Direct Assessment of Student Learning Outcomes by Analysis of Performance Evaluation of Student Employees

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ABSTRACT

Experiential learning provides opportunities for engineering students to engage in the engineering workforce prior to completion of their studies and provides employers with an opportunity to assess the suitability of a particular student for employment as an engineering upon graduation. The assessment conducted by employers of student workers may also be used to provide a quantifiable direct assessment of student achievement of the standard outcomes required for accreditation of bachelor of science degree programs in engineering by the engineering accreditation commission of ABET. The objective of this work is to demonstrate the manner in which employer assessment of student work may be used to assess student learning and document the continuous improvement of engineering curricula. Exemplar results are presented to illustrate a statistical process for student learning outcomes assessment. The work concludes that analysis of employer assessment of student employee performance provides valuable insight for curricular design. Future work is recommended to study the correlation between observed performance metrics and key factors influencing student performance and to study the cross correlation between employer assessment and student self-assessment.

Keywords: Assessment, Co-operative Education, Experiential Learning

1. INTRODUCTION

The Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET) has established eight criteria for all programs seeking accreditation from the EAC. Programs seeking accreditation must "*demonstrate that they satisfy all of the following General Criteria for Baccalaureate Level Programs*" (ABET, 2014).

1. *Students*
2. *Program Educational Objectives*
3. *Student Outcomes*
4. *Continuous Improvement*
5. *Curriculum*
6. *Faculty*
7. *Facilities*
8. *Institutional Support*

This paper focuses on direct assessment of student achievement under ABET EAC Criterion 3 - Student Outcomes and 4 - Continuous Improvement using performance evaluations of students by their immediate supervisors at the conclusion of co-operative education work experience blocks in an industry setting. Programs seeking EAC review during the 2014-15 academic year review cycle must demonstrate (ABET, 2014)

> ***Criterion 3. Student Outcomes***
>
> *The program must have documented student outcomes that prepare graduates to attain the program educational objectives ... Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.*

(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 within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary 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, economic, environmental, 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.

Criterion 4. Continuous Improvement

The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program. Other available information may also be used to assist in the continuous improvement of the program.

Figure 1 illustrates the four constituencies engaged in providing input to the establishment and revision of mechanical engineering program objectives and student learning outcomes. Students provide input to the ME program design through indirect assessment instruments such as exit surveys and student club feedback and direct

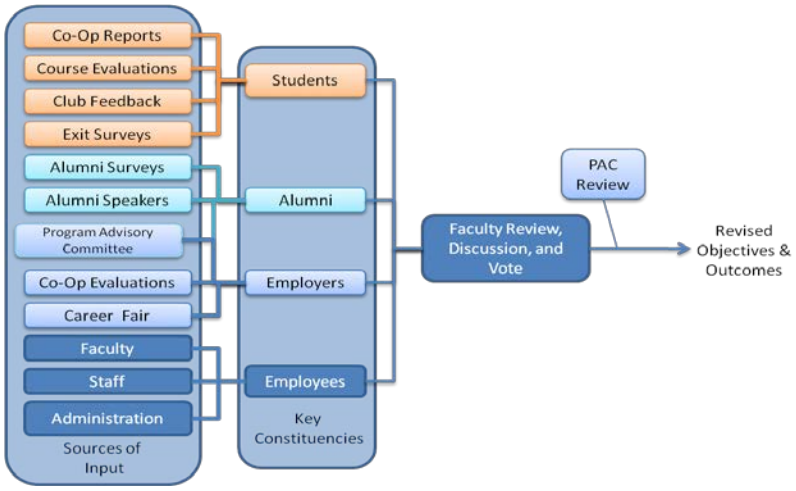

Figure 1. Sources of inputs from each constituency, and how their needs are reflected in mechanical engineering program educational objectives and student learning outcomes (RIT ME, 2010).

assessment methods such as course evaluations and reports of the work experiences while on co-operative education work blocks. Alumni provide indirect feedback through surveys and directly when they are brought to campus as speakers to share their perspectives. Employers provide feedback indirectly through focus groups conducted with engineering employers annually at the Rochester Institute of Technology (RIT) career fair and

directly through assessments of courses, course sequences and individual faculty conducted by the Program Advisory Committee (PAC). Employers provide a wealth of direct assessment feedback through their assessment of student workers at the conclusion of each co-operative education work block. RIT faculty, staff and administration provide both indirect feedback through instruments such as surveys and direct assessment through evaluation of student work, assessment of employee performance and standardized testing. The input from all of these stakeholders is provided to the faculty of the mechanical engineering department, who have responsibility for establishing, revising, and improving the program objectives and Student Learning Outcomes (SLOs).

In addition to the general Student Learning Outcomes (SLO) denoted as *"a-k"* and required by the ABET EAC, the RIT Mechanical Engineering (ME) Department has adopted one additional over-arching ME Program Outcome (MEPO) of **"preparing students to engage in the mechanical engineering profession."** There is no directly corresponding ABET EAC Student Learning Outcome, and this MEPO is used to maintain the focus of the RIT ME program of study on career-oriented education. The primary focus of this article is on SLO assessment. However, assessment of the MEPO will be briefly discussed to provide a complete context for the use of employer assessment of student worker performance as one element of a comprehensive outcomes assessment method to satisfy ABET EAC Criterion 3 and Criterion 4.

2. LITERATURE REVIEW

Direct measures of assessment involve individual students demonstrating that they have achieved a particular skill. In contrast, indirect measures of assessment may imply that students have achieved a particular skill, but student work product or performance is not directly measured (Spurlin, 2008). For example, direct measures would include exams, technical reports or presentations and employer supervisor evaluations. Indirect measures would include exit or alumni surveys (Lending 2010), employer focus groups, retention, graduation and placement rates and graduate school admissions. Both direct assessment and indirect assessment (Lending 2005) are widely used in higher education.

Course-based direct assessment can require significant effort on the part of faculty, however it is the gold standard on how to directly measure performance (Gnanapragasam 2008; Yue 2007; Burge and Leach 2010; McKenzie 2004; Meyer2005). However, by course-based measures alone, it is difficult to assess professional skills such as communication, teamwork, understanding of ethics and contemporary issues, professionalism and leadership (Shuman, 2013). Employer-based direct assessment has not been done to a large extent (Rainsbury1998; Brumm 2006; Jaekel 2011). Many times employer feedback is used only as indirect assessment via population survey. Co-op employer performance evaluations provide the benefit of direct formative assessment, while the student is going through the program rather than just after graduation. In this paper, we describe a process and report data that allows the direct assessment of student performance with minimal effort.

3. INSTITUTIONAL BACKGROUND AND CONTEXT

The history of Rochester Institute of Technology (RIT) provides insight into the defining role that co-operative education plays in the learning environment that RIT students participate in as they prepare "for successful careers in a global society." (RIT ME, 2010). Colonel Nathaniel Rochester founded the *Rochester Athenaeum* in 1829 as an association “for the purpose of cultivating and promoting literature, science, and the arts.” In 1847 the *Rochester Athenaeum* merged with the *Mechanics Literary Association*, founded in 1836 by W. A. Reynolds, to form the *Rochester Athenaeum and Mechanics Association*. Distinguished speakers during this time period included Charles Dickens, Ralph Waldo Emerson, Oliver Wendell Holmes, and Frederick Douglass. As the *Rochester Athenaeum and Mechanics Association* matured, this led to formation of the *Mechanics Institute* in 1885. The first class offered at the *Mechanics Institute* was mechanical drawing, held in the evening on November 23, 1885. Thus, the Mechanical Engineering (ME) Department of the modern RIT heralds its roots back to the first class of the *Mechanics Institute*. The ME Department has sustained an integrated co-operative working and learning philosophy throughout its history (RIT ME, 2010).

Today, RIT is a private coeducational university in upstate New York, USA offering more than 200 academic programs. The career orientation of RIT program offerings reflect changes in technology and engineering and are designed to cultivate an appreciation of, and desire for, life-long learning in all students. The faculty focuses on integrating professional practice into the academic programs offered by the university. Nearly 30% of RIT's 18,292 students are women, and RIT's full-time undergraduate students include 1,200 deaf and hard-of-hearing students. Most of RIT's deaf and hard-of-hearing students receive support services such as American Sign Language (ASL) interpreting services through the National Technical Institute for the Deaf (NTID) at RIT. RIT consists of ten colleges and degree granting academic units (http://www.rit.edu/overview/rit-in-brief).

The Kate Gleason College of Engineering (KGCOE) at RIT offers career-oriented degree programs. With an enrollment of 2,584 undergraduate and 645 graduate students, the KGCOE offers Advanced Certificates, Bachelor of Science (BS), Master of Engineering (MEng), Master of Science (MS) and doctoral (PhD) degree programs. KGCOE includes undergraduate and graduate degree programs in mechanical, electrical & micro-electronic, computer, industrial & systems, chemical and biomedical engineering, as well as graduate programs in quality & applied statistics, product development and manufacturing leadership. All BS programs in the KGCOE require five years of study. The first two years of KGCOE BS programs engage students in on-campus classroom and laboratory learning environments. During the third and fourth years, students alternate between time on campus and time working as a full time, paid, employee in a corporate co-operative education (co-op) setting. During this extended "junior year" students spend the equivalent of one academic year on campus and 12 to 15 months in a series of engineering work assignments referred to as "co-op blocks." The co-op program at RIT is the fourth oldest and one of the largest in the world. RIT places more than 2,600 students in 4,000 co-op positions with 1,300 employers every year, and more than 600 companies visit RIT annually to conduct 6,500 employment interviews. Students typically return to campus during their fifth year of study to complete their technical elective courses and participate in the KGOCE multi-disciplinary capstone design program. Approximately two thirds of ME graduates accept a position with one of their co-op employers while the remaining graduates may continue graduate studies, work or become entrepreneurs. (http://www.rit.edu/kgcoe/about/fast-facts).

As a result of this extensive co-op program, the Mechanical Engineering (ME) Department has excellent relationships with a wide variety of employers. Every student who completes a co-op block is required to complete a formal written assessment of their experience with the employer and meet with their faculty advisor upon return to the campus, to reflect on how the co-op experience may influence the students academic and career preparation. The immediate supervisor of each co-op student placed at a corporate partner is also required to complete a formal direct assessment of the co-op students performance as an engineer during their co-op block. Both the student and employer reports have been conducted on-line for over a decade. RIT has excellent placement data for co-op employers, updated on a quarterly basis, enabling the university to track trends in industry sectors and respond quickly to changing market conditions, which may not be as obvious when trying to track full-time placement statistics on smaller student populations at the time of graduation. Each employer is required to complete an on-line employer evaluation related to the performance of each student under their direct supervision at the conclusion of the student's work period.

3. METHODS

The supervisor's direct evaluation of student performance provides a rich data set for conducting assessment of Student Learning Outcomes (SLO's) as required by Criterion 4 for accreditation by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET). Analysis of co-op evaluation data for the period from June 2004 (Summer 2003-4 Quarter) through August 2012 (Summer 2012-4 Quarter) is presented here. During these 37 seven quarters (response periods) 5,667 supervisory assessments of more than 2,000 unique student co-op blocks at more than 700 company locations were collected. Note that one student doing two co-op blocks with the same company at the same location would count as two placements. A summary of the number of unique employer evaluations completed during each response period is presented in Table 1.

Table 1. Number of employer evaluations of student performance completed during each response period. Each evaluation represents a one-quarter work period for one student.

Academic Year (AY)	Fall (-1) Quarter (Sep - Nov)	Winter (-2) Quarter (Dec - Feb)	Spring (-3) Quarter (Mar - May)	Summer (-4) Quarter (Jun - Aug)	AY Total
AY 2003				217	**217**
AY 2004	178	109	77	267	**631**
AY 2005	162	103	99	268	**632**
AY 2006	165	88	104	264	**621**
AY 2007	105	64	95	275	**539**
AY 2008	126	75	96	184	**481**
AY 2009	107	89	112	234	**542**
AY 2010	118	107	138	264	**627**
AY 2011	144	111	138	297	**690**
AY 2012	201	139	130	217	**687**
Column Sum	**1306**	**885**	**989**	**2487**	**5667**

Each employer is asked to evaluate several attributes of performance for each student employee. Several of the employer feedback assessment attributes are directly related to the ABET a-k student learning outcomes, as indicated in the first column of Table 2. The employer is provided with a "prompt" to guide their assessment of each student employee. The supervisor was asked to *"Rate the student on his/her performance in the following areas using an integer rating scale where 5 = Excellent and 1 = Poor."* The supervisor also had an opportunity to select "N/A" if the particular attribute was not applicable to the student's work assignment." In addition to providing a numerical assessment of student performance on each attribute, the employer was provided with a free-response comment box in which they were encouraged to provide written feedback to the student employee.

Table 2. Attributes assessed by immediate supervisor at the end of each student co-op work period, mapped to ABET Student Learning Outcomes *a-k*.

ABET SLO	Attribute	Assessment Solicited from Immediate Supervisor (5 = Excellent and 1 = Poor)
a	**Knowledge**	Ability to apply knowledge of mathematics, science, and engineering
b	**Experiment**	Ability to design and conduct experiments, as well as to analyze and interpret data
c	**SystemDesign**	Ability to design a system, component, or process to meet desired needs
d	**TeamWork**	Ability to function on multi-disciplinary teams
e	**ProblemSolving**	Ability to identify, formulate, and solve engineering problems
f	**Ethics**	Demonstration of professional and ethical responsibility
g	**Communication**	Ability to communicate effectively, written and oral
h, j	**Respect**	Respect for diversity and a knowledge of contemporary professional, societal, and global issues
i	**Learning**	Ability to learn: Grasps and retains new skills and concepts
k	**ApplyingSkills**	Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Several additional attributes are assessed in support of the ME Program Outcome (MEPO) of "preparing students to engage in the mechanical engineering profession." These additional assessment attributes, which are not directly related to ABET SLO *a-k* are presented in Table 3.

Table 3. Attributes assessed by immediate supervisor at the end of each student co-op work period related to the assessment of the general ME Program Outcome (MEPO).

Attribute	Assessment Solicited from Immediate Supervisor (5 = Excellent and 1 = Poor)
Overall	Overall Performance
Preparation	Quality of technical preparation
Initiative	Initiative: Originates ideas and seeks new responsibilities, proactively seeks assistance
Quantity	Quantity of work: Volume, pace, and effort
Quality	Quality of Work: Accuracy, thoroughness
Leadership	Ability or potential to lead others and/or projects, set and achieve goals, create change and inspire confidence
Self-Awareness	The ability to understand own strengths and weaknesses and receive feedback

Finally, the supervisor was asked to respond to several attributes which are intended to provide a summative assessment of student performance, as opposed to being an assessment of any particular student learning outcome or program outcome. The summative attributes are presented in Table 4.

Table 4. Summative attributes assessed by immediate supervisor at the end of each work period.

Attribute	Assessment Solicited from Immediate Supervisor
Future	If an appropriate position was available, would you offer a regular employment position to this student upon graduation? Available responses: Yes / No.
Wages	Numerical response box in which the employer quantified the wages per hour paid to the student employee ($/hr).
Hours	Numerical response box in which the employer quantified the normal number of work hours per week expected of the student employee (hr).
Start	Employment Start Date
End	Employment End Date
Dept.	Free response comment box in which the supervisor described the work area that the student employee was assigned to work within the employer's organization.
Job Title	Free response comment box in which the supervisor described the position title assigned to the student employee.
Responsibilities	Free response comment box in which the supervisor described the responsibilities assigned to the student employee.
Strengths	Free response comment box in which the supervisor responded to the prompt "Strengths".
Needs Improvement	Free response comment box in which the supervisor responded to the prompt "Recommended areas for improvement".
Other	Free response comment box in which the supervisor responded to the prompt "Feel free to enter any additional comments you would like to add about this student's performance in the box below".

4. RESULTS

The 5,667 evaluations of student workers conducted by their employers provide opportunity for both demonstrating achievement of ABET SLO's and the ME Program Outcome under ABET EAC Criterion 3, and for identifying areas that are candidates for continuous improvement in accordance with ABET EAC Criterion 4.

4.1 AGGREGATE RESULTS OVER A TEN YEAR PERIOD

Criterion 4 of the ABET EAC "CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS" (ABET, 2014) requires that *"The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained."* The RIT Mechanical Engineering department has established a benchmark that when *"an attribute is assessed such that 70% of the responses are rated at a score of 3/5 or higher"* then that metric is an indicator of successfully meeting the student learning outcomes *a-k*. While the mean value of the response set may be a reliable performance indicator of performance in large populations with low standard deviation, the mean may not be a reliable measure in the presence of large standard deviations, or when the population is bimodally distributed. The mean value of the employer assessment of each SLO is documented in Table 5, along with the mode, low, and high values. The nominal value of 5,667 responses indicates the number of work experiences for which both the student and employer completed their assessments in timely fashion. When a value is less that 5,667 this may indicate that the employer did not respond to that particular attribute, or listed it as "Not Applicable" to the individual student's work assignment.

Table 5. Aggregate results of immediate supervisor assessment of student employee performance attributes related to ABET Student Learning Outcomes *a-k*.

ABET SLO	Attribute	Mean	Mode	Lowest	Highest	% 3-4-5	Count
a	**Knowledge**	4.22	4	1	5	94.1	5,505
b	**Experiment**	4.15	4	1	5	98.6	4,561
c	**SystemDesign**	4.16	4	1	5	98.4	4,638
d	**TeamWork**	4.31	5	1	5	98.7	5,191
e	**ProblemSolving**	4.12	4	1	5	98.5	5,265
f	**Ethics**	4.34	5	1	5	98.0	5,544
g	**Communication**	4.11	4	1	5	97.3	5,646
h, j	**Respect**	4.31	5	1	5	99.3	4,817
i	**Learn**	4.44	5	1	5	99.0	5,656
k	**ApplyingSkills**	4.29	4	1	5	99.4	5,468

As evident from Table 5, the mean assessment value for every SLO *a-k* is above 4.0 / 5, well above a "3 = Satisfactory" performance level. The mode value of each response is either 4 or 5, indicating the most frequently selected assessment for each attribute was "Very Good" or "Excellent". The data presented in Table 5 suggests that the attributes of "Team Work", "Ethics", "Respect" and "Learn" may be the highest performing characteristics. All attributes for ABET SLO *a-k* exceed the ME Benchmark of 70% responses earning an assessment of 3 or higher on a 1 to 5 scale. As one indicator of achievement the employer direct evaluation of student work suggests that every ABET SLO *a-k* is satisfied. When combined with other direct and indirect assessment instruments not discussed herein, a comprehensive view of SLO achievement emerges. While all indicators in Table 5 exceed the benchmark of 70% scoring satisfactory or higher, it may be observed that certain attributes have relatively low benchmark performance (*e.g.* Knowledge) and others have relatively high benchmark performance (*e.g.* Applying Skills). The data in this table suggests that SLO *a* - Knowledge is worthy of further investigation. If several assessment instrument suggest a similar trend, then corrective action may be warranted.

The mean value of the employer assessment of each attribute in support of the program MEPO is documented in Table 6, along with the mode, low, and high values. As with Table 5, when a count is less that 5,667 this may indicate that the employer did not respond to that particular attribute, or listed it as "Not Applicable" to the individual student's work assignment. As is evident from Table 6, the mean assessment value for every MEPO attribute except leadership is above 4.0 / 5, well above a "3 = Satisfactory" performance level. The mode value of each response is either 4 or 5, indicating the most frequently selected assessment for each attribute was "Very

Good" or "Excellent". The Mean and Mode data presented in this table suggests that the "Leadership" attribute is worthy of further investigation. Every MEPO attribute exceeds the 70% benchmark of the ME Department.

Table 6. Aggregate results of immediate supervisor assessment of student employee performance attributes related to the assessment of the general ME Program Outcome (MEPO).

Attribute	Mean	Mode	Lowest	Highest	% 3-4-5	Count
Overall	4.30	4	1	5	98.7	5,659
Preparation	4.18	4	1	5	98.6	5,477
Initiative	4.16	4	1	5	96.6	5,630
Quantity	4.27	5	1	5	98.0	5,660
Quality	4.30	4	1	5	98.5	5,661
Leadership	3.89	4	1	5	94.1	4,281
Self-Awareness	4.18	4	1	5	98.3	4,817

Every employer was also asked to respond to a "bottom-line" question: "Future - If an appropriate position was available, would you offer a regular employment position to this student upon graduation?" For the nine year period between August 2004 and August 2013, the ME department has accumulated 5,436 co-op employer responses to this question. Employers answered "Yes" in 91.7% of the cases. Placement history during the same time interval suggests that about two thirds of our graduates accept a full-time position with one of their co-op employers upon graduation. The mean hourly wage for co-op students was reported as US$15.63/hr, with a low of US$6.00/hr (which is below the minimum legal wage and represented a cost-of-living support stipend for a student working in a non-profit volunteer setting) and a maximum of US$70.00/hr.

4.2 EXEMPLAR INVESTIGATION OF AN ASSESSMENT ATTRIBUTE

Using the descriptive statistics presented in Tables 5 and 6 it is possible to focus attention on assessment attributes warranting further investigation as areas for potential improvement. The attribute of "Leadership" was identified as being one such opportunity. To illustrate the manner in which a more detailed analysis may be performed for any attribute, the "Leadership" attribute is examined further here. The aggregate data presented in Table 5 includes assessment of students at all year levels including graduate students, transfer students and part-time students. Attention is centered now on the core undergraduate BS student population, representing third, fourth and fifth year level students. A third year student is one who has accumulated sufficient academic credit (through a combination of earned credit, transfer credit and advanced placement credit) to be considered a third year student in the ME BS program. Third year students are often on their first co-op block. A fourth year student almost certainly has at least one prior co-op block of experience prior to the current employer assessment, while a fifth year student is likely near the end of their co-op block rotations. The historical trends of performance data for the attribute of "Leadership" are presented in Figure 2. The fall quarter of academic year 2004 is denoted 20041, the winter is 20042, spring is 20043 and the following summer is 20044. Thus, the data in Figure 2 is presented sequentially for each academic quarter during nine full academic years. Figure 2 shows the assessment data for each academic year level, along with vertical errors bars representing one standard deviation on the response set. Standard deviations tend to be much larger for social science data such as this, in comparison to values that engineers are typically comfortable with in technical experimental settings. The data in Figure 2 exhibits significant fluctuation, though it appears that third year students generally perform at a lower level than fifth year students on the attribute of "Leadership." This observation is suggestive of a possible correlation between academic year level and performance on the "Leadership" attribute.

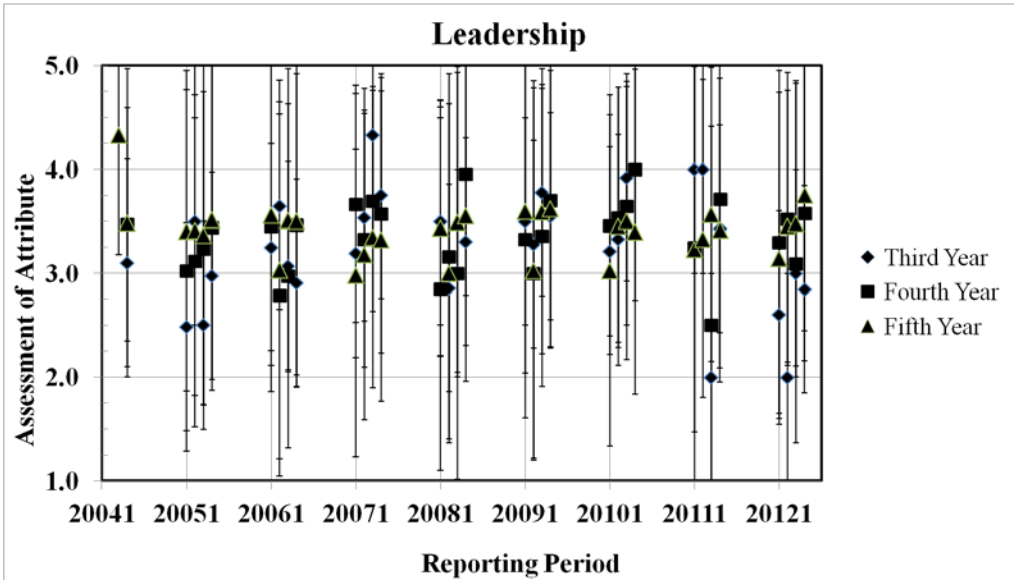

Figure 2. Historical trend of supervisor assessment of student "Leadership" attribute as a function of student's academic year level. Values reported as sample means plus/minus one standard deviation.

Leadership assessment data was aggregated across the nine year response interval by academic year level. Results of the aggregate analysis, extended to include graduate students, are presented in Figure 3. The graduate students present in this population represent one of two cohorts: dual degree students who are concurrently pursuing a BS and a Masters (MEng or MS) degree, or full time graduate students in the MEng program who elected to participate in the optional graduate co-op sequence. The data presented in Figure 3 indeed are supportive of a possible correlation between academic year level and assessment of the "Leadership" attribute. However, the standard deviations on the data set are relatively large in comparison to the upward trend on the means.

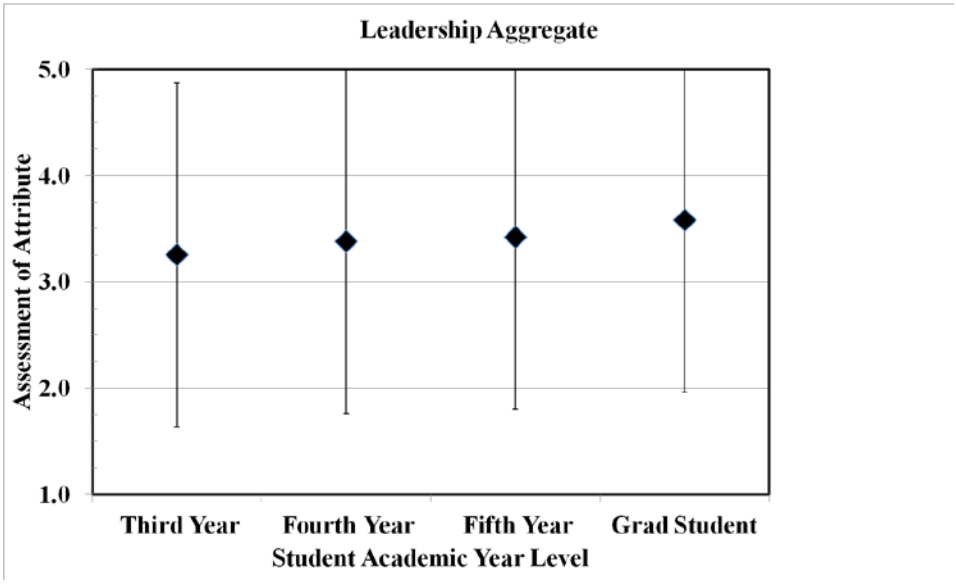

Figure 4. Aggregate supervisor assessment of student "Leadership" attribute as a function of student's academic year level. Values reported as sample means plus/minus one standard deviation.

5. CONCLUSION AND RECOMMENDATIONS

Employer assessment of student employee performance on a variety of attributes related to ABET SLO *a-k* and MEPO is a valuable tool for quantifying achievement. Assessment data analyzed over a 9 year interval indicates that the benchmark performance indicators have been satisfied. Further study is necessary to assess the hypotheses that could correlate student performance attributes with academic year level. Other factors that may influence assessment of student performance attributes should be investigated. An analysis of variance may determine if low performance on any attribute could be correlated with student year level or other factors. Additional work remains to be done to correlate employer assessment of student performance with student self-assessment, and to investigate causal relationships between curricular revisions and employer assessment of performance attributes. The proposed study is currently under way and will be reported in a future paper.

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