The Data Are In: Student Workplace Competencies in the Experiential Workplace

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Abstract

Workplace competencies describe the skills, knowledge and behaviors students will need to be successful as engineers. Experiential education (co-ops and internships) is critical to the preparation of engineering students as practicing professionals. The experiential workplace is one of the best places for students to develop and demonstrate workplace competencies. At Iowa State University, we have been assessing the workplace competencies of engineering students in the experiential workplace for the past four years. This paper discusses the process by which we identified the most important workplace competencies in partnership with our constituents (employers, faculty, experiential education students, and parents), the assessment tools used, the results across from the last four years, and the implications of these results for engineering education at Iowa State, outcomes assessment and continuous improvement in our curricula.

Introduction

Many engineering programs are well on their way to adopting the outcomes-based ABET criteria, now well know as the ABET (a-k) Outcomes[1]. This new accreditation process emphasizes the use of continuous quality improvement and measured outcomes for professional preparation.

Eight of the ABET (a-k) Outcomes address "an ability to…"; two address "understanding"; and only one addresses "knowledge." The direct measurement of "an ability to…" presents challenges very different from those of measuring knowledge and understanding. George Peterson, ABET Executive Director, stated, "…evaluating their outcomes are sophisticated activities with which most engineering educators have had little or no experience"[2].

There is no universal approach to using the ABET outcomes-based criteria. Each program must interpret the criteria as they see fit for them. A cursory examination of the *Journal of Engineering Education* reveals numerous different approaches to implementing ABET criteria. A good example is the paper by Felder and Brent.[3]

At Iowa State University (ISU), we realized that we did not know how to directly measure "an ability." We believe that such complex abilities cannot be observed directly – they must be inferred from actual performance. We hypothesize that each of the outcomes are multidimensional and represent some collection of workplace competencies necessary for the practice of engineering at the professional level.

In today's workplace, employers need different measures to use when recruiting and retraining employees[4]. Competencies fulfill this need by focusing on what people can do with what they learn, not solely on the acquisition of skill or knowledge[5]. We define workplace competencies as the application of knowledge, skills, attitudes and values, and behaviors, as identified by Elwell[6], in the engineering workplace. They are "the result of integrative learning experiences in which skills, abilities and knowledge interact" to impact the task at hand.[7] As such, competencies are directly measurable through key actions or demonstrations of the existence of those competencies in the individual.

A list of such competencies could be endless. Which are the most important relative to students becoming successful engineers? Rogers[8] stated that "…faculty must determine what competencies that the student must demonstrate in order to know that they have achieved the outcome." She also stated that "key stakeholders need to be involved in determining which competencies should be the focus from all the possible competencies for any given outcome." We could not agree more.

Experiential education can be broadly defined as a philosophy and methodology in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, and clarify values[9]. In the College of Engineering at Iowa State University, we use a much narrower definition for engineering experiential education. For us, it is work experience in an engineering setting, outside of the academic classroom, and before graduation. Iowa State engineering students work in either a cooperative education program (alternating periods of full-time academic college training and full-time work experience of approximately equal length) or an internship (a single work period of institutional supervised full-time employment of a summer or at least one semester)[10]. The experiential workplace for us is where students are working when on an internship or participating in a cooperative education program.

Engineering experiential education programs, such as cooperative education and internships, present the best place to directly observe and measure students developing and demonstrating competencies while engaged in the practice of engineering at the professional level. Measurements made by employers of student competencies 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 and not assessed separately.

This has at least two important implications for engineering educators at ISU. First, we must re-examine how we use the classroom in educating future engineers, broadening our focus to include competency development. Second, these results confirm our belief that experiential education (internships) is critical to students becoming successful in the engineering workplace.
With all this in mind, we identified the workplace competencies most important to our stakeholders to the practice of engineering at the professional level, how those competencies

might encompass the ABET (a-k) Outcomes, and began to assess them in ISU engineering students on co-op and internship experiences.

Methods

Identification and Validation of Competencies

In the Fall of 1999, we engaged a constituency of 212 ISU employers, alumni, faculty, partnering international faculty, and co-op and intern students, to assist the ISU College of Engineering Cooperative Education and Internship Program in developing performance assessment tools, ones that would be aligned with the ABET's then new Engineering Criteria 2000. The College collaborated with Development Dimensions International, Inc. (DDI), a global provider of competency-based performance management tools and services[11].

This process[12] identified and validated fourteen "ISU Competencies" that encompass the eleven ABET Outcomes:

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

Note that these are "ISU Competencies" that resulted from dialogue with our key stakeholders (ISU employers, faculty, experiential education students, and parents). Other programs or institutions might develop a different set of competencies.

Based on their experience, DDI provided definitions for each competency. The College's Experiential Education Committee reviewed these definitions and Key Actions, and revised them to be consistent with Iowa State University's and the College of Engineering's vision and missions. 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. These Key Actions are the basis of our assessment tools. An example of one workplace competency, Innovation, is given in Table 1.

Also associated with each ISU Competency is a set of Representative Career Activities, which represent the workplace settings. These are actual statements mined from the Critical Incidence stories from focus groups during the development stage of the competency selection. A complete listing of the ISU Competencies can be found at <http://learn.ae.iastate.edu>.

This process also resulted in a mapping of the fourteen ISU Competencies to the ABET (a-k) Outcomes. A matrix of this mapping is given in Table 2. Thus, measuring the successful achievement of an outcome is dependent on the development and demonstration of multiple competencies.

The process of identifying and validating the ISU Competencies also confirmed our contention that engineering experiential education programs, such as our cooperative education and internships, present the best place to directly observe and measure students developing and demonstrating competencies while engaged in the practice of engineering at the professional level. For most of the ISU Competencies, stakeholders ranked the engineering workplace as the place to best develop and demonstrate the Competencies, followed by coop/internships. The classroom consistently ranked last. Other settings included laboratories, professional activities, nonprofessional activities, and capstone design activities.

Competency Assessment in Experiential Education

The College of Engineering, through the office of Engineering Career Services, has implemented competency-based assessment tools for the engineering experiential education workplace, using Online Performance and Learning (OPAL™)[13]. OPAL™ is DDI's web-based competency development and performance management software that provides assessment, development, coaching and learning tools. OPAL™ was customized to present the ISU Competencies, corresponding Key Actions, and assessment surveys. To receive academic credit for their work experience, each student is required to complete the standard self-assessment and to ensure that their supervisor completes the same assessment of the student. This system has been in place since the fall semester of 2001.

A standard assessment survey consists of rating the student on the following question: "When given the opportunity, how often does this individual perform the action?" The rating for each Key Action is on a Likert scale (1 = never or almost never; 2 = seldom; 3 = sometimes; 4 = often; 5 = always or almost always). A total of 61 Key Actions must be rated in the survey, which takes about 20 to 30 minutes to complete.

DDI recommends that we look more carefully at patterns than a mean value. A ranking of the fourteen competencies (1 = highest mean score value, 14 = lowest mean score value) were made. While data are available for individual programs within the College, college-wide rankings are presented here. Data from nine different assessment periods, beginning with the fall semester of 2001, had a total of 2,382 responses (Table 3.) Limitations of the data analysis portion of the OPAL™ software did not allow us to rank the competencies across all reporting periods.

Results of Competency Assessment in Experiential Education Settings

Table 4 lists the results from one typical assessment period, the summer session of 2003. In this case, there was a great deal of agreement between the student and the supervisor. They agreed on the top five competencies: Integrity, Cultural Adaptability, Professional Impact, Quality Orientation and Teamwork. They also agreed on the bottom three competencies: Customer Focus, Communication and Innovation.

Table 5 summarizes the results of the ranking comparisons across all nine assessment periods. Some very interesting trends appear. For example, students believe, and supervisors agree, that they adequately demonstrate the competencies of Integrity, Quality Orientation, Cultural Adaptability, and Teamwork – these competencies were ranked in the top in nearly all assessment periods. Students tend to rank themselves lower on Professional Impact than do their supervisors (students five times, supervisors eight times). Students sometime appear to "over-rank" their planning competency (four times in the top five) than do their supervisors (zero times).

There is clear agreement between students and supervisors that the least-demonstrated competencies are Innovation, Communication and Customer Focus – these competencies were ranked in the bottom five in all assessment periods. Students rank their Initiative competency lower than their supervisors (nine times in the bottom five vs. three times in the bottom five). Supervisors ranked Analysis and Judgment, and General Knowledge in the bottom five more often than did students. It should be noted though, that on the average all fourteen competencies ranked above a "3", which would indicate that our engineering students are at least "sometimes" demonstrating each of the ISU competencies in the engineering workplace.

Implications for Programs

It is clear that our students are developing and demonstrating the competencies of Integrity, Quality Orientation, Cultural Adaptability and Teamwork. Changes in our curriculum and educational experiences need not be made to address these competencies. They are consistently ranked higher by both student and supervisor.

However, we face the challenge of helping students develop the Innovation, Communication and Customer Focus competencies, all consistently ranked lower by both student and supervisor. One could also argue that we should also address the Analysis and Judgment, and General Knowledge competencies, since they tended to be ranked lower by supervisors.

These results should cause engineering educators at Iowa State, and elsewhere, to pause and reflect on their programs. On one hand, our students seem to be demonstrating a number of desirable qualities (competencies) as they participate in experiential education. However, the five competencies that are consistently ranked lower by supervisors (Initiative, Communication, Customer Focus, Analysis and Judgment, and General Knowledge) are mapped to outcomes many would consider essential to the professional practice of engineering. While we believe we have excellent engineering education programs, there is definitely room for improvement. This type of information is what educators need to improve their programs and truly make assessment part of the continual improvement process.

At Iowa State University, engineering programs are beginning to implement competency-based learning and assessment, and using the results of assessments for continuous curriculum improvement. For example, the Department of Agricultural and Biosystems Engineering is implementing a competency-based assessment strategy, and is identifying the degree to which the engineering courses they offer address the 14 ISU Competencies.[14] They are providing more opportunities for their students to develop and demonstrate the Innovation competency across their entire curriculum by incorporating more open-ended problems and case-studies in their classes, motivated to a large degree by the results of experiential education assessments.

Conclusions

If our competencies are the lens through which we view student learning outcomes, competencies must be integral to our engineering education programs. "Competencies can have a stronger impact on student learning when they are linked and embedded within specific courses and across both general education and academic majors"[15]. Competency-based learning involves redefining program, classroom, and experiential education objectives as competencies or skills, and focusing coursework on competency development. Competencies are transparent; that is, all participants in the learning process understand the learning goals and outcomes. Competencies provide students with a clear map and the navigational tools needed to move expeditiously toward their goals[16].

We now have a mechanism at Iowa State (competency assessment in experiential education), along with other assessment measures, to help us identify ways in which students both achieve and fall short of the desired outcomes. How we use this assessment data will ultimately determine the success of our graduates in the engineering workplace.

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Table 1. The "Innovation" workplace competency.

Definition	Generating innovative solutions in work situations; trying different and novel ways to deal with work problems and opportunities.
Key Actions	1. Challenges paradigms. Identifies implicit assumptions in the way problems or situations are defined or presented; sees alternative ways to view or define problems; is not constrained by the thoughts or approaches of others. 2. Leverages diverse resources. Draws upon multiple and diverse sources (individuals, disciplines, bodies of knowledge) for ideas and inspiration 3. Thinks expansively. Combines ideas in unique ways or makes connections between disparate ideas; explores different lines of thought; views situations from multiple perspectives; brainstorms multiple approaches/solutions. 4. Evaluates multiple solutions. Examines numerous potential solutions and evaluates each before accepting any. 5. Ensures relevance. Targets important areas for innovation and develops solutions that address meaningful work issues.
Representative Career Activities	• Designing and conducting novel engineering experiments (i.e., novel topics, methods, etc.) that can be readily applied in a work setting • Assessing different methodologies and analytical procedures. • Constructing new tools for use in experiments. • Developing innovated processes to use on engineering products • Developing new products that improve work processes • Addressing engineering problems in unique ways to come up with a solution. • Validating assumptions of clients, supervisors, and team members. • Developing novel solutions rather than "re-configuring" previous, non-effective solutions.

Table 2. Matrix of ABET (a-k) Outcomes vs. ISU Competencies[12].

ABET Criterion 3 Outcomes	ISU Competency													
	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 3. Number of respondents[a] for each assessment period.

Assessment Period	Number of Respondents
Fall 2001	423
Spring/Summer 2002	293
Summer 2002	326
Fall 2002	275
Spring 2003	122
Spring/Summer 2003	153
Summer 2003	309
Fall 2003	247
Spring/Summer 2004	234
TOTAL	**2,382**

[a]One respondent = one pair of student self-assessing and her/his supervisor assessing the student.

Table 4. Competency ranking of all Iowa State University engineering interns in the Summer of 2003 (n=309).

Self	Ranking	Supervisor
	Top	
Integrity	1	Integrity
Cultural Adaptability	2	Cultural Adaptability
Professional Impact	3	Quality Orientation
Quality Orientation	4	Teamwork
Teamwork	5	Professional Impact
	Bottom	
Engineering Knowledge	10	Analysis & Judgment
Initiative	11	General Knowledge
Communication	12	Customer Focus
Customer Focus	13	Communication
Innovation	14	Innovation

Table 5. Summary of ranking comparisons across all nine assessment periods.

Competency	Self	Supervisor
	Number of Assessment Periods Ranked in the Bottom 5	
Innovation	9	9
Communication	9	9
Customer Focus	9	9
Initiative	9	3
Analysis and Judgment	2	8
General Knowledge	3	7
	Number of Assessment Periods Ranked in the Top 5	
Integrity	9	9
Quality Orientation	9	9
Teamwork	8	7
Cultural Adaptability	8	7
Professional Impact	5	8
Planning	4	0