

Development of Workplace Competencies Sufficient to Measure ABET Outcomes

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Abstract

The opening paragraphs of the ABET Engineering Criteria 2000 state: “To be considered for accreditation, engineering programs must prepare graduates for the practice of engineering at the professional level.” Criterion 3, Program Outcomes and Assessment, states, “Engineering programs must demonstrate that their graduates have...” and presents a list of eleven specific outcomes, now well known as, ABET (a-k) Outcomes.

Each of the ABET (a-k) Outcomes is too complex to measure directly; several are interdependent. Eight of outcomes address “an ability to”; two address “understanding”; and only one addresses the graduates’ “knowledge”. The direct measurement of “an ability to...” presents challenges very different from those of measuring knowledge and understanding.

Taking the unique approach of addressing the ABET (a-k) Outcomes as workplace competencies, Iowa State University (ISU) College of Engineering partnered with Development Dimensions International (DDI), Inc., 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 the ABET (a-k) Outcomes.

From the analysis of the “critical incidents,” fourteen unique dimensions, called “ISU Competencies”, were identified as necessary and sufficient to measure the ABET (a-k) Outcomes. Each Competency has been clearly defined, independent of all the others. The fourteen ISU Competencies have been mapped to the ABET (a-k) Outcomes. For each Competency an independent set of observable and measurable Key Actions, which students may take to demonstrate their development, have been defined. An appropriate measurement approach has been identified for the Key Actions. Validation of the development process by the contributing constituents is in progress.

Introduction

The Accreditation Board for Engineering and Technology (ABET) has instituted fundamental changes in accreditation procedures. A shift in focus from traditional "inputs" metrics to defining and measuring what is expected of graduates is well into implementation¹. Criterion 3, Program Outcomes and Assessment, states, “Engineering programs must demonstrate that their graduates have...” and

presents a list of eleven specific outcomes, and now well known, ABET (a-k) Outcomes (Table 1). This new accreditation process emphasizes the use of continuous quality improvement processes and professional preparation. Perhaps anticipating these challenges, George Peterson, Executive Director Accreditation Board for Engineering and Technology, stated,² " ... evaluating their outcomes are sophisticated activities with which most engineering educators have had little or no experience."

Outcome	Description
a	an ability to apply knowledge of mathematics, science, and engineering
b	an ability to design and conduct experiments, as well as to analyze and interpret data
c	an ability to design a system, component, or process to meet desired needs
d	an ability to function on multi-disciplinary teams
e	an ability to identify, formulate, and solve engineering problems
f	an understanding of professional and ethical responsibility
g	an ability to communicate effectively
h	the broad education necessary to understand the impact of engineering solutions in a global and societal context
i	a recognition of the need for, and an ability to engage in life-long learning
j	a knowledge of contemporary issues
k	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 1. ABET 2000 Criterion 3, Program Outcomes and Assessment: outcomes that all Engineering programs must demonstrate that their graduates have.

Paradigm Shifts

Consider three generally disconnected educational processes of accreditation, experiential education, and career self-management. Paradigm shifts in thinking about these three processes and their interdependence present exciting and unique opportunities for enhancing engineering education.

ABET Accreditation: ABET (a-k) Outcomes represent engineering workplace competencies, not learning outcomes. Knowledge is necessary; but it is not sufficient. One may apply a well-developed, globally implemented workplace competency technology that is supported by a twenty-five-year-old industry. Because most employers of engineers have been using this technology for more than a decade to select, hire, develop, promote and support engineering professionals' development, these constituents represent a valuable resource for developing and delivering ABET assessment tools.

Experiential Education: Engineering experiential education programs, such as cooperative education and internship, present the best, and, perhaps, the only true opportunity to directly observe and measure students developing and demonstrating ABET (a-k) Outcomes while engaged in *"the practice of engineering at the professional level."* Measurements made by employers of student outcomes present the best opportunity for feedback and curricular change with a cycle time that can address rapidly changing employer needs and expectations.

Engineering experiential education must be well integrated into the curricular quality management process, assessed and accredited (not delivered) independently.

Career Self-Management: Existing competency-based career self-management tools may be implemented in the higher education setting. Student owned, faculty facilitated processes (such as pre- and post-assessment after significant course or work events) may be used to define, measure, and document demonstrated outcomes. Measurements of the developing outcomes may be used to advise, coach and mentor the students' professional development.

Implementation of Paradigm Shifts

In the Fall of 1999, a constituency of over one 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 ABET (a-k) 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)³, a global provider of competency-based performance management tools and services.

Constituents participated in DDI-facilitated focus sessions, using a "Critical Incident" data gathering technique³. In these sessions, they provided hundreds of examples of successful and unsuccessful demonstrations of the eleven ABET (a-k) 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 the ABET (a-k) Outcomes:

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

A definition of each of these ISU Competencies, specific to Iowa State University's and the College of Engineering's vision and missions, has been created. An example, Continuous Learning, is given in Figure 1. Each definition is 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. (The Key Actions for Continuous Learning is given in Figure 2.) These Key Actions will be the basis of our future 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" (Figure 3). Using the Key Actions and Representative Career Activities that were used to describe the Critical Incidents, these fourteen ISU Competencies have been mapped to the ABET (a-k) Outcomes in matrix form (Table 2).

CONTINUOUS LEARNING

Actively identifying new areas for learning; regularly creating and taking advantage of learning opportunities; using newly gained knowledge and skill on the job, and learning through application.

Figure 1. Definition for the “Continuous Learning” competency

Targets learning needs—Seeks and uses feedback and other sources of information to identify appropriate areas for learning.
Seeks learning activities—Identifies and participates in appropriate learning activities (e.g., courses, reading, self-study, coaching, experiential learning) that help fulfill learning needs.
Maximizes learning—Actively participates in learning activities in a way that makes the most of the learning experience (e.g., takes notes, asks questions, critically analyzes information, keeps on-the-job application in mind, completes required tasks).
Applies knowledge or skill—Puts new knowledge, understanding, or skill to practical use on the job; furthers learning through trial and error.
Takes risks in learning—Puts oneself in unfamiliar or uncomfortable situation in order to learn; asks questions at the risk of appearing foolish; takes on challenging or unfamiliar assignments.

Figure 2. Key Actions for the “Continuous Learning” competency

REPRESENTATIVE CAREER ACTIVITIES:

- Participating in applied projects that require new knowledge.
- Designing and/or performing experiments that require new knowledge.
- Designing products that require engineers to learn new subject areas.
- Questioning ethical professional responsibility when undertaking sensitive tasks.
- Engaging in discussions on professional responsibility.
- Taking courses outside of the “hard sciences” while in the workplace.
- Using feedback from “customers” to learn new material that will improve a product.
- Reading non-assigned books to learn new topics.
- Attending conferences and seminars.
- Learning local, state, and federal laws to understand impact on engineering practices.
- Learning new software programs to design a product or solve a problem.
- Participating in experiential education opportunities.

Figure 3. Representative Career Activities for the “Continuous Learning” competency

ABET Criterion 3 Outcomes	ISU Competency (Dimension)													
	Engineering Knowledge	General Knowledge	Continuous Learning	Quality Orientation	Initiative	Innovation	Cultural Adaptability	Analysis & Judgment	Planning	Communication	Team-work	Integrity	Professional Impact	Customer Focus
(a) An ability to apply knowledge of mathematics, science, and engineering	X		X		X			X						
(b) An ability to design and conduct experiments, as well as to analyze and interpret data	X		X	X	X	X		X	X		X			X
(c) An ability to design a system, component, or process to meet desired needs	X		X	X	X	X	X	X	X	X	X			X
(d) An ability to function on multidisciplinary teams					X		X	X	X	X	X	X	X	X
(e) An ability to identify, formulate, and solve engineering problems	X		X	X	X	X		X		X	X			X
(f) An understanding of professional and ethical responsibility		X	X	X			X	X				X		
(g) An ability to communicate effectively		X			X					X			X	X
(h) The broad education necessary to understand the impact of engineering solutions in a global & societal context	X	X	X				X	X						
(i) A recognition of the need for, and ability to engage in, life-long learning			X		X									
(j) A knowledge of contemporary issues		X	X				X	X						
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	X		X	X	X		X	X						

Table 2. ABET Criterion3 Outcomes vs. ISU Competency Matrix

There are some interesting observations to be made and correlations to be discovered in this matrix. For example, Initiative is linked to each Outcome that asks us to measure “an ability to ...”. Outcome (c), “an ability to design a system...” requires the greatest number of ISU Competencies. Interestingly, the Continuous Learning and Analysis & Judgment competencies are the most highly leveraged to the successful demonstration of these Outcomes.

Validation

To validate the ISU Competency Matrix, a survey was sent to each of the original constituents. In this survey, we first asked them 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 each of the ABET Outcomes to which that competency is correlated. Then we asked that, after considering the Key Actions, they offer their assessment of the probability that a student and/or graduate will have the opportunity to take those actions to develop and demonstrate that competency in each setting. Finally, we asked the degree to which the ISU Competencies collectively cover ABET Criterion 3 Program Outcomes (a-k) and the degree to which all of the ISU Competencies cover the practice of engineering at the professional level. Figure 4 shows an example assessment form for one of the ISU Competencies, “Initiative”, that was part of the survey. As of this writing, approximately 40 percent of the constituents have completed and returned their survey. This validation data will be analyzed in the late spring of 2001.

The contributions by the constituents in developing this unique set of assessment tools for cooperative education and engineering internship are 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.

Future Efforts

Using experiential education performance assessment based on these metrics, our ABET (a-k) Outcomes quality management approach will be validated against traditional outcomes measures, such as, in-profession placement at graduation. The implementation of a student-owned, e-career self-management system, delivering competency information, advising, assessment surveying, and documentation tools, is planned.

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 processes, including experiential education, and to the success of our graduates.

ABET Outcomes							
A	B	C	D	E	G	I	K

5 – Essential
4 – Very Important
3 – Important
2 – Useful, but not essential
1 - Unnecessary

Refer to the ABET Outcomes vs. ISU Competency Matrix.

INITIATIVE

Taking prompt action to accomplish objectives; taking action to achieve goals beyond what is required; being proactive.

Key Actions:

- Responds quickly**—Takes immediate action when confronted with a problem or when made aware of a situation.
- Takes independent action**—Implements new ideas or potential solutions without prompting; does not wait for others to take action or to request action.
- Goes above and beyond**—Takes action that goes beyond job requirements in order to achieve objectives.

REPRESENTATIVE CAREER ACTIVITIES:

- Checking validity of processes or tools without being asked.
- Immediately finding information for use on a project or product.
- Responding effectively with minimal direction by identifying appropriate information, tools, or people.
- Creating new and effective solutions to problems.
- Responding quickly to feedback.
- Initiating discussions with team members when faced with a problem.
- Developing solutions to engineering problems in a timely manner.
- Independently conducting follow-up reviews of products and/or customer satisfaction.

What is the probability that a student/graduate will have the opportunity to develop and demonstrate this competency in the following settings? Please give a probability rating between 0 - 100%.

INITIATIVE	
Setting	Rating
Engineering Coop/Intern workplace	
Full-time engineering employment workplace	
Classroom - Traditional setting	
Classroom - Laboratory setting	
Classroom - Capstone design setting	
Extracurricular Activities - Engineering profession related.	
Extracurricular Activities - Non-engineering profession related	

Figure 4. Assessment form for the ISU “Initiative” competency

Bibliography

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