Validation of Workplace Competencies Sufficient to Measure ABET Outcomes

S. K. Mickelson, L. F. Hanneman, and Tomm Brumm
Iowa State University

Abstract

Taking the unique approach of addressing ABET criteria (a-k) as workplace competencies, Iowa State University College of Engineering partnered with Development Dimensions International (DDI), a global provider of competency-based performance management tools and services, to develop the processes and products to support this approach. Using "critical incident" based data gathering, the College and DDI brought together approximately one hundred constituents, representing ISU faculty, partnering international faculty, co-op and intern students, employers, parents and alumni to provide input to the design of the measurements of ABET (a-k). From the analysis of the “critical incidents” fourteen unique competencies, that are necessary and sufficient to measure ABET Outcomes (a-k) were identified. Each competency was clearly defined, independent of all the others. The fourteen competencies were then mapped to ABET (a-k). For each competency an independent set of observable and measurable key actions, which students may take to demonstrate their development, were defined. An appropriate measurement approach was identified for the key actions. Validation of the development process by the contributing constituents is presented in this paper. Also, curricular implementation is discussed.

Background

The background for the new competency based program at Iowa State University discussed in this paper is covered in a prior paper written by Mickelson et al., 2000. Some of the background will be covered here again for clarity in discussing the validation and implementation of the new program.

In the Fall of 1999, a constituency of over two hundred ISU faculty, partnering international faculty, co-op and intern students, employers, and alumni were asked to assist the ISU College of Engineering Cooperative Education and Internship Program in developing a next generation of performance assessment tools, ones that would be aligned with the ABET’s new Engineering Criteria 2000. Specifically, we set out to create a set of assessment metrics for the co-op and intern workplace that would be sufficient to document our students’ development and demonstration of the (a-k) student outcomes. Our hypotheses were that each these outcomes are too complex to measure directly and that each outcome represented some collection of workplace competencies necessary for the practice of engineering at the professional level. To support our efforts, the College collaborated with Development Dimensions International, Inc. (DDI), a global provider of competency-based performance management tools and services.
Constituents participated in DDI-facilitated focus sessions, using a “Critical Incident” data gathering technique Figure 1. In these sessions, they provided hundreds of examples of successful and unsuccessful demonstrations of the eleven Criterion 3 outcomes by engineering students and graduates. DDI professionals analyzed these “Critical Incident” stories and extracted fourteen dimensions or “ISU Competencies” that we believe are necessary and sufficient to demonstrate Criterion 3 (a-k) Outcomes:

- Engineering Knowledge
- Quality Orientation
- Cultural Adaptability
- Integrity
- Professional Impact
- General Knowledge
- Initiative
- Communication
- Analysis & Judgment
- Customer Focus
- Continuous Learning
- Innovation
- Teamwork
- Planning

Definitions for each of these ISU Competencies, specific to Iowa State University’s and the College of Engineering’s vision and missions, were then created. Each definition was designed to be clear, concise and independent of all others. Specific to each definition is a set of observable and measurable key actions that a student may take that demonstrates their development of that ISU Competency. These key actions are the basis of our assessment tools. Also associated with each ISU Competency is a set of representative career activities, which represent the workplace settings, used to describe a “Critical Incident”. Using the key actions and representative career activities described in the critical incidents, these fourteen ISU Competencies were mapped to the Criterion 3 outcomes in matrix form (Figure 2).
Validation

The contributions by the constituents in developing this unique set of assessment tools for cooperative education and engineering internship were very important. Use of these tools presents an opportunity for our students to derive value from their workplace experiences and significantly enhance their academic preparation for the practice of engineering at the professional level. The assessments provided by these tools will significantly enhance our ability to ensure that the value our students derive from these experiences is measured, understood and factored into the quality management of our curricula. Without proper validation of the assessment tools, little significance could be given to the use of the tools.

To validate the ISU Competency Matrix, a “Competency Selection Survey” (Figure 3) was sent to each of the 212 original constituents. In this survey, we first asked constituents to carefully read the competency definition and key actions and assess how important each competency is to a student’s or a graduate’s successful demonstration of the ABET outcome to
Figure 3. Competency selection survey, “Judgment and Analysis” competency example page
which that competency is correlated. Then we asked that, after considering the key actions, that they assess the probability that a student and/or graduate would have the opportunity to actually take those actions in each of the settings. Finally, we asked the degree to which the ISU Competencies collectively cover ABET Criterion 3 and the degree to which all fourteen of the ISU Competencies cover the practice of engineering at the professional level. Figure 3 also shows an example assessment form for one of the ISU Competencies, “Analysis and Judgment”, that was part of the survey.

Of the 212 constituents mailed a survey, 67 responded, a 32% return rate. The respondents represented industry and faculty from each of the engineering disciplines in the college. Each accredited program had a minimum of six respondents that identified with the degree. Thirty-six percent represented faculty, fifty-eight percent of whom are Iowa State alumni. Sixty-four percent of respondents represented industry; sixty-nine percent of whom are Iowa State alumni.

The average ratings for each competency in assessing how important each competency is to a student’s or a graduate’s successful demonstration of each of the ABET Outcomes to which that competency is correlated is shown in Figure 4 next to each corresponding X mark. A rating of a 1 is considered “not necessary”, 3 is “important”, 5 is “essential”. All but one average value was determined to be greater than or equal to that a 3. This confirms the previously determined associations between the ISU competencies and the corresponding ABET criteria.

![ABET OUTCOMES VERSUS ISU COMPETENCY MATRIX](image)

Figure 4. Importance rating of each Competency in the demonstration of the linked ABET (a-k) Outcomes

“Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition
Copyright © 2002, American Society for Engineering Education”
Next, the survey asked the respondents to focus on the key actions for each ISU Competency and to access from their experience the probability that a student or graduate would have, on average, to actually take those key actions in seven settings: the engineering workplace, the cooperative education/internship workplace, the traditional classroom, the laboratory, the capstone design course, professional-related extracurricular activity and non-profession related extracurricular activities. Examples of these results are illustrated for two ISU Competencies in Figures 5-6.

**Analysis & Judgement**

- **Key Actions:**
  - Identifies issues, problems, ...
  - Gathers information ...
  - Interprets information ...
  - Generates alternatives ...
  - Chooses appropriate action ...
  - Commits to action ...
  - Involves others ...
  - Values diversity ...

![Figure 5. The opportunity to develop and demonstrate analysis & judgment](image)

**Communication**

- **Key Actions:**
  - Organizes the communication ...
  - Maintains audience attention ...
  - Adjusts to the audience ...
  - Ensures understanding ...
  - Adheres to accepted conventions ...
  - Comprehends communication from others...

![Figure 6. The opportunity to develop and demonstrate communication](image)
Finally, we asked constituents to consider the ISU Competencies and their associated key actions collectively and to assess, using a defined rating scale, to what degree does this set of fourteen ISU Competencies cover the ABET Criterion 3 (a-k) Outcomes and to what degree does the set cover the practice of engineering at the professional level. Surprisingly, the response average to both questions was 89%. Figure 7, however, shows us that constituents analyzed these two questions very differently.

**Comprehensiveness of the Competencies**

![Bar Chart](chart.png)

Figure 7. Coverage of ABET outcomes and the practice of engineering at the professional level

**Future Efforts**

The implementation of a student-owned, e-career self-management system, delivering competency information, advising, assessment surveying, and documentation tools, is underway. The pilot program will report to each ABET accredited engineering program a free detailed report of the rank order of competencies for students who have completed cooperative or internship experiences for each semester. The engineering programs will also receive average student self-rankings and average supervisor rankings for their students for each semester. This feedback could be helpful in identifying competency weaknesses that need to be addressed in
any one of the potential settings for demonstrating these competencies, but particularly in the classroom, laboratory, capstone design course, and coop/intern settings.

The implementation of such an e-career self-management system in a large practice-oriented engineering college presents an outstanding opportunity to collect very large volumes of competency-based assessment data and to study the correlation of these data to curricular extra curricular and co-curricular processes, including experiential education, and to the success of our graduates.

The use of this e-career self-management system also has great potential for use in course assessment related to meeting the ABET Criteria. Pre- and post- assessment related to competencies addressed in the course or a major project can help instructors validate that course objectives are being meet.

Bibliography


STEVEN MICKELSON
Steven K. Mickelson is an Associate Professor of Agricultural and Biosystems Engineering (ABE) at Iowa State University. Dr. Mickelson is the teaching/advising coordinator for the ABE department. His teaching specialties include computer-aided graphics, engineering design, soil and water conservation engineering, and land surveying. His research areas include soil quality evaluation using x-ray tomography, evaluation of best management practices for reducing surface and groundwater contamination, and manure management evaluation for environmental protection of water resources. Dr. Mickelson has been very active in the American Society for Engineering Education for the past 17 years. He received his Agricultural Engineering Degrees from Iowa State University in 1982, 1984, and 1991.

LARRY F. HANNEMAN
Larry F. Hanneman is Director of Engineering Career Services and Adjunct Associate Professor of Chemical Engineering at Iowa State University. In his role as Career Services Director he has responsibility for delivering the College of Engineering's programs for Career Services, serving more than 5000 students and 500 employers; Experiential Education; serving more than 1000 students and 450 employers; and Strategic Industrial Partners/Employer Relations Programs. Prior to joining Iowa State University, Hanneman enjoyed a twenty-five year career in research and development at Dow Corning Corp., serving for twenty years as a lead recruiter and university liaison to Iowa State University.

THOMAS J. BRUMM
Dr. Thomas J. Brumm is Assistant Professor in the Department of Agricultural and Biosystems Engineering (ABE) at Iowa State University (ISU). Before joining the ISU faculty in 2000, he worked in the seed industry for 10 years. He leads the Agricultural Systems Technology curriculum in the ABE department. His technical expertise includes: near-infrared analysis technology; grain processing; grain and seed quality; and the evaluation of grains and oilseeds for food and feed use. He received Bachelor's degree from ISU, and his Master's degree from Purdue University, both in Agricultural Engineering. He received his Ph.D. from ISU in 1990 in Agricultural Engineering with a minor in Chemical Engineering.