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A capstone design experience that makes easy the assessment of the some of the trickier ABET Student Outcomes to measure

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Introduction

This paper describes a one-year nuclear engineering capstone design course that is rich in assessment data to evaluate student achievement in several ABET (previously known as the *Accreditation Board for Engineering and Technology*) Student Outcomes (SOs). Efforts in the course begin about six months prior to its start by engaging students with a course overview, general guidance about design project options, and a requirement for students to provide professors with their topical interest areas. Over the summer, professors work to align student interests with faculty capabilities and with possible external project clients. Students are organized into groups of 2-3 with a direct faculty mentor and an external client who is recognized as a subject matter expert doing current work in that field. In the fall of senior year, the course starts deliberately slow and exhaustive in identifying, analyzing, and communicating design options to peers, faculty mentors, and external clients. Throughout the course, a thread that ties the two semesters together is the writing and presenting for an engineering conference which usually occurs within a month of graduation. All students finish the experience with a publication in the conference proceedings. Rather than assess all ABET SOs a-k, the course has a central focuses on assessing the ability to design a system, component, or process (SO c) and through carefully developed student experiences and assessment rubrics, course administrators have relatively easy access to some of the more difficult SOs to measure. These include student attainment of understanding the impact of their solution (SO h), recognizing the need for life-lone learning (SO i), and knowledge of contemporary issues (SO j). This paper presents assessment data for some of the trickier student outcomes to measure and some lessons learned on how they were measured.

The nuclear engineering curriculum

This curriculum is embedded in a university program that offers a broad liberal education for which generally 75% of the undergraduate experience is a common core experience that includes four semesters of history, four semesters of English, two semesters of foreign language, and another three semesters of social sciences (American Politics, Economics, and International Relations). As depicted in the annual ABET self-study template, ABET requires that the curriculum to be summarized by credit hour and by course type (Engineering Topics, ET; Math and Basic Sciences, MS; and General Education, GE) in what is commonly known as *ABET Table 5.1*. Our Nuclear Engineering (NE) curriculum

has the following credit hour distribution: 51.5 *Engineering Topics* (ET), 37.0 *Math and Basic Sciences* (MS), and 54.0 *General Education* (GE), and 12.0 *Other* (physical education and military science). The NE Curriculum is shown in *Figure 1*, and *Figure 2* offers an accompanying legend with course titles. *Figure 1* shows the default sequencing of the required courses by year where the unshaded courses represent the common core courses, and the shaded courses represent the required courses for the NE Major. For those courses in the NE Major, those with the prefix "NE" or "PH" are taught in our department, and the others shown in italics are taught outside of this department, e.g., EE, ME, MC, and MA which represent courses in electrical engineering, mechanical engineering, civil engineering, and mathematics, respectively. Two points are important to highlight from this NE curriculum review. First, there are more credit hours to general education (54.0) than there are to engineering topics (51.5). Second, there is nearly the same number of classes taught from other disciplines (8) as there are taught in NE (10). While these two facts may cast some suspicions about the depth of study in NE, they are viewed as important enablers for the achievement of students in ABET Student Outcome h, i, and j because of the broadened perspective offered to our students, the learning competencies developed through a diverse field of study, and the development of insights on how their engineering might be applied to other fields.

As with any ABET Engineering Program, Student Outcome assessment rests principally with direct measures of embedded indicators in this NE curriculum. Each of the NE courses in *Figure 1* is assigned responsibility for assessment of certain Student Outcomes each time that the course is taught and this data is integrated into a program level evaluation of the curriculum. Like other programs, embedded indictors include tests, laboratories, papers, presentations, and projects. What follows are some unique ideas for assessing the student outcomes. Each of these is a graded event in the NE Capstone Course, NE495/496. They include (1) *Student Outcome Essays* to assess student perspectives on their attainment of ABET Student Outcomes a-k, (2) *Capstone Project Elevator Pitch* to convey a broad perspective of the engineering environment ABET Student Outcomes h, (3) an *Oral Examination* to assess student dedication to continued learning Student Outcomes i, and (4) a series of *Journal Articles* to articulate contemporary issues related to the capstone project ABET Student Outcomes j. Students have a strong awareness of the Student Outcomes since the SOs are published in all of the NE course syllabi for the previous two years and are used for assessment data in each of these earlier courses.

Student Outcome Essays

The Student Outcome Essay is an announced, in-class reflective writing assignment during which students are asked to write two essays that are 500-1000

words on their laptops. Students are asked to develop a convincing argument that identifies the Student Outcomes for which they have attained the highest and the lowest levels of achievement. They see the two essay prompts when they enter the classroom, and they have a total of 55 minutes to write their two essays and to send them to the instructor before the end of this time period. Half the group is directed to write first about the Student Outcomes with the highest levels of achievement; the other half started first on the lowest levels of achievement. The essay prompts are shown in *Figure 3* which also provides a list of ABET Student Outcomes a-k and the default NE curriculum. In the class of 2015, there were 21 students each providing their three strongest and three weakest Student Outcomes. When examining the frequency of just the strongest or just the weakest Student Outcomes, the individual responses showed no apparent trend in revealing the strengths or weaknesses in the NE Curriculum. However, when combining the data and examining each Student Outcome, the difference between frequency selected as strongest and frequency selected as weakest, provided assessment data that at a minimum provided student confidence in attainment of Student Outcomes. As shown in *Figure 4*, these differences taken from the Student Outcome Essays provided some insights on areas for NE Program sustainment such as in Student Outcomes e and i and on areas for NE Program improvement such as in Student Outcomes b, j and k. This assessment should not be confused with a simple survey that students could answer in a few minutes. What's different is that this was done in the context of an event worth 5% of the course grade where students were evaluated for their writing style and the evidence that they provided to support their positions. While the Student Outcome Essays provided an indirect assessment of all Student Outcomes, a-k, this next indicator provided direct assessment on Student Outcome h.

Capstone Project Elevator Pitch

The Elevator Pitch was a short but intense graded event that lasted no more than 10 minutes. This event placed the students outside of their comfort zone by removing them from the crutch they often find in PowerPoint slides and demanding them to communicate to an unfamiliar VIP in a hurried situation of briskly walking down a hallway, riding an elevator, and then drawing a figure on a hallway whiteboard to communicate their design. The two-student design groups moved with the VIP and one course administrator serving as an evaluator. Additional stressors were added by only providing students with verbal guidance (see *Figure 5*) about this graded event worth 5% of their course grade and by placing a digital audio recorder on one of the students to record the entire conversation. The verbal guidance provided a list of possible questions that might interest the VIP. However, the VIP, an external role player, was really focused on probing into why the design project was so important. This was framed with the idea of assessing Student Outcome h, assessing the impact both positive and negative of the student design project. While the impact of the students'

composure, verbal and physical gestures, and technical and professional language contributed to part of their grade, an even greater quality of a learning experience occurred when the students would asked to listen to the recordings with their project advisor. This event, generally within a week of execution, was done with deliberate steps to get the students to do self-assessment. The guidance and grading rubric for this self-assessment is shown in *Figure 6*. Student Outcome h was assessed through the "quality" and the "style" of the communication shown in the grading rubric. The most impressive outcome was revealed in the last element of the grading rubric when ALL students demonstrated professionalism and mature learning through a "reflective, self-critical, and thoughtful plan to improve." We believe that this was a result of the unique learning environment presenting the student with the recorded performance of their pitch and with the personal engagement with the mentor who inspired development and growth.

Oral Examinations

The Oral Exams were focused on what we call Fundamental Nuclear Engineering Knowledge which is a cumulating body of knowledge gained from each of the nuclear engineering courses in the curriculum. Through each course, there are facts and concepts learned that we expect students to be able to recall for the remainder of their time in our curriculum and for that matter for the rest of their engineering careers. The culminating event of the Oral Exams is just a few weeks before graduation with one student being asked questions (akin to a dissertation defense) by three faculty members. Ahead of this, there are written exams on the Fundamental Knowledge each semester, and there is another form of the Oral Exam but in a group setting with peer evaluators. This was an indicator used to assess Student Outcome i, the recognition for the need for lifelong learning. In a group setting, a faculty member asked each student a series of questions of nuclear engineering facts and concepts. The questions persisted for 10-15 minutes while faculty member and two other students evaluated the quality of the responses. This was worth 5% of the course grade, but unbeknownst to the peer evaluators, they were also being evaluated on the quality of their peer review as benchmarked with consistency with the faculty evaluation of the student questioned in the oral exam. *Figure 7* shows the checklist used by students and faculty while evaluating the tested student. In some cases, the peer offered a level of grade inflation but more often the peer evaluation was consistent with the faculty evaluation. Each student peer evaluated two other students and those results were compared to the faculty evaluation using the *Figure 7* checklist. *Figure 8* portrays the level of consistency between evaluation of peers and evaluations by the faculty member; most students evaluated their peers similarly to the faculty member's evaluation. And, the peers were honest providing excellent grades generally when deserved and poor grades when warranted, as shown in *Figure 9*. The Oral Exams offered two data for Student Outcome i assessment. The first was an assessment of performance in answering

the questions presented during the exam. Since the content of the exam reached back in some cases to courses two years earlier, this represented retained learning. The second was an assessment of the peer evaluation which represented a loyalty to the process of learning. When put together, this data contributes to the assessment of Student Outcome i.

Journal Articles

The final indicator provided assessment of Student Outcome j, a knowledge of contemporary issues. Most writing assignments in the NE Capstone course leaned towards students publishing with the American Nuclear Society (ANS). In fact, we strive to take all of our seniors to the Student ANS Conference each year. We direct our students to write frequently using the ANS Template for conference proceedings. This style of writing was done for 4-6 times during the NE495 course and there was some professional but relatively harsh critique of student writing styles. Writing concisely and using technical language was somewhat foreign to students at first. Great emphasis was placed on the Introduction as a necessary place to capture the reader's attention, to convey the importance of the work, and to present a thesis statement and an overview of the body of the paper. In assessing student writing of Introduction, a faculty asked a fundamental question, "Why should the reader continue reading?" This was a means to emphasize the contemporary value of the design project and to demand that students recognize the contemporary value and effectively and concisely communicate the contemporary value of their project. This is assessed repeatedly in the process of the Capstone Design Course, and it is through this iterative framework there was emphasis and recurring effort devoted to understanding contemporary issues.

Conclusions

In this paper, four course indicators in the first semester course of the NE Design Project (NE495) were discussed as novel means to assess ABET Student Outcomes. Except for the Student Outcome Essays, these were all direct measures of student achievement. While these essays offered an overview of the student confidence in attainment of Student Outcomes. The Elevator Pitch provided some assessment data on Student Outcome, h; the Oral Exam provided some assessment data on Student Outcome, i; and the Journal Articles provided some assessment data on Student Outcome, j. Students generally enjoyed these course experiences because of their novelty and the break from traditional evaluation tools. Faculty appreciated these indicators as offering new and fresh insights to what sometimes are difficult ABET Student Outcomes to measures. Additionally, some of these assessment instruments take only a few minutes to assess the student. It is the hope that these four ideas of assessing students will

make easy the assessment of the some of the trickier ABET Student Outcomes to measure.

LIST OF FIGURES

Freshman		Sophomore		Junior		Senior	
Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
CH101	CH102	PH201	PH202	NE350	SS307	HI301	HI302
EN101	EN102	SS201	SS202	EN302	MA206	*ME480*	LW403
MA103	MA104	MA205	L_204	PH365	PL300	NE450	NE474
HI10_	HI10_	L_203	PY201	*MC311*	*ME370*	NE452	*EE301*
IT105	PL100	EV203	*MC300*	*MC364*	*MC312*	NE495	NE496
			NE300	*MA364*	NE355		NE400

Figure 1. NE Curriculum default sequence by year shown with shaded courses required for the NE major and yellow courses taught outside the NE Department

Courses Specific to the Major

EE301	**Fundamentals of Electrical Engineering**
MA364	**Engineering Mathematics**
MC300	**Fundamentals of Engineering Mechanics and Design**
MC311	**Thermal-Fluid Systems I**
MC312	**Thermal-Fluid Systems II**
MC364	**Mechanics of Materials**
ME370	**Computer Aided Design**
ME480	**Heat Transfer**
NE300	**Fundamentals of NE**
NE350	**Radiological Engr. Design**
NE355	**Nuclear Reactor Engineering**
NE400	**Nuclear Engineering Seminar**
NE450	**Nuclear Weapons Effects**
NE452	**Instrumentation and Shielding**
NE474	**Radiological Safety**
NE495	**Advanced Nuclear System Design Project I**
NE496	**Advanced Nuclear System Design Project II**
PH365	**Modern Physics**

Figure 2. NE curriculum course number legend.

Administrative Instructions. This is a reflective essay that is worth 125marks (5% of the course grade) in NE495. You will be assessed on your ability to effectively communicate and to demonstrate self-awareness and educational analysis of your curricular experience and development in the Nuclear Engineering (NE) Program. While the focus of this essay is on NE Student Outcomes, the scope of your analysis may reach back to the beginning of your West Point academic experience Fall plebe (freshman) year and extend to this point at the half-way mark of Fall Semester Firstie (senior) year. A list of NE Student Outcomes and the NE Curriculum is offered as a reference for this graded event. You must write essays for both essay prompts below. Your responses should each be 500-1000 words each, and you may type your essay on your computers or write your essays on paper.

Two Essay Prompts

1. Consider the Student Outcomes listed below. List the three that you feel that you have attained the highest level of achievement. Present a convincing argument supporting your three selected student outcomes by identifying courses and course events that provided you with the greatest confidence and development in the achievement of these student outcomes.
2. Consider the Student Outcomes listed below. List the three that you feel that you have attained the lowest level of achievement. Present a convincing argument supporting your three selected student outcomes by identifying courses and proposing course events that should be added to provide you with the greatest confidence and development in the achievement of these student outcomes.

Nuclear Engineering Student Outcomes.

Cadets possess:

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 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, 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.

Figure 3. Student Outcome essay prompt.

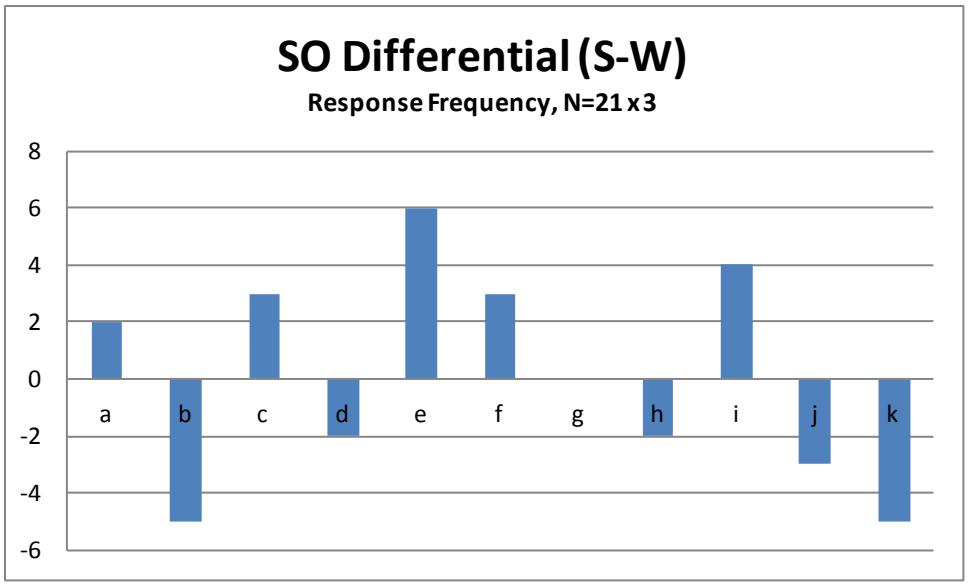

Figure 4. Student Outcome essay response delta.

Verbal Instructions to Cadets:

All Cadets report on Monday A hour class on 10 Nov. Five groups will be selected at random to execute the client update that day. The remaining groups will do their update on Thu, A hour class on 13 Nov.

Each group will have about 8 minutes with a VIP guest who will serve as your audience for your pitch.

You should be able to work without use of note cards or AV support. You may be briefing while on the move, such as walking or in an elevator.

You fundamentally need to express the importance of your work and to influence a non technical decision maker to re-allocate resources from one priority to yours.

Some questions that you might be asked:
Why is this important to the Army?
What are the costs involved in developing this project?
How long do you expect it will take to get this into soldiers' hands?
What public relationship ambush is lurking out there for the Army?
How does this work?
How does this fit into existing commercial products?
What type of unit will employ this and is there a need for a new military specialty?
What is the required maintenance?
What's the long pole in the tent for the design?
What resources do you need from me?

Figure 5. Verbal guidance for elevator pitch.

MENTOR Grading Rubric for Pitch Audio Recording

Please play the entire recording with your group and have them lead an AAR with generally four areas of focus:

1. Style of communication. Where they concise, direct, and quantifiable?
2. Quality of message. Did they present a convincing message that affected the decision maker?
3. Preparation for the event. Did they seem rehearsed and prepared for the questions that were posed to them?
4. Teamwork. Was there evidence of (1) sharing the responsibility for this briefing task and (2) levels of support and responsiveness to complement the briefer with a seamless addition of facts?
5. Professionalism and Mature Learner. This is a fifth area that YOU will assess BUT NOT INCLUDED in the AAR.

Assign grades to nearest 0.5 Marks

Focus Area/Weight	**Fail <9**	**Marginal 9.0-11.5**	**Good 12-13.5**	**Excellent 14.0-15.0**
Style of communication (15 Marks)	Numerous examples when was improvement needed	3-5 examples when was improvement needed	1-2 examples when was improvement needed	Consistent, always spoke effectively
Quality of message (15 Marks)	Unable to address need and feasibility	Attempted to addressed need or feasibility, NOT convincing	Clear message of one or the other: need OR feasibility	Clear message of need and feasibility
Preparation for the event (15 Marks)	No evidence of rehearsals	Little evidence of rehearsals	Some evidence of rehearsals	Strong evidence of rehearsals
Teamwork (15 Marks)	Disjointed team response, unclear roles and responsibilities	One cadet clearly shouldered the load	All contribute and but little evidence of team support	All contribute and several examples of team support
Professionalism and Mature Learner (15 Marks)	Had difficulty to ID areas for improvement even with some coaching	Could ID areas for improvement after some coaching	Could ID areas of improvement, but with weak action plan to improve	Reflective, self-critical, and thoughtful plan to improve

TOTAL:____ /75 Marks

Figure 6. Guidance for evaluating elevator pitch recordings.

1. Knowledge Asked:
   Quality of response:
   a. Excellent (got everything correct)
   b. Good (missed a minor point)
   c. Satisfactory (got most of the questions correct)
   d. Unsatisfactory (missed most of the questions)
2. Concept 1 Asked:
   Quality of response:
   a. Excellent (demonstrated full mastery of the topic)
   b. Good (demonstrated mastery but some subtle misunderstanding of the topic)
   c. Satisfactory (demonstrated basic understanding of the topic)
   d. Unsatisfactory (Could NOT demonstrated understanding of the topic)
3. Concept 2 Asked:
   Quality of response:
   a. Excellent (demonstrated full mastery of the topic)
   b. Good (demonstrated mastery but some subtle misunderstanding of the topic)
   c. Satisfactory (demonstrated basic understanding of the topic)
   d. Unsatisfactory (Could NOT demonstrated understanding of the topic)

Figure 7. Peer and faculty evaluation checklist for Oral Exams.

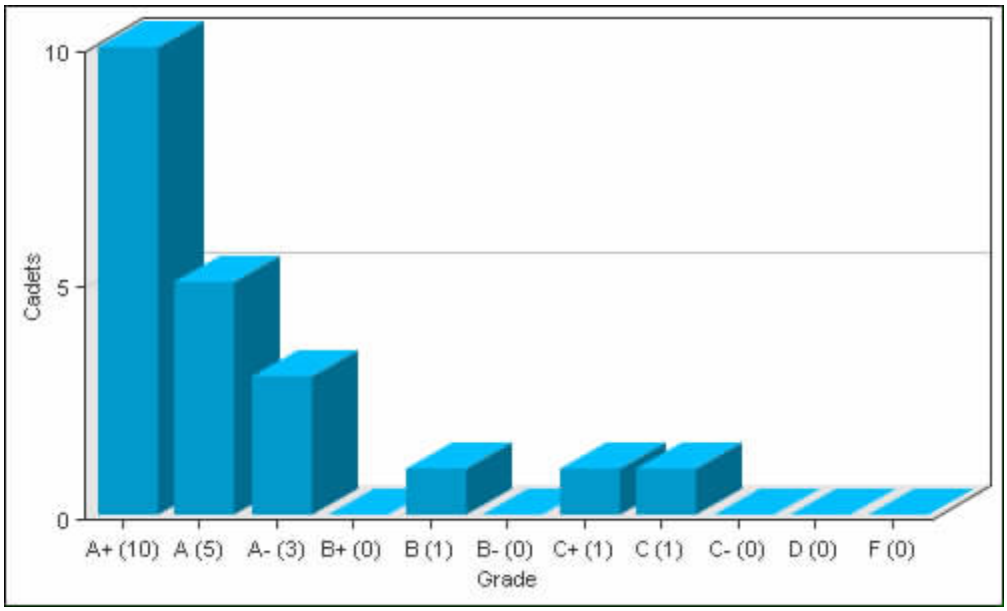

Figure 8. Oral Exams, peer consistency with faculty.

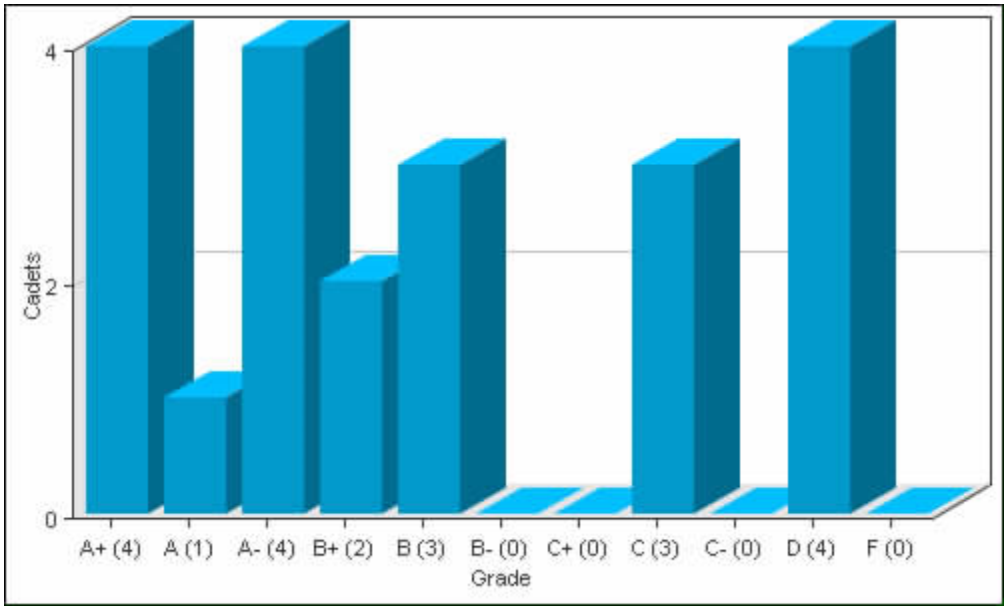

Figure 9. Oral Exams, peer evaluations of fellow students.