Tools for Assessing Student Outcomes: Use of Faculty and Student Assessments

Ann M. Anderson and Richard D. Wilk
Department of Mechanical Engineering
Union College
Schenectady, NY

Abstract
With the adoption of an outcomes-based approach to engineering education, it has become necessary to develop methods for assessing students' abilities to meet program outcomes. In the mid 1990's, a major reform was undertaken in the mechanical engineering curriculum at Union College. This was preceded by the development of a mission statement, program objectives, and specification of program-specific student outcomes. An initial assessment program to measure and evaluate the attainment of the outcomes was developed and implemented. Since then we have developed several additional assessment strategies. Our objective is to find the best way to maximize the useful information on student outcomes so that the faculty can make informed decisions about the program. As a small school we felt that it was important to include direct faculty input on students' abilities. This paper will describe a technique in which faculty "graded" each individual graduating student on how well they met each program outcome. We will describe the faculty assessment process and present several ways of examining the results. We also compared the results to student self assessments. One interesting and challenging aspect of using multiple assessment strategies occurs when the results attained through each method yield conflicting data. We will describe the faculty assessment technique and discuss how we resolved conflicting information.

Introduction

There has been a major change in engineering education in the last 10 years motivated by the adoption of ABET Engineering Criteria 2000 which is now being used for evaluating and accrediting engineering programs. This outcomes-based approach requires all accredited engineering programs to develop and implement an assessment process to evaluate the attainment of student outcomes and to use the results to improve the program.

At Union College we underwent a major curriculum revision in the mid 1990's. This was preceded by the development of a mission statement and program objectives designed to achieve specified student outcomes. In developing these, we solicited input on the program from major constituencies including students, alumni, faculty and industry via a newly created departmental industrial advisory council. In addition, as part of the process we had to develop a methodology for measuring the attainment of the program outcomes by the students. This was done by defining measurable performance criteria for each specified outcome and then selecting or developing appropriate assessment tools for gathering data pertinent to each criterion.

The assessment tools used include course assessments, student course portfolios, senior exit surveys and interviews, alumni surveys, the FE Exam results, co-op employer evaluations, degree audits, ME curriculum audits, course-end evaluations, and career surveys. Table 1 lists these assessment tools and some of the associated details.

We are constantly looking for new and better assessment tools for obtaining data on the student outcomes. Recently, we introduced formal faculty assessment of individual students (seniors) relative to the program outcomes. Faculty rate each of the students relative to the attainment of the stated outcomes. This complements the existing student self-assessment. Student self-assessment is done through the senior exit surveys and interviews and provides information about the students' own perceptions of their attainment of stated outcomes. Thus we have two independent assessments of student outcomes one by the students and one by faculty.

This paper describes these assessment tools, their implementation and compares the results.

Faculty Assessment Technique

The Mechanical Engineering program at Union graduates about 25 students per year. As a small school with close contact between faculty and students, we felt that the assessment process could and should involve more direct faculty input. Therefore we developed a faculty assessment tool to evaluate the graduating seniors. We created a "Faculty Assessment Form" which was distributed to all faculty in the department during the end of the student's final term at Union. A copy of the form is included in Table 2. The form lists our 13 student outcomes. Each faculty member was asked to rate each student's ability in each of the 13 outcomes. We used a scale of 1 (no ability) to 3 (has the ability) to 5 (excels) in the "Rating Column" and indicated a confidence level on our ability to assess each student ability by placing a 3 (high confidence), 2 (medium confidence) or 1 (low confidence) in the "Confidence" column. We compiled the data from these survey forms and used only that data for which faculty had medium to high confidence in their ability to evaluate each student. For the purposes of this paper, we will present the results from a subset of 15 students.

Figure 1 shows the average rating for each of the 13 outcomes. The average was calculated by averaging across all faculty and all students. The outcomes are listed from highest to lowest numerical rating. For the subgroup of students studied we found that "on average" all students have all 13 of the abilities. If we attempt to rank order the data as shown we might conclude that the students are best at being a member/leader of a team and weakest at understanding professional and ethical responsibilities and at designing and conducting experiments. However, the spread among the ratings is small and in fact the standard deviation for the averages across faculty is as high as 0.5 so it is impossible to draw conclusions about the relative rankings.

Figure 2 presents an alternate way of looking at the assessment data. The figure plots the percent of students who are judged by the faculty to have the ability. These percentages were calculated by totaling the number of 3, 4, and 5 ratings and dividing by the number of faculty and students. These results indicate that we think the students can use computers effectively and can use techniques, skills and modern engineering tools. We also think that the smallest percentage have the ability to design and conduct experiments and to apply math science and engineering fundamentals.

Figures 3 and 4 present another interpretation of the data. In this case we examined each individual faculty rating of each individual student and counted the number of times that an outcome was rated as a students strongest ability (Figure 3) and each time an outcome was rated as a students weakest ability (Figure 4). A student with ratings of 4 and 5 would have a "4" rating for his or her weakest ability while a student with ratings of 2 and 3 would have a "2" rating for his or her weakest ability. (Note: If a faculty member rated a student as "3" in all areas then all outcome would be both strongest and weakest). This was done to determine what areas are weakest, regardless of overall student ability. In this case we found the students to be strongest at being a member or leader of a team, designing components processes and systems and applying math science and engineering fundamentals and weakest at understanding professional and ethical responsibilities and contemporary issues.

Comparison to Other Assessment Tools

All graduating students were asked to complete an online survey that included 70 questions about the engineering program and about their Union College education. A number of the questions asked specific questions about their abilities in the 13 outcome areas. The questions are summarized in Table 3. The first column lists the 13 outcomes (as described in Table 2) and the second column lists the survey questions related to each outcome. Students were asked to respond to each question using the following response key: 5 – Agree; 4- Agree Somewhat; 3- Neutral; 2- Disagree Somewhat; 1 –Disagree. The average student response was calculated for each of the questions.

In addition the graduating seniors were asked to complete EBI (Educational Benchmarking) surveys. We mapped the answers to a number of these questions into our 13 outcomes. These questions are presented in Table 3. The EBI surveys used a scale of 1 to 7 while the Union College surveys were based on a 1 to 5 scale. The EBI results were re-scaled to match the Union College scale. The students responded to these questions using two different response key. For EBI Q38-71: 1- not at all, 4-moderately, 7-extremely. For EBI Q24-37: 1-very dissatisfied, 2- moderately dissatisfied, 4 neutral, 6-moderately satisfied, 7- very satisfied.

Figure 5 plots the rating results from each of the three assessment surveys on a scale from 1 to 5 for each of the outcomes. In all cases the faculty ratings are lower than the Student-Union and Student-EBI results which is probably attributable to the different scales. (For the faculty surveys "3" indicated that they have the ability, while for the student surveys "3" was neutral.) The figure also shows that the two student surveys are generally in agreement.

To determine any differences between our perceptions and the student perceptions about their abilities we rank ordered the results of each assessment tool/interpretation into approximately the top third, middle third and bottom third of abilities. This is presented in Table 3 which lists the faculty and student assessment tools across the top and the outcomes in each row. The number 1, 2 or 3 indicates the ranking of the outcome (top, middle or bottom third). Looking at each outcome we can determine the level of "agreement" in the assessments. The results indicate that the assessment tools yield different results for outcomes 1 (math, science, and engineering fundamentals), 2 (design/conduct experiments), 8 (impact of engineering), 10 (use techniques, skills, tools) and 11 (use computers effectively). For outcomes 1 and 2 the faculty ranking is lower than the student ranking while for outcomes 8, 10 and 11 the faculty ranking is higher.

On 8 of the 13 outcomes both faculty and student assessment are in agreement. The assessment indicates that students are doing well in 6 of these 8 areas and that 2 areas could use improvement. Assessing our program in terms of the remaining 5 outcomes requires further input. Some of the discrepancy may be due to the phrasing of the particular questions. For example the faculty question on using computers effectively is slightly different from the student question. Faculty assessed student ability to use computers while students also commented on their ability to use a programming language and on the availability of computers.

Conclusion

In a small engineering program the use of direct faculty input is a valuable tool in assessing student outcomes. The use of multiple assessment techniques provides increased confidence in the ability to assess these outcomes. Our results indicated that student and faculty assessment was in agreement on 8 of the 13 outcomes and that there was disagreement on 5 of the outcomes. In the future we plan to modify some of the assessment questions and to determine the reasons for the differences in outcome assessment.

ANN M. ANDERSON
Ann M. Anderson is an Associate Professor at Union College. She received her BS in Mechanical Engineering from Tufts University and her MS and PhD in Mechanical Engineering from Stanford University. Before coming to Union College she spent two years designing computer cooling systems at IBM in Poughkeepsie NY. In addition to her research in the field of turbulent heat transfer and aerogel manufacturing techniques, she teaches courses in introductory mechanics, fluid mechanics, heat transfer and thermal-fluid science design.

RICHARD D. WILK
Richard D. Wilk is a Professor of Mechanical Engineering at Union College. He received his B.S, M.S. and Ph.D. in Mechanical Engineering from Drexel University. He conducts research in the fields of combustion and alternative energy systems and teaches courses in freshman design, thermodynamics, heat transfer, solar energy, turbomachinery, compressible fluid flow, and design of thermal-fluid systems.

Table 1. Mechanical Engineering Program Outcomes Assessment Instruments

	Assessment Instrument	Who Administers/Conducts	Data Obtained	Frequency
1	Course Assessments	Faculty	Information on the attainment of course objectives	Each term
2	Senior Exit Survey	MEAC (Mechanical Engineering Assessment Coordinator)	Student experiences, Student perceptions of their attainment of stated outcomes	Annually
3	Alumni Survey	Dean of Engineering	Post-graduate experiences; Alumni perceptions of their attainment of stated outcomes	Every 3 years
4	FE Exam	NSPE/NY State Education Department	Student knowledge of engineering fundamentals relative to national performance	Annually
5	Co-op Employer Evaluation	Career Development Center	Performance of students in a work environment; rating on the attainment of certain outcomes	Periodically
6	Degree Audit	Registrar	Certification that all degree requirements have been met	Annually
7	MEAC Audit	MEAC	Institutional and departmental data on student experiences and performance	Annually
8	Instructor Course-End Evaluations	Faculty	Student perception of course quality/instructor performance	Each term
9	Career Survey	Career Development Center	Post graduate positions of alumni	Annually
10	Faculty Assessment	Faculty	Faculty perceptions of students' attainment of outcomes	Annually

Table 2. Faculty Assessment Form

	Please rate each student's ability in each of the outcome areas on a scale of 1 (no ability) to 5 (excels) in the "Rating Column". In addition please indicate a confidence level on your ability to assess each student ability by placing a 3 (high confidence), 2 (medium confidence) or 1 (low confidence) in the "Confidence" Column.	Student 1		Student 2		Student 3		Student 4		Student 5		Student 6		Student 7		Student 8		Student 9		Student 10	
	Student Outcomes	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence	Rating	Confidence
1	A sufficient understanding of mathematics, the physical sciences, and engineering fundamentals and how to apply them to solve engineering problems (ABET EC2000 Criterion 3a).																				
2	The ability to design and conduct experiments, collect and analyze data, and draw conclusions from the results (ABET EC2000 Criterion 3b).																				
3	The ability to apply engineering fundamentals, creativity and accepted design methodology to design components, processes and systems (ABET EC2000 Criterion 3c).																				
4	The ability to participate and contribute effectively as a member or a leader of a (1) team or (2) multidisciplin ary team (ABET EC2000 Criterion 3d).																				
5	The ability to define, formulate and solve techni cal problems (ABET EC2000 Criterion 3e).																				
6	An understanding of professional and ethical responsibilities in the engineering profession (ABET EC2000 Criterion 3f).																				
7	The ability to communicate effectively (oral, written, graphical, electronic). (ABET EC2000 Criterion 3g).																				
8	A sufficiently broad education that provides a context for understanding the impact of engineering solutions on society (ABET EC2000 Criterion 3h).																				
9	The ability to acquire new knowledge and capabilities on their own (ABET EC2000 Criterion 3i).																				
10	Knowledge of contemporary issues facing society (ABET EC2000 Criterion 3j).																				
11	The ability to use techniques, skills, and modern engineering tools necessary for engineering practice (ABET EC2000 Criterion 3k).																				
12	The ability to use computers effectively as a tool in engineering practice for analysis, design, research, and communication (ABET EC2000 Criterion 3k).																				
13	A significant exposure to a foreign culture to provide a better awareness of the global context of engineering practice (ABET EC2000 Criterion 3h).																				

Table 3. **Mapping of Union On-Line Survey questions to Outcomes.**
(Response Key: 5 – Agree. 4- Agree Somewhat, 3-Neutral, 2- Disagree Somewhat, 1 –Disagree)

Outcome	Question
1	I am able to apply knowledge of mathematics and physical sciences in the development and evaluation of solutions to engineering problems. (1a) I have a good knowledge of engineering fundamentals. (1b) I have knowledge of engineering fundamentals sufficient enough to allow me to approach the technical challenges related to mechanical engineering to which I have not yet been exposed. (1c)
2	I am able to analyze and interpret experimental data. (2)
3	I am able to design a system, component, or process to meet a desired need. (3)
4	I am able to function and participate effectively as one member of a multidisciplinary team of engineers working on project. (4a) I feel I am able to be an effective leader of a multidisciplinary team of engineers. (4b)
5	I learned how to think critically and analytically. (5)
6	I have a sufficient understanding of professional ethics to guide the decisions I will make in situations I will encounter in engineering practice. (6)
7	I am able to communicate effectively in writing to a variety of audiences. (7a) I am able to make effective oral presentations to a variety of audiences. (7b) I am comfortable expressing my views and questioning others in a group discussion situation. (7c) I am comfortable communicating electronically (email) with a variety of audiences.(7d) I am able to create a web page for a specific purpose. (7e)
10	I feel I am able to interact comfortably with people of other cultures. (8a) I am able to function comfortably in a foreign country. (8b)
9	I am comfortable using information technology to search and gather relevant information from a variety of sources for use in the solution of engineering problems. (9a) As a graduating engineer, I recognize the need to continuously update my professional skills. (9b) In the future I anticipate continuing my education and pursuing an additional or advanced degree in either an engineering or non-engineering field. (9c) In the future I anticipate taking professional development courses in order to stay current in my field or to learn new skills. (9d)
10	I am able to assess the economic, social, environmental impacts of my actions as an engineer. (10a) Compared with all other Union College graduating seniors, I have a good knowledge of contemporary issues facing society. (10b) Compared with all other graduating engineering majors across the U.S., I have a good knowledge of contemporary issues facing society. (10c)
11	I am proficient in the use of modern instrumentation for making engineering measurements. (11a)

12	I am able to use computer-based data acquisition to gather test data. (11b) I am able to use software tools to analyze data and represent information graphically. (12) The computer facilities at Union are more than adequate. (13) I am proficient with at least one CAD application package. (14) I am proficient in at least one computer programming language. (15)
13	I feel I am able to interact comfortably with people of other cultures (8a) I am able to function comfortably in a foreign country. (8b)

Table 4. Mapping of EBI Survey questions to Outcomes List
(Key for EBI Q38-71: 1- not at all, 4-moderately, 7-extremely)
(Key for EBI Q24-37: 1-very dissatisfied, 2-moderately dissatisfied, 4 neutral, 6-moderately satisfied, 7-very satisfied) *note 1-7 response were mapped into 1-5 responses

Outcome	EBI SURVEY Question
1	To what Degree did your Engineering Education enhance your ability to: apply your knowledge of mathematics (52) apply your knowledge of science (53) apply your knowledge of engineering (54)
2	To what Degree did your Engineering Education enhance your ability to: design experiments (38) conduct experiments (39) analyze and interpret data (40)
3	To what Degree did your Engineering Education enhance your ability to design a system component or process to meet a desired need (41)
4	To what Degree did your Engineering Education enhance your ability to function on a multidisciplinary team (42)
5	To what Degree did your Engineering Education enhance your ability to: Solve engineering problems (43) Identify Engineering Problems (55) Formulate engineering problems (56)
6	To what Degree did your Engineering Education enhance your ability to understand ethical responsibilities (44)
7	To what Degree did your Engineering Education enhance your ability to: Communicate using oral progress reports (47) Communicate using written progress reports (48)
8	To what Degree did your Engineering Education enhance your ability to understand the impact of engineering solutions in a global/societal context (45)
9	To what Degree did your Engineering Education enhance your ability to recognize need to engage in lifelong learning (51)
10	To what Degree did your Engineering Education enhance your ability to understand contemporary issues (57)
11	What is your satisfaction with: Availability of computers (27) Remote access to school's computer network (28) Training to utilize the school's computing resources (29) To what Degree did your Engineering Education enhance your ability to se modern Engineering tools (46) To what degree did laboratory facilities allow you to use modern engineering tools (71)
12	What is your satisfaction with: Availability of computers (27) Remote access to school's computer network (28) Training to utilize the school's computing resources (29)
13	My experience abroad gave me a good understanding of a different culture (80)

Table 5. Summary of Assessment Tool Results by placement of outcome in overall ranking (1 ~ top third, 2 ~ middle third, 3 ~ bottom third)

	Outcome	Faculty					Student
		Overall Rating (Figure 2)	Achieve Outcome (Figure 3)	Strongest Outcome (Figure 4)	Weakest Outcome (Figure 5)	Internal UC (Figure 6)	External EBI (Figure 6)
1	math, sciences, eng fundamentals	2	3	1	2	1	1
2	design and conduct experiments	3	3	3	3	1	1
3	design comp, proc and systems	1	1	1	1	2	2
4	a member or a leader of a team	1	1	1	1	1	2
5	define, formulate solve technical	2	2	2	2	1	1
6	prof and ethical responsibilities	3	2	3	3	2	3
7	communicate effectively	2	1	2	2	2	1
8	impact of engineering	1	1	3	2	3	2
9	new knowledge	2	2	2	2	2	2
10	contemporary issues	2	2	3	3	3	3
11	use techniques, skills, tools	1	1	1	1	3	2
12	use computers effectively	1	1	2	2	3	3
13	foreign culture	2	2	2	1	2	1

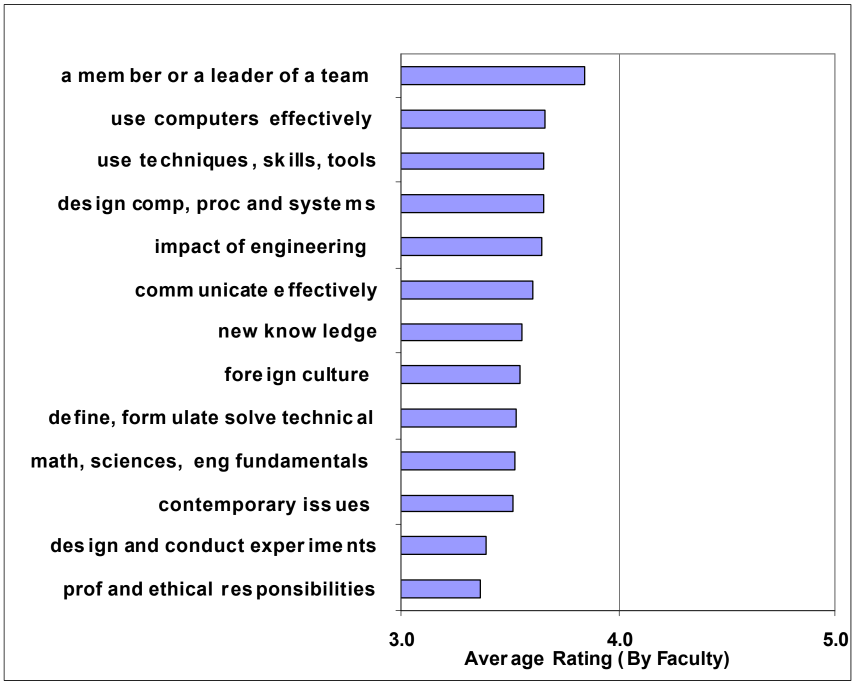

Figure 1. Faculty assessment tools results. For each outcome we averaged the ratings across all 15 students and all faculty surveys.

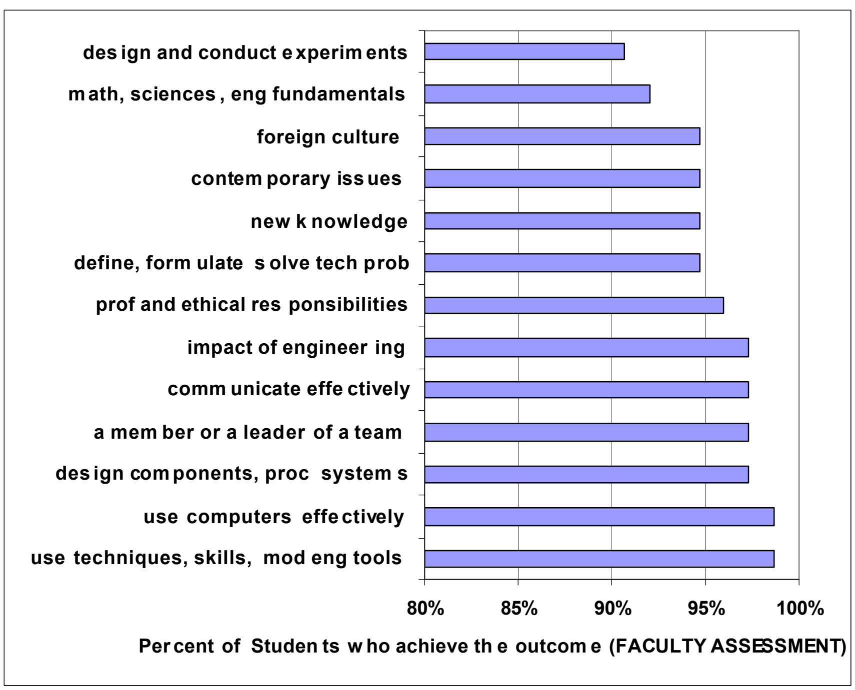

Figure 2. Percent of Students who achieve outcome based on Faculty Assessment.

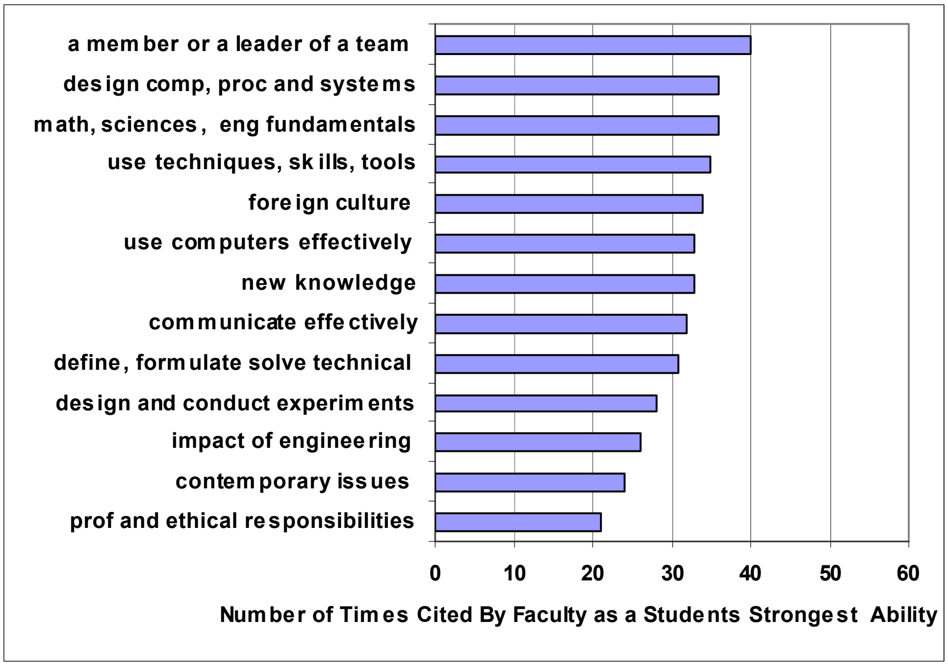

Figure 3. Number of Times an Outcome is cited as student's strongest ability.

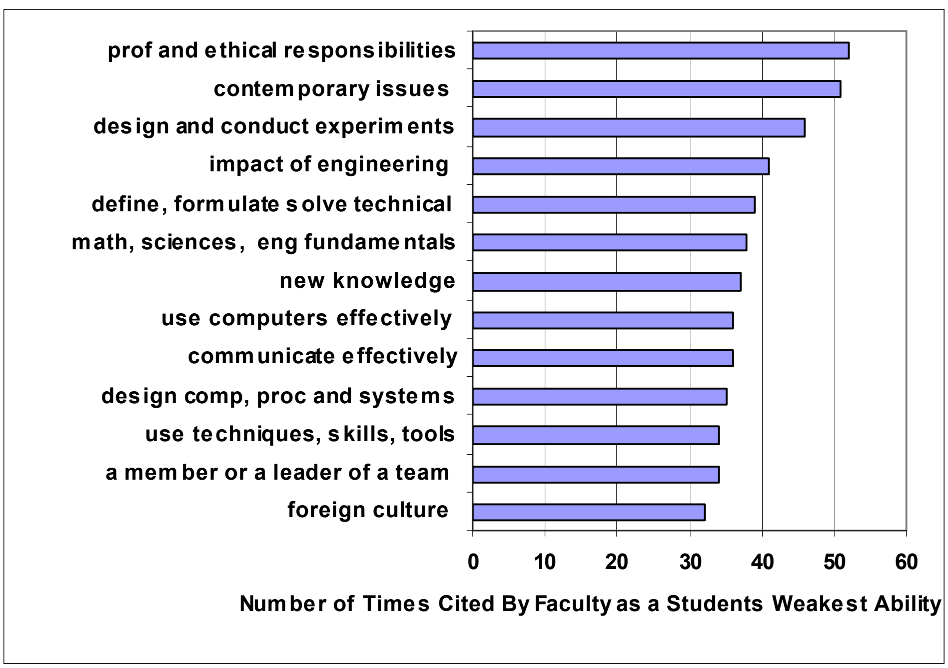

Figure 4. Number of Times an Outcome is cited as student's weakest ability.

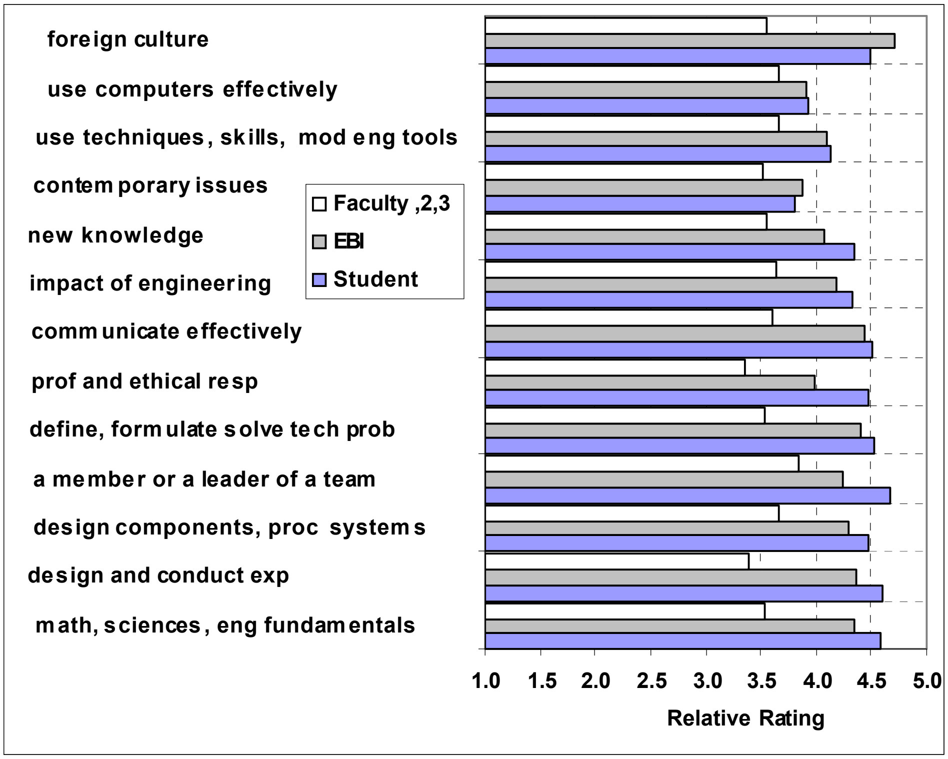

Figure 5. Comparison of Faculty and Student Assessment Tools