AC 2012-4598: APPLICATION OF DATA MANAGEMENT TOOLS FOR ABET ACCREDITATION

Abby M Kelly, University of Nebraska, Lincoln
Evan T. Curtis, Univeristy of Nebraska, Lincoln
Johnathan Ian Edward McCoy, University of Nebraska, Lincoln
Dr. Dennis D. Schulte P.E., University of Nebraska, Lincoln
Dr. David Jones, University of Nebraska, Lincoln

David Jones is a professor of biological systems engineering and the Associate Dean of the College of Engineering at the University of Nebraska, Lincoln.

Application of data management tools for ABET accreditation

A task of the ABET accreditation process is to document achievement of student outcomes and to link student outcomes to the attainment of program educational objectives. Traditionally, evidence for individual courses is stored in a hard copy sampling of student work. However, the advent of electronic document conversion and database management enables instructors the ability to readily prepare documents for continuous assessment. Recently, a data management and assessment tool was created and applied for documenting and evaluating student outcomes for courses within an engineering program. Documents included course syllabi, lecture notes, video recordings of oral presentations, and handwritten samples of student work, all saved to an electronic format. Once the evidence was compiled, the achievement of student outcomes for each piece of evidence was ranked based on the cognitive domain of Bloom's taxonomic scale and cataloged into an Access database by course. Following this assessment, the actual achieved Bloom's level of each student outcome was compared to a previously determined course target. This relation demonstrated whether an instructor was over or under achieving the intended student outcomes for the course and provided a basis for course and curricular improvement. The purpose of this paper is to discuss the application and usefulness of these data management tools in evidence collection, curriculum assessment, and continuous improvement.

Introduction

As the principal means of engineering accreditation, ABET, inc. serves as the primary driver in many engineering college and departmental actions in terms of curriculum management and course evaluation[1]. In accordance with ABET, inc. the University of Nebraska-Lincoln (UNL) agricultural engineering (AGEN) and biological systems engineering (BSEN) programs have continued to deepen their understanding and development of outcomes based assessment strategies. In the shift to outcomes based evaluation, the programs sought to become more focused on student performance rather than instructional methodology. As a result, the department made it a priority that each program requires its instructors to collect evidence for the purpose of outcome evaluation. The intent was to assess student outcomes of specific courses as well as identify outcome fulfillment across the curriculum.

In previous ABET review cycles, the evidence collection and assessment had been conducted using hardcopies. Evidence collection is a key component of the ABET accreditation process, and because evidence typically consists of items such as syllabi, lecture notes, homework, exams, presentations, etc. collection and storage of this evidence is often a hurdle in the ABET review process[2]. Consequently, it proved difficult to compare courses in terms of outcomes or to evaluate the progression of student learning throughout the curriculum using hardcopies. This problem was addressed though the development of two tools for use by both the AGEN and BSEN programs. The first tool was the establishment of an electronic evidence repository through which instructors would be expected to submit evidence for their courses. The second tool was developed to provide a mechanism for assessing the gap between each course's achieved outcomes in comparison to the target outcomes across both the AGEN and BSEN programs in a unified manner.

This paper will outline the application of the data collection and assessment tools that were utilized to better evaluate course and curriculum targets for the AGEN and BSEN ABET reviews conducted in 2011. Additionally, a tool for effective mapping of program education objectives (PEOs) with the student outcomes will be discussed as well as future goals and directions for these data management tools.

SOMs

Student outcomes matrices (SOMs) (Figure 1) for each core, emphasis, and supporting course were initiated in 2003, and were refined in 2006 in an effort to improve the degree to which the departments could assess the attainment of student outcomes. Each AGEN and BSEN course has its own SOM which relates the course objectives to the ABET student outcomes using the cognitive domain of the Bloom's taxonomic scale[3] (Figure 2). At the time of development, the SOM's Bloom's levels were determined solely on course instructor opinions and were set as targets for future evaluation.

Student Outcomes Matrix (SOM) for BSEN 470

Course Objectives	The Course Objectives to the Left Affect Student Outcomes A-K to the Extent †Indicated Below											
	A.1	A.2	B	C	D	E	F	G	H	I	J	K
Students will identify and formulate an engineering design problem or engineering experiment.		4	4	4		4	3		3		3	4
Students will identify and persuade classmates to serve on a team to execute the engineering design problem or engineering experiment.					4			5				
Students will Apply the process of engineering design or engineering experimentation.	5	4	4	4	4	4					3	4
Students will utilize oral, written, and persuasive abilities to lead classmates, clients and advisors.					4			5				
Students will gain insight into global variations in engineering solutions due to cultural and environmental factors.									3		3	

† Numbers in this table correspond to Bloom's Taxonomy: 1=Knowledge, 2=Comprehension, 3=Application, 4=Analysis, 5= Synthesis, 6=Evaluation

A.1 An ability to apply knowledge of mathematics, physics and the engineering sciences.
A.2 An ability to apply knowledge of the chemical and biological sciences, and biological systems engineering.
B An ability to design and conduct experiments, utilize probability and statistics, 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 teams including 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.

Figure 1: Student Outcomes Matrix (SOM) for AGEN/BSEN 470 and descriptions of each student outcome A.1-K

Bloom's Taxonomy - Cognitive Domain					
Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1	2	3	4	5	6

Figure 2: Blooms taxonomic scale in the cognitive domain, ranked 1-6

In order to minimize classification error and bias in analysis of student work and the attainment of student outcomes, a Bloom's based student outcomes rubric was created. The Bloom's based student outcomes rubric (Appendix I) describes in detail how each Bloom's classification level (knowledge, comprehension, etc.) relates to each student outcome A.1-K. This also enabled the evaluator to rank the degree to which the student outcomes were attained, using a universally accepted classification scale.

Evidence - Collection

Evidence, such as student homework, exams, projects, and presentations, as well as course syllabi and lecture notes, were collected from faculty and students. The evidence was scanned and stored electronically in class specific folders within a departmentally shared program assessment folder on the local network.

SOMs - Analysis

The maximum Bloom's level found in the SOM for each of the student outcomes, without regard for the course objectives was used as a target in assessment of all student work for each course. It was assumed that if the maximum Bloom's level was achieved, the lower levels were also achieved.

Evidence – Analysis

A comprehensive understanding of the evidence provided by the instructor was accomplished by reviewing each piece of evidence in the context of the assignment to discover the intended breadth and complexity of the assignment, exam, etc. The evidence was then examined from a student's perspective, to grasp the methods, tools, skills, and knowledge used in the completion of the work.

After analysis, specific pieces of evidence were selected based on the indicated achievement of the maximum Bloom's levels for each of the student outcomes. Multiple instances of each piece of evidence were used to show high, medium, and low grade material. In cases where the evidence fell outside the wording parameters set in the outcomes rubric, professional judgment was used. In rare cases course instructors were consulted for assistance.

After evaluation, evidence was uploaded into a Microsoft Access database and stored in a secure network folder. This folder was available only to those active in the ABET analysis process to ensure preservation of the document.

Within the Access database, courses were organized based on course number and in order to view specific courses, a user could scroll using the arrows seen in Figure 3.A to cycle through the list of courses. The top matrix for each course, labeled “Target”, is a repetition of the SOM, showing the courses targeted Bloom’s levels for each of the ABET Student Outcomes (Figure 3.B). The lower matrix, labeled “Evidence”, is where each piece of evidence was cataloged, and could be accessed. Each category of evidence (Project, Exam, Homework, etc.) was entered into its own row and labeled. The Bloom’s levels achieved for each ABET Student Outcome were then placed in the corresponding columns (Figure 3.C).

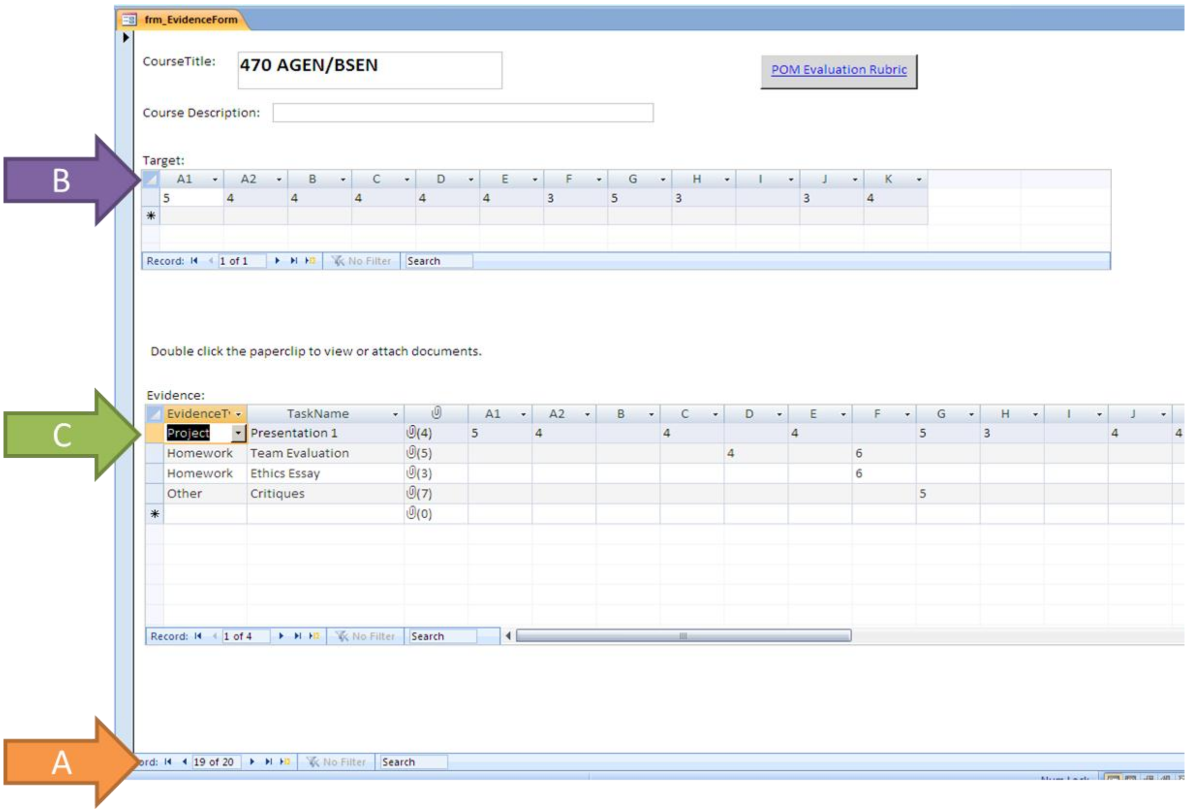

Figure 3. Evidence Collection Database. The evidence database form contained mechanisms for selecting the desired course (A), inputting target student outcomes (B), and adding evidence to support student outcome achievement (C).

Course evidence could be accessed by double clicking on the paperclip icon that corresponded to each row of evidence. Within the pop-up window, each piece of supporting evidence for the row was listed. In many cases a “Read Me” file was also listed. “Read Me” files are Microsoft Word documents and were created to explicitly list justifications for why specific Bloom’s levels were selected for that particular piece of supporting evidence. If a “Read Me” file was not created, the link between the evidence, student outcome, and Bloom’s level should have been explicit. From the pop-up window found by double clicking the paperclip icon, evidence could be viewed, added, and removed using the corresponding buttons on the right side of the window.

To add new evidence, the user would click inside the blank box to the right of the asterisk (*) in the “Evidence Type” column and select from the drop down menu: Project, Exam, Quiz, Homework, or Other. Under “TaskName” the user could enter a more specific evidence name, such as “Guest Lecture Notes” or “Midterm Exams 2011”. More evidence could be added by double clicking the paperclip. Finally, a user could enter each Bloom’s level achieved by placing a value (1-6) in the corresponding student outcomes column (A.1-K). Each row corresponded to a different piece of evidence.

The Access database automatically stores each piece of evidence as a separate, unalterable file, not as a link to the original file. If evidence or “Read Me” files had to be edited, they were removed from Access, modified from the original document, and then reloaded into the Access database.

Gap Analysis

An Excel program named “Gap analysis” was used to analyze four aspects of the AGEN/BSEN curricula:

1. Individual course analysis
2. How the courses fit within the curricula
3. Relationship of PEO’s to the student outcomes.
4. How successfully the curricula matches the PEO’s

Gap Analysis for Individual Courses

Each course contained its own sheet within the Gap Analysis file. The course analysis sheet was composed of one large matrix relating student outcomes and Bloom’s levels (Figure 4). The maximum Bloom’s level achieved by each course for each student outcome, as determined from the evidence analysis, as well as the target maximum Bloom’s levels from the SOM were transferred from Access to the Gap Analysis file. The achieved Bloom’s levels were compared to the Bloom’s level targets to determine if the targets were being met, exceeded, or lacking. Gap analysis is a critical tool for identifying specific faults within the course and curriculum pathway[4]. When a gap between the achieved and target Bloom’s level was found, suggestions were made on whether to improve the course, change the SOM, or collect additional evidence. When possible, detailed suggestions on how to improve assignments, projects, etc. were given. Three additional columns were also created, which display whether the achieved Bloom’s level is high or low when compared to the target Bloom’s level, or not found at all.

Class:	470											
Student Outcomes	Bloom's Level						Achieved Bloom's Level	Target Bloom's Level	Higher than target (H)	Lower than target (L)	Not Found (N)	Comments:
	1	2	3	4	5	6						
A.1					x		5	5				Ample Evidence
A.2				x			4	4				Ample Evidence
B								4			N	Not enough evidence. Suggestion: Stress docu
C				x			4	4				Ample Evidence
D				x			4	4				Ample Evidence
E				x			4	4				Ample Evidence
F						x	6	3	H			Ample evidence, though this is a level 6 which i
G						x	6	5	H			Ample evidence, though this is a level 6 which i
H			x				3	3				Ample evidence
I												Could hit a level 4 by asking studens to include additional knowledge is needed to complete th
J				x			4	3	H			Ample evidence, though this is a level 4 which i
K				x			4	4				Ample Evidence

Figure 4. Gap Analysis tool for course analysis.

Gap Analysis for the Curricula

The AGEN and BSEN curricula contained their own sheets within the Gap Analysis file. The curricula analysis sheet was composed of one large matrix relating student outcomes and Bloom's levels (Figure 5). Each course number was entered into the matrix for each student outcome it fulfilled in the corresponding Bloom's level column to show how each course contributes to the overall curricula. In 2003 when the AGEN and BSEN departments created their SOMs, they also set target Bloom's levels for each student outcome on a curricular level. The targets are highlighted on each curricula matrix. For example, the green regions of Figure 5 show the curriculum Bloom's level targets for each student outcome and courses that indicate a max achievement of that Bloom's level. The highlighted regions also provided indication as to which courses are most critical to outcome achievement.

To determine whether the target Bloom's levels were achieved, a weighted average, median, and maximum Bloom's level for each student outcome was calculated and placed into its own column. While each statistic has merit, no single statistic is a complete representation of the success of the curricula in achieving the target Bloom's levels, therefore an average of the three is taken and used as the "Achieved Bloom's level" for comparison purposes.

Student Outcomes	Bloom's Level						Curriculum Target	Achieved via PEO mapping	Most Frequent Level found	Weighted average	Max Bloom's Level Achieved	Achieved Bloom's Level
	1	2	3	4	5	6						
A1		100,	112,206,225,350,	303,321,443,	344,470,480,	325,424,453,460,	5	4.56	4.5	4.33	6	4.94
A2		100,	112,225,350,	303,443,470,480,	344,	325,424,453,460,	4	4.00	5	4.31	6	5.10
B	112,	225,443,		303,321,325,424, 453,480,	350,	460,	4	4.00	4	3.64	6	4.55
C			100,225,344,350, 424,	470,		303,325,443,453, 460,480,	6	4.33	6	4.61	6	5.54
D		112,	100,225,303,325, 350,443,460,	470,		480,	4	3.67	3	3.29	6	4.10
E			100,112,225,	206,321,350,424, 470,	344,	303,325,443,453, 460,480,	6	4.33	6	4.68	6	5.56
F	112,	100,	325,350,	443,453,		470,480,	3	4.67	4.5	3.63	6	4.71
G		112,	100,225,303,350, 424,443,453,460,		325,	470,480,	5	4.67	3	3.57	6	4.19
H	112,	100,206,225,303, 325,	443,470,480,	350,453,			3	5.00	2	2.53	4	2.84
I	303,460,	453,	225,325,350,443,	344,			2	5.33	3	2.50	4	3.17
J	112,321,	100,	206,225,325,443,	424,453,470,	303,480,	350,460,	5	5.33	3	3.57	6	4.19
K	100,		112,206,	225,321,325,350, 424,443,453,470, 480,	303,344,	460,	4	4.00	4	3.94	6	4.65

Figure 5. Curriculum Gap Analysis matrix. The green highlighted regions indicate the target Bloom's level for each student outcome at the curricular level.

Mapping PEOs to Student Outcomes

The relationship of PEOs to course and curriculum student outcome achievement is an essential element of the ABET program evaluation and continuous improvement process. Furthermore, PEOs should directly support student outcomes. The PEOs were determined by faculty in this context and largely conformed to outcomes suggested by ABET. Thus, a matrix-like instrument (Curricular SOM) was developed to relate student outcomes A.1-K to the PEOs. The matrix matched the student outcomes and the PEOs via a strong, medium, or low correlation scale (Table 1). The table showed the correlation of the desired 3-5 year post graduation competencies of the PEOs to their foundation in student outcomes A.1-K.

Table 1

AGEN Mapping of Student Outcomes to PEOs

PEOs	Student Outcomes											
	A.1	**A.2**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
1	S	S	S	S	M	S	M	S	M	M	S	S
2	M	M	M	S	L	S	M	L	M	S	S	S
3	S	M	S	S	L	S	L	S	M	S	S	S
4	M	M	L	L	S	L	S	S	S	S	S	L
5	M	M	M	M	L	M	S	M	S	S	S	L
6	L	L	L	L	S	L	S	M	S	M	L	L
Strong correlation (S), Medium correlation (M), Low correlation (L)												

Table 2

AGEN Student Outcomes (Composite mapping)

	A.1	**A.2**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Bloom's Level	4.56	4.00	4.00	4.33	3.67	4.33	4.67	4.67	5.00	5.33	5.33	4.00

Expressing PEO Achievement as Bloom's Descriptors and Comparison to Target Levels

From the PEOs to student outcomes matrix (Table 1), new Bloom's levels were calculated for each of the 72 cells by converting the strong, medium, and low ranking scale to 6 (Evaluation), 3 (Application) and 1 (Knowledge), respectively. An average of each outcome column was then calculated and aggregated with the mappings by both student and faculty perspectives in order to help minimize subjectivity (Table 2). While this was not a perfect normalization of the strong, medium, and low scale to the Bloom's taxonomic scale, valuable information was gained by representing all data in a 1-6 scale for equal comparison. Given that the midrange of Bloom's descriptors includes Application (3) and Analysis (which would be 4), the 6, 3 and 1 conversion provided a conservative assessment of achievement. The numeric Bloom's levels of achievement developed for each student outcome across all PEOs were then compared to the departmental target Bloom's levels as shown for 2011 in Figures 6 and 7.

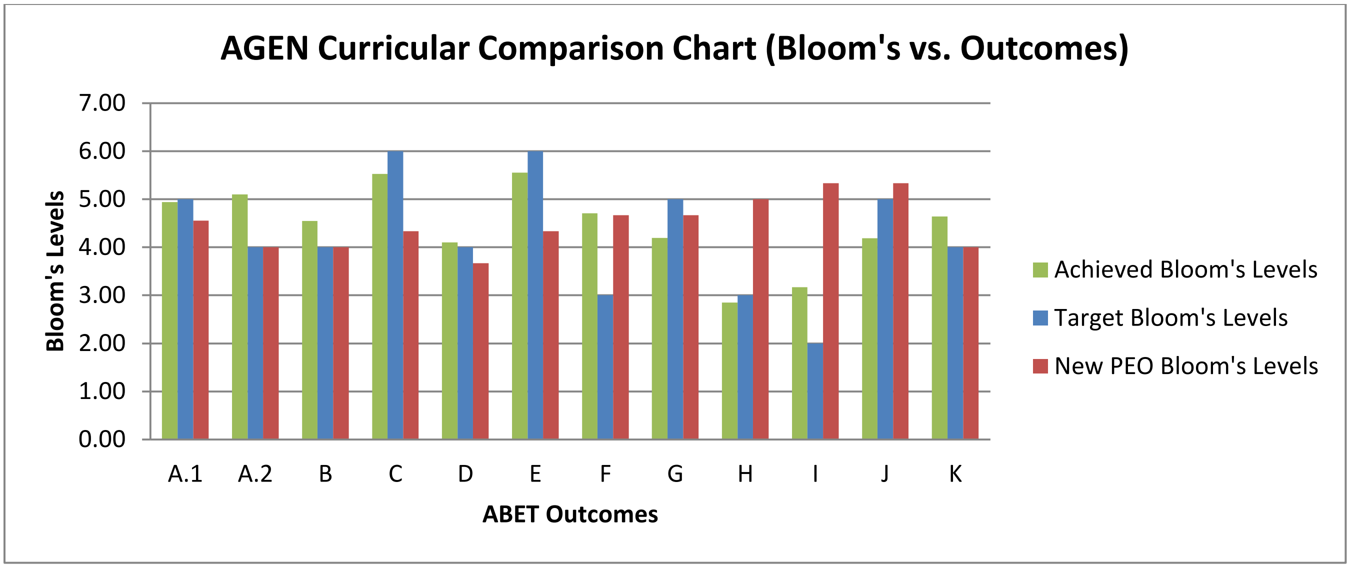

Figure 6. AGEN curricular Bloom's level vs. student outcomes comparison

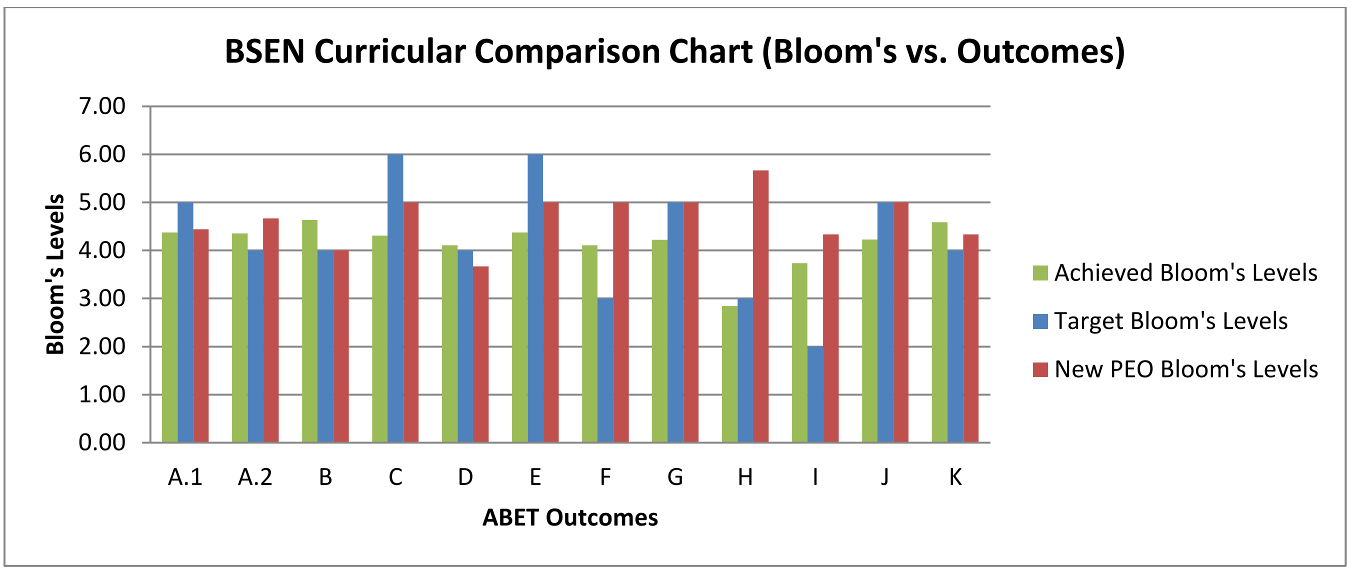

Figure 7. BSEN curricular Bloom's level vs. student outcomes comparison

The comparison of achieved, targeted, and calculated PEO Bloom's levels provided a tool for direct analysis of the curriculum's ability to achieve the PEOs via student outcomes as well as a tool for reevaluation of the PEOs themselves. For example, student outcome H: "the broad education necessary to understand the impact of engineering solutions in a global and societal context," according to the PEOs is the most important student outcome. However based on the target and achieved student outcomes levels this is one of the least taught outcomes. This gap provides a specific topic for analysis. If student outcome H truly is the most important student outcome then either curricular changes need to be made, otherwise the PEOs need to be reworked. Due to the application of these data management tools, this type of analysis can now be conducted by the department.

Conclusion and future works

For the purposes of ABET accreditation and continuous improvement, the evidence collection database and gap analysis tools were exceptionally well received by the faculty, department head, other college of engineering administrators, and even other engineering departments. The development and implementation of the evidence collection database allowed for easy storage of course evidence, quick access of the evidence, and thus provided the ability to conduct outcomes-based analysis at the course and curricular level. As a result, instead of simply collecting evidence for specific student outcomes without regard to the degree of achievement, the introduction of Bloom's taxonomic scale provided a direct means of assessment between achieved level and targeted level. In addition, the resolution of the analysis took place on a question by question level rather than assignment by assignment, providing additional means of analysis.

Furthermore, the gap analysis tool presented the results of the outcomes based analysis in a simple, instructor friendly manner. The tool compared achieved student outcome levels to the targeted student outcomes levels and identified specific areas of concern as well as provided detailed suggestions for course, assignment, and even specific question improvements. Many instructors have already implemented suggested course changes and received positive reviews from students as a result.

Even in the larger picture of determining the applicability of student outcomes to PEOs, the mapping of PEOs to student outcomes not only fulfilled the ABET requirement, but also, the calculation of Bloom's levels relations provided direct comparison of PEOs to curricular student outcomes. This provided an effective means for evaluating whether PEOs were being appropriately reinforced in the classroom. The tool also provided a rationale for reassessing the wording of the PEOs themselves.

For future version of these tools, collaboration between the AGEN/BSEN departments and other engineering departments such as computer engineering, is expected in order to develop a more robust and streamlined package. Possible future directions include the migration from the current Microsoft Office suite system to a more accessible web-based service. Such a migration would increase the ease of access for users as well as enable more state-of-the-art methods for data organization. Other possible ventures include working with existing software or web-based services to see if integration into their systems is a possibility.

Whatever the future may hold, the present data management tools contributed to ABET assessment preparation in a way that had not been possible prior. Besides, it is likely that the world of assessment will continue to migrate to a paperless environment, and it will be through evidence collection and analysis tools such as the ones demonstrated here that a more complete picture of the state of outcomes based education will be possible. For such progressions in assessment will continue to be a benefit not only to instructors and administrators, but also the students who will go through the programs assessed with these tools.

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Appendix I

Course _________ Evaluator Date _________

Objective	N/A	1. Knowledge:	2. Comprehension:	3. Application:	4. Analysis:	5. Synthesis:	6. Evaluation:
Students will be able to demonstrate the following skills:							
A1 **An Ability to Apply Knowledge of Mathematics, Physics and the Engineering Sciences**	___	___ Describe prevailing mathematical, physical, and engineering limitations and solutions to defined problems.	___ **Discuss** and describe prevailing mathematical, physical, and engineering limitations and solutions to defined problems.	___ **Solve** prevailing mathematical, physical, and engineering limitations and solutions to **partially** defined **complex** problems.	___ **Explain** prevailing mathematical, physical, and engineering limitations and solutions to **ill-defined** problems.	___ **Generalize** prevailing mathematical, physical, and engineering limitations and solutions to ill-defined problems.	___ **Assess and compare** prevailing mathematical, physical, and engineering limitations and solutions to ill-defined **complex** problems.
A2 **An Ability to Apply Knowledge of the Chemical and Biological Sciences, and Biological Systems Engineering.**	___	___ Describe prevailing chemical and biological sciences and biological systems engineering limitations and solutions to **predefined** simple problems.	___ **Discuss** and describe prevailing chemical and biological sciences and biological systems engineering limitations and solutions to a **partially** defined problems.	___ **Solve** prevailing chemical and biological sciences and biological systems engineering limitations and solutions to **ill-defined** problems.	___ **Explain** prevailing chemical and biological sciences and biological systems engineering limitations and solutions to ill-defined problems.	___ **Generalize** prevailing chemical and biological sciences and biological systems engineering limitations and solutions to ill-defined problems.	___ **Assess and compare** prevailing chemical and biological sciences and biological systems engineering limitations and solutions to ill-defined problems.
B **An Ability to Design and Conduct Experiments, Utilize Probability and Statistics, as well as to Analyze and Interpret Data**	___	___ Define the hypothesis for relevant experimental exercises.	___ Describe and **order** the experimental design for relevant exercises.	___ **Conduct** experimental exercises.	___ **Generate** the statistics and **explain** significant effects.	___ **Formulate** alternative experimental designs or **substitute** alternative analysis techniques.	___ **Interpret and rank** criteria for measuring effectiveness of experimental design.
			___		___ **Analyze and compare** treatment variables.		___ **Assess** value of the hypothesis for each relevant experimental exercise.