data again to complete the first two semesters of data collection for the newly defined program outcomes. These reviews included data from all our designed assessment sources and were very useful in helping us to improve our assessment processes and strategy.

K-STATE IE PROGRAM OBJECTIVES

The IE program educational objectives were based on the department vision, mission, and statement of philosophy. A major thrust of the IMSE mission is the education of undergraduate students. Our statement of philosophy explains the IMSE faculty view of our undergraduate program and embodies our program educational objectives: “We take incoming students and mold them into industrial and manufacturing systems engineers. These engineers will enhance the productivity of the organizations that employ them. Our graduates will design, analyze, and improve production processes and systems in manufacturing, service,
and information organizations. Our critical educational processes are: developing sound curricula, teaching, advising, developing laboratories, and sponsoring extracurricular professional activities.”

The IMSE faculty developed the industrial engineering educational program objectives after consulting with our industrial advisory council, alumni, and representatives of companies that recruit our graduates. These objectives were then formally discussed with the IMSE Advisory Council and finally approved by the IMSE faculty. The latest version of our program educational objectives was approved at our November, 2004 faculty meeting. They have been shared with the undergraduate students in a public forum and are presented on our web site, in our classroom and in our office complex.

**K-STATE IE EDUCATIONAL OBJECTIVES**

Revised: November 2004

K-State B.S.I.E. graduates can use modern engineering & scientific management tools to design, develop, implement & improve integrated systems to produce goods and services in a professional and ethical manner.

**Technical Performance Goals:**

1. Identify problems and improvement opportunities related to the production of goods and services.
2. Measure, evaluate, and improve production of good and services.
3. Develop and design production processes and systems to produce goods and services.
4. Implement efficient and effective production processes and systems to produce goods and services.

**Professional Performance Goals:**

1. Participate & function effectively in team environments.
2. Communicate in a professional role with capability to write technical reports and present results effectively.
3. Understand ethical & social responsibility.
4. Understand the individual’s responsibility for their professional development & career path.

**DEVELOPMENT OF PROGRAM OUTCOMES**

The K-State industrial engineering program outcomes define what we expect a K-State IE student to know and be able to do by the time they graduate. To develop these outcomes, we took ABET criterion 3 as a guideline and adapted the specific criterion to fit our program educational objectives. The faculty debated and eventually agreed upon the program outcomes that both reflected the heart of ABET criterion 3 and would lead to the achievement of our educational objectives. So for example, in criterion 3(a) “Apply knowledge of mathematics, science and engineering,” the IMSE faculty determined that the critical outcomes that we should directly assess were: the student’s ability to: 1. Apply matrix theory; 2. Use computer to reach numerical solutions; and 3. Apply knowledge of Statistics. These are the aspects of criterion 3(a) that are most important for K-State IE graduates.

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**K-STATE IE STUDENT LEARNING OUTCOMES**

IMSE graduates upon graduation are able to:

a) Apply knowledge of mathematics, science and engineering
   1. Use matrix theory.
   2. Use computer to reach numerical solutions
   3. Apply knowledge of Statistics

b) Design and conduct experiments and analyze and interpret data
   1. Design an experiment and collect data
   2. Implement appropriate statistical methods
   3. Identify significant factors of the experiment & make recommendations based on analytical results

c) Design a system, component or process
   1. Identify system requirements, constraints and assumptions
   2. Create alternative designs
   3. Evaluate alternatives

d) Function on a multi-disciplinary team
   1. Understand your role and the effect this has on a group
   2. Be a member of groups composed of various individuals
   3. Evaluate the contribution of team members

e) Identify, formulate, and solve engineering problems
   1. Identify objectives, constraints, assumptions and problems
   2. Model the problem
   3. Obtain solution to the problem
   4. Interpret and validate the solution.

f) Understand professional ethics
   1. Identify situations related to ethical dilemmas.
   2. Know IMSE professional and academic ethics.

g) Communicate effectively
   1. Write a technical report.
   2. Write an executive summary.
   3. Identify factors that make or break a professional presentation.

h) Understand impact of engineering solutions on society
   1. Know key Industrial Engineers and their contribution to society
   2. Understand the impact of design in a global, economic, environmental, and societal context.

i) Engage in lifelong learning
   1. Participate in IMSE Assembly and learn about current career requirements
   2. Develop a career plan
   3. Collect information from various sources and present results

j) Knowledge of contemporary issues
   1. Know contemporary issues facing IEs in industry
   2. Know skills needed for contemporary IE activities

k) Use modern engineering tools
   1. Use modern mathematical and computational tools
   2. Use modern statistical tools
   3. Use modern communication tools to communicate with class instructor and team members
Once the faculty agreed to the specific outcomes, we designed a direct assessment strategy for our program outcomes. This process started with brainstorming all the possible ways that we could assess each component of each criterion. After a list of possibilities was generated, the IMSE faculty chose courses in which to assign assessments based first of all on the course that seemed most appropriate for the assessment and then tried to spread the work of conducting direct assessments across the curriculum as evenly as possible.

The faculty member who teaches a course in which there is a defined assessment activity is expected to assess whether our program adequately prepares our students to achieve the assigned component of the allocated criterion. We did not specify how the instructor should assess this capability. Instead, the instructor must describe their assessment methods in their report so that we can review their methods and assure that the assessment methods are sound.

For example, IMSE student learning outcome (b) “Design and conduct experiments & analyze and interpret data,” is divided into three components. Component B1: Design an experiment and collect data, is assessed in labs 6, 8, and 9 by the faculty member who is assigned to teach the course IMSE 541: Statistical Quality Control. Labs 6, 8, and 9 each require students to design experiments. The IMSE 541 instructor must isolate and collect data about the student’s ability to design experiments in these labs and report the results to the IMSE faculty using a standard report format.

Similarly, Outcome a3 – Apply knowledge of statistics is assessed in three different ways. First, in IMSE 643: Industrial Simulation, students must use statistics to compare alternatives. In IMSE 623: Ergonomics, the student’s ability to analyze and interpret project results is examined. Finally, IMSE 541: Statistical Quality Control requires students to solve various data analysis problems using statistical foundations they learned in prerequisite statistical courses – STAT 510: Introduction to Probability and Statistics I and STAT 511: Introduction to Probability and Statistics II. Therefore, we chose to assess student capability to apply knowledge of statistics in the IMSE 541 course. Faculty in these courses isolate the student’s ability to apply knowledge of statistics and report their findings.

Each IMSE student learning outcome was broken into detailed assessment components that can be directly assessed according to the means that the IMSE faculty defined. Each student learning outcome component is assessed at least once each year. Our direct assessments are completed in required IMSE courses. These assessments are not course grades or scores of exams, but rather a direct evaluation of student capability to achieve the IE program outcome component. For example, the instructor used a specific question on the simplex method in an IMSE 560 exam to determine whether students can apply matrix theory to solve the Simplex method (criterion a1). We also use the score of a lab on hypothesis testing in IMSE 541 to assess student performance on student learning criterion a3 (apply knowledge of statistics).

Table 1 provides a summary of the assessment strategies used for IMSE program outcomes (a) – (f). The first row in the table identifies the student learning outcome while the second row breaks down a particular criterion into more detailed components. The third row identifies the assessment method for each outcome component.

**Process for Collecting Data**

IMSE faculty who teach required IE courses with an assigned student learning outcomes assessment are required to complete an assessment report for each assessment component assigned to that course. Required courses that are taught both semesters and have an assigned student learning outcome to be assessed will normally be assessed only during the fall semester.

The assessment report follows a template that was developed by the IMSE faculty. A completed assessment report provides the following information: components to be assessed; description of the assessment method; number of students in class; analysis and conclusion of student performance based on assessment standard; and corrective actions taken in this class or for the future classes. Faculty members submit their reports to the chair of the undergraduate committee.

**Metric Goal**

The IMSE faculty approved the following statement as a universal standard to judge whether our program outcomes are being achieved.

*At least 80% of our students should perform at an acceptable level for each assessment exercise. Acceptable is defined to mean the equivalent of a “C” in terms of the teacher’s definition of that grade.*

For example, one of the components for assessing our student learning outcome (a) is to “apply matrix theory to manually solve a problem with the simplex method.” If there are 20 students in the IMSE 560 – Operations Research I course, our minimum standard for this component is that at least 16 out of the 20 students in the class should obtain the equivalent of a “C” or better for the specific assignment/question that is used to assess this component.

**Evaluation**

Outcomes assessment reports are collected each semester and provided to our undergraduate studies committee. The committee arranges the reports in the order of student learning outcomes and summarizes the data. The committee meets to discuss the findings and to develop recommendations for actions to be taken based on the assessment reports. We collect all course action items in a summary report for each outcome. The summary report quickly shows the faculty whether each component of an outcome was achieved.

The summary reports from both semesters are discussed with the IMSE faculty at an annual retreat. We expect that each and every outcome component assessed should meet the department’s assessment standard. When the department standard is not met, the faculty work together to determine
### Table 1: K-State IMSE Program Outcomes Definitions and Assessment Strategy (revised 8/23/05)

<table>
<thead>
<tr>
<th>Assessment Strategy</th>
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<th>Assessment Strategy</th>
<th>Assessment Strategy</th>
<th>Assessment Strategy</th>
<th>Assessment Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Apply knowledge of mathematics, science and Engineering</td>
<td>(b) Design and conduct experiments &amp; Analyze and interpret data</td>
<td>(c) Design a system, component or process</td>
<td>(d) Function on a multi-disciplinary team</td>
<td>(e) Identify, formulate and solve engineering problems</td>
<td>(f) Understand professional ethics</td>
</tr>
<tr>
<td>1. Apply matrix theory. 2. Use computer to reach numerical solutions 3. Apply knowledge of Statistics</td>
<td>1. Design an experiment and collect data 2. Implement appropriate statistical methods 3. Identify significant factors of the experiment &amp; make recommendations based on analytical results</td>
<td>1. Identify system requirements, constraints and assumptions 2. Create alternative designs 3. Evaluate alternatives</td>
<td>1. Understand your role and the effect it has on a group 2. Be a member of groups composed of various individuals 3. Evaluate the contribution of team members</td>
<td>1. Identify objectives, constraints, assumptions and problems 2. Model the problem 3. Obtain solution to the problem 4. Interpret and validate the solution</td>
<td>1. Identify situations related to ethical dilemmas. 2. Know IMSE professional and academic ethics.</td>
</tr>
</tbody>
</table>
reasons behind the failure and to define correction/program improvement strategies. These actions are documented in the summary report and assigned to the appropriate faculty member for execution. In addition to the information listed in course reports, the outcome assessment summary form describes the action items, implementation issues, expected action completion dates, and faculty (or committee) responsible for assignments. This summary form is used to document program improvement actions and the execution and completion of each action item. The department maintains an archive of past assessment data that makes it easy for faculty to refer back to previous assessment reports to identify and analyze trends in assessment results as part of the annual IMSE faculty retreat.

The student learning outcomes are reviewed every other year by the IMSE Advisory Council and the IMSE faculty to make sure that our assessment strategy adequately reflects the achievement of program outcomes. This program improvement process is illustrated in Figure 1.

**FIGURE 1. K-STATE INDUSTRIAL ENGINEERING PROGRAM IMPROVEMENT PROCESS**

**EXAMPLES ASSESSMENT OF PROGRAM OUTCOMES**

Direct assessment data are summarized from class reports after the faculty have reviewed the data and outlined action plans. As an example, the major findings and action items from the Spring 2005 semester are provided below.

Out of a total of 31 program assessment components, 20 were assessed during the spring 2005 semester. Approximately sixty percent of the assessed components required no immediate action to be taken since at least 80% of the students performed at an acceptable level on the assessed component. For the rest of assessed components some type of action/recommendation was indicated. The recommendations...
range from very detailed, i.e., “A guided discussion will be conducted to help students identify and analyze the assumptions and constraints. VP (group leader) will verify and sign for the work each student has contributed” to more general “Faculty will discuss alternative ways to evaluate this component during the fall 2005 retreat.”

The faculty member responsible for each specific outcome/component was identified and charged with executing the recommended action with a specific deadline. Based on the results of the spring component/outcome assessment one general change to the process was recommended. The faculty suggested and agreed that grading spreadsheets should be provided with course reports so that distribution of student performance on assessment assignments can be reviewed if necessary. Component grades should be marked clearly and provided in grading spreadsheets if possible.

An example of the outcomes assessment summary form is provided in Table 2.

<table>
<thead>
<tr>
<th>Outcome/Components</th>
<th>Assessment Methods</th>
<th>Assessment Results</th>
<th>Conclusions, Recommendations and Actions</th>
<th>Completion Date</th>
<th>Faculty Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify system requirements, constraints and assumptions</td>
<td>IMSE 643 - three projects</td>
<td>All 36 of 36 reports performed C or better</td>
<td>The instructor needs to provide the information on number of students in the future report. Faculty also recommend the report of grading spreadsheets</td>
<td>FA 05</td>
<td>Faculty member #1</td>
</tr>
<tr>
<td></td>
<td>IMSE 555 Final project</td>
<td>All teams performed satisfactory on this component. The scores range from 80 to 100%</td>
<td>All requirement, constraints and assumptions should be provided in one section in the final project</td>
<td>SP 06</td>
<td>Faculty member #2</td>
</tr>
<tr>
<td></td>
<td>IMSE 580 Report this component in student journal</td>
<td>23 out 29 students (79%) performed at a satisfactory level at C or better.</td>
<td>Some students did not discuss this component in sufficient depth. A guided discussion will be conducted to help students identify and analyze the assumptions and constraints. VP (group leader) will verify and sign for the work each student has done.</td>
<td>SP 06</td>
<td>Faculty member #3</td>
</tr>
<tr>
<td>2. Create alternative designs</td>
<td>IMSE 643 - three projects</td>
<td>All 36 of 36 reports performed C or better</td>
<td>Same as C.1</td>
<td>FA 05</td>
<td>Faculty member #1</td>
</tr>
<tr>
<td></td>
<td>IMSE 555 Final project</td>
<td>All teams performed satisfactory on this component. The scores range from 80 to 95%</td>
<td>No recommendation.</td>
<td>N/A</td>
<td>Faculty member #2</td>
</tr>
<tr>
<td></td>
<td>IMSE 580</td>
<td>25 out of 29 (86%) students are able to provide an alternative “product” design</td>
<td>Faculty decided not to use 580 for assessing C2 in the future due to the variety of tasks in this class</td>
<td>N/A</td>
<td>Faculty member #3</td>
</tr>
<tr>
<td>3. Evaluate alternatives</td>
<td>IMSE 555 Final project</td>
<td>All teams performed satisfactory on this component. The scores range from 70 to 95%</td>
<td>More details in justification and values used in economical designs should be provided in future reports.</td>
<td>SP 06</td>
<td>Faculty member #2</td>
</tr>
<tr>
<td></td>
<td>IMSE 580 3 product design ideas Various alternatives for mfg. system</td>
<td>Assessment is anecdotal. No grades were given to students.</td>
<td>Faculty will discuss IMSE 580 for accessing C3 in the Fall 2005 retreat.</td>
<td>FA 05</td>
<td>All Faculty</td>
</tr>
<tr>
<td></td>
<td>IMSE 643 - three projects</td>
<td>All 36 of 36 reports performed C or better</td>
<td>Same as C.1</td>
<td>FA 05</td>
<td>Faculty member #1</td>
</tr>
</tbody>
</table>

**RESULTS AND CONCLUSIONS**

The system described in this paper has been implemented. Though it took a lot of effort to define the system, it requires relatively little extra work of the faculty to directly assess program outcomes. Though faculty members must isolate direct assessment data from other course work grading to assure that program outcomes assessments are not confounded, the additional work is relatively light and easily incorporated into the faculty member’s teaching/grading duties. Furthermore, data generated from this effort provides adequate and specific feedback to faculty to clearly identify whether the program is adequately preparing students to achieve program outcomes.

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