AC 2011-505: IMPROVING STUDENT ATTAINMENT OF ABET OUTCOMES USING MODEL-ELICITING ACTIVITIES (MEAS)

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Improving Student Attainment of ABET Outcomes Using Model-Eliciting Activities (MEAs)

Abstract

One of the challenges for engineering educators has been how to assess the ABET professional skills. We suggest that Model-Eliciting Activities (MEAs), which are a proven educational methodology for presenting complex, realistic, open-ended problems to students, can also serve as an assessment tool, both in the classroom, and, by extension for ABET. Although originally developed by mathematics education researchers, MEAs have recently seen increased use in engineering curricula. These posed, realistic scenarios require a student team to develop a generalizable model and then use it for the specific problem at hand. Recent research has demonstrated that they improve student problem solving and modeling skills as well as increase their understanding of course concepts. Our research also has identified additional benefits of using well-constructed MEAs in the engineering classroom. In particular, they can be an effective tool to improve students' knowledge and understanding of certain ABET professional skills including professional and ethical responsibility, understanding the impact of engineering solutions in a global and societal context, communication, as well as teamwork. We have conducted a series of experiments in industrial engineering courses in which students in sections using MEAs were compared to parallel sections in which MEAs were not used. A series of assessments were performed including pre and post concept tests and student course evaluations. Analysis was also done using student reflections recorded after completing MEAs. Students in sections of the courses that used MEAs rated their knowledge and understanding of these professional skills significantly higher than students in sections that did not use the MEAs. As a result we suggest that engineering faculty seriously consider using MEAs as a tool to improve both student learning and the attainment of a number of ABET outcomes in addition to providing a process for assessing that attainment. By combining pre- and post-concept inventories with the MEA implementation, faculty can better document learning gains, and thus have a comprehensive tool for ABET assessment. This should prove especially helpful in those areas where previous assessments may have shown weaknesses or inadequate attainment.

Introduction

One of the most challenging responsibilities for ABET (formally the Accreditation Board for Engineering and Technology) accredited engineering programs is ensuring student attainment of its minimum set of eleven program learning outcomes[1]. This paper reports on the use of a proven educational methodology, Model-Eliciting Activities or MEAs, in two different undergraduate engineering courses as one way to improve this attainment. MEAs present complex, realistic, open-ended client-driven problems to students. Originally developed by mathematics education researchers, MEAs have recently seen increased use in engineering.

They are carefully constructed using six specific principles that include model construction, reality, self-assessment, model documentation, generalizability, and an effective prototype. These posed problems require that the student teams provide both a general and a specific solution. While they have been shown to improve student problem solving skills as well increase student understanding of course concepts, in this paper we focus on some additional benefits of well-constructed MEAs in the engineering classroom. As part of a seven university collaborative research project we have been extending the MEA construct to upper division engineering courses while also introducing new elements.[2-5] One element in particular, ethical MEAs or E-MEAs are an extension that incorporates an ethical dilemma into the problem situation.[6]

In what has become a widely cited paper, Shuman, Besterfield-Sacre and McGourty examined the ABET "professional skills" in terms of how they might best be taught and how they could be assessed.[7] Here they divided these into two sets: process skills (communications, functioning on multidisciplinary teams, and understanding professional and ethical responsibilities) and awareness skills (understanding engineering solutions in a global and societal context, knowledge of contemporary issues, and need for lifelong learning). In a follow-up book chapter on the future of assessment, Besterfield-Sacre and Shuman next introduced the idea of assessing problem solving by using either Model Eliciting Activities or the concept of "adaptive expertise" as embodied in the Star.Legacy cycle as a means for more accurately assessing student problem solving abilities.[8] In particular, with respect to MEAs, they proposed:

> *Indeed, the attributes of MEAs support the development of the abilities and skills stated in ABET's Criterion 3. Studies by Diefus-Dux, et al with first-year engineering students indicate that MEA tasks can be effective learning exercises.* [9, 10] *Their work has focused on refining design principles for posing MEAs within engineering contexts. As such, MEAs can provide innovative assessment opportunities, especially when MEA exercises are combined with scoring rubrics.*

Because MEAs pose realistic problem scenarios for which the required solution goes well beyond the typical scope of a textbook problem, we have always believed that they could be used to improve students' knowledge and understanding of certain process and awareness professional skills, especially professional and ethical responsibility, understanding the impact of engineering solutions in a global and societal context, communication, and, of course, teamwork. During the past four years as we have researched the MEA construct, we have analyzed how they can best serve as both an intervention and an assessment tool.[11-13] Here we describe how the MEAs, in fact, can not only help students better acquire the professional skills, but also how at the same time they can be used for ABET assessment purposes. Specifically, we consider the question: To what degree can MEAs and E-MEAs impact the professional skills?

Methodology

We have conducted a series of experiments in the industrial engineering curriculum at a large public university. First, in the fall of 2009, two sections of an introductory Engineering Economy course were taught by the same instructor. The instructor incorporated three E-MEAs throughout the semester in one section that consisted primarily of industrial engineering students and had a total enrollment of 49 students (experimental group). The second section consisted primarily of civil engineering students but also included students from each of the other five engineering departments. A total of 70 students were enrolled in this section (comparison group). Also, in the fall of 2009, three sections on an introductory Engineering Statistics were taught by three different instructors. In one section (experimental group consisting of primarily industrial engineering students and an enrollment of 49) E-MEAs were incorporated into the course in addition to the traditional homework assignments, in-class problems, and quizzes. E-MEAs were not introduced into the two comparison sections that consisted of a mix of other engineering disciplines (61 and 65 students). Then in the spring of 2010, E-MEAs were incorporated into an additional section of the introductory Engineering Statistics course (51 students), which consisted of a mix of students from across the School. That section was taught by the same instructor who taught the fall 2009 experimental group. This was done in order to see if there was an effect since the fall experimental section consisted of only industrial engineering students as noted.

In order to assess effect size (gain), all participating students completed pre- and post-concept inventories. We have used concept inventories as an effective means of assessing the learning impact of a particular MEA or a set of MEAs.[14] Since each E-MEA was constructed around one or two key concepts, we wanted concept inventories that only addressed those concepts. For the Engineering Statistics course we selected a set of appropriate items from the statistics concept inventory originally developed and validated by Reed-Rhoads and colleagues.[15] In contrast, for Engineering Economics we had to create our own concept inventory, since none was available. In all cases students were given the pre concept inventory on the first class session and the post inventory during the last week of the course. By using concept inventories in this fashion we have been able to calculate effect sizes for each course and mode of instruction.[16, 17]

The MEAs: Each E-MEA consisted of both an individual part (worth 15-20 points) and a group part (worth 80-100 points). The individual parts typically consisted of three or four short answer questions aimed at encouraging the students to think about the particular decision situation and the relevant issues that would be posed in the E-MEA scenario. The group part consisted of an assignment to the engineering economy or engineering statistics team (groups of 3 or 4 students each) from a fictional client. The team had to address a particular decision situation, develop a model for solving the problem that they identified from the E-MEA, apply the model to the specific case described in the MEA, and write a memo to the "client" that details the team's results, solution procedure and recommended decision. Students worked in the same groups for all E-MEAs during the semester. These exercises were a required part of the course. Grading rubrics were developed for each MEA to ensure consistency. The E-MEAs were either graded by the instructor or by the same graduate student (who had been "calibrated" by the instructor) throughout the semester. The E-MEAs are described in Table 1. Students in the comparison courses were only given the traditional assignments and not the E-MEAs.

Table 1: E-MEAs used in the Industrial Engineering Curriculum

Title	Originally Developed by	Decision Situation	Ethical Dilemma	Relevant Concepts
Campus Lighting Economics	Purdue University	Which lighting proposal for a college campus is the least costly and addresses the campus community's safety concerns?	Campus safety concerns vs. cost of new lighting	Cost Estimation; Time Value of Money; Comparing Alternative Investments
Trees and Road Safety	University of Pittsburgh	Should old trees in parks be removed to provide greater road safety?	Destruction of old trees (environmental concerns) vs. driver/passenger safety	Cost Estimation; Time Value of Money; Benefit/Cost Ratios; Consideration of all relevant criteria; Contemporary Problems
Dams, Earthquakes, and Budget Cuts.	University of Pittsburgh	How should a major dam project in Turkey be completed given required budget cuts?	Provision of water, job creation, economic stability vs. risks of construction in earthquake prone regions, environmental concerns, and international relations	Cost Estimation; Time Value of Money; Benefit/Cost Ratios; Uncertainty; Consideration of all relevant criteria; Contemporary Problems
Tire Reliability	Purdue University	To develop a general procedure that can be used to analyze the reliability of any set of tires based on a given "acceptable reliability" data set.	Safety concerns regarding a reliable vs. unreliable tire production run.	Mean; Median; Variance; Histogram; Probability plots; Outliers; and Reliability.
Test Leads	University of Pittsburgh	To develop a sampling procedure for ensuring that an incoming batch of leads is of acceptable dimensions as well as to determine the minimum sample size for a specified precision.	Making a decision to recall a batch of defibrillators.	Central limit theorem; Uniform distribution; Sample size; Means; Sample of the means; Distribution of the sample mean (mean and variance); and Confidence intervals.
CNC Machine	University of Pittsburgh	To demonstrate if one type of the machine outperforms the other in terms of unit production time, cost, and quality, in order to build support for the purchase.	Agreeing with management's decision vs. risking a promotion and providing a realistic report.	Hypothesis testing; Standard deviation; Variance and Confidence intervals.

In addition to the concept inventories and the grading rubric (and a reflection instrument), one other measure was available - the school wide student evaluation of teaching, which included a number of questions designed specifically to measure attainment of ABET outcomes 3. a. - k. (see Figure 1). The items from this assessment are outlined in Table 2. Note that the evaluation questions are not ordered sequentially. The 3.a. to k. items and results tables (shown later) are consistent with the order of the questions as they appeared on the teaching evaluation instrument. Students were asked to respond to each item on a 1 (not at all) to 5 (a great deal) scale. The questions were prefixed with "The School of Engineering is interested in learning how this course has improved your competence in a number of important areas. For each of the following, please indicate how much this course has improved your knowledge or skill."

Program outcomes:

(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 *industrial* engineering tools necessary for engineering practice.

Figure 1: Recommended ABET Program Outcomes[18]

As noted, a second assessment method that was used in each of the course sections that incorporated the E-MEAs was a student "reflection" instrument. These were recorded after completion of each of the E-MEAs.

Table 2: Teaching Evaluation Questions Related to ABET Outcomes

Outcome	Item number	Course Evaluation Statement "This course has improved my . . ."	Code
A	3.1	Ability to use math concepts to solve engineering problems	Math
A	3.2	Ability to use chemistry concepts to solve engineering problems	Chem
A	3.3	Ability to use physics concepts to help solve engineering problems	Phys
A	3.4	Ability to use engineering concepts to solve problems	Engr
B	3.5	Ability to design an experiment to obtain measurements or gain additional knowledge about a process	Exp
B	3.6	Ability to analyze and interpret engineering data	Data
C	3.7	Ability to design a device or process to meet a stated need	Design
D	3.8	Ability to function effectively in different team roles	Team
E	3.9	Ability to formulate and solve engineering problems	PS
K	3.10	Ability to use laboratory procedures and equipment	Equip
K	3.11	Ability to use software packages to solve engineering problems	Soft
K	3.12	Ability to use cad software	CAD
F	3.13	Knowledge of professional and ethical responsibility	Ethics
G	3.14	Ability to write reports effectively	Write
G	3.15	Ability to make effective oral presentations	Oral
H	3.16	Knowledge about the potential risks (to the public) and impacts that an engineering solution or design may have	Risks
J	3.17	Ability to apply knowledge about current issues (economic, environmental, political, societal, etc.) to engineering related problems	Issues
I	3.18	Appreciation of the need to engage in lifelong learning	LLL

Results

Table 3 shows the course evaluation results for ABET outcome related questions in the two engineering economy sections. As can be seen in the data, significant differences were found between the students in the two sections regarding their confidence in knowledge and skills related to outcomes a, c, d, f, g, and h. With the exception of outcome a, all of these outcomes are related to either the process or awareness professional skills. These two courses were taught in precisely the same manner by the same instructor, the difference being the addition of the MEAs in the experimental section. Further, the pre- and post-concept inventories indicated that there was substantial learning gain for both courses.[19]

Next, consider the results from the three sections of the introductory probability and statistics course shown in Table 4. Again, these results show a significant difference between the students in the experimental versus comparison sections regarding their confidence in their knowledge and skills in a number of the ABET areas, specifically, outcomes a, d, e, f, g, h, and j, primarily the professional skill areas. There was a difference found between the two comparison groups on outcome k, specifically the question related to software, which is attributed to differences between instructor use of Minitab in the courses. The only difference in the professional skills areas was in outcome d (teamwork), which could also be attributed to pedagogical differences in teaching. Thus the two comparison groups do appear to have much different results than the experimental group. Again, the pre- and post-concept inventories indicated there was substantial learning gain in all three courses.

Table 3: Fall 2009 Engineering Economy Course Results

Outcome	Item	p-value[1]	Comparison Section (no MEAs)			Experimental Section (MEAs)		
			Mean	Std. Dev.	n	Mean	Std. Dev.	n
a	Math	**0.007**	3.83	0.97	59	4.26	0.72	39
	Chem	0.938	1.19	0.61	57	1.20	0.64	41
	Physics	0.483	1.22	0.62	59	1.32	0.71	37
	Engr	0.184	3.49	1.21	57	3.69	0.95	39
b	Exp	0.077	2.31	1.21	59	2.68	1.29	40
	Data	0.500	3.72	1.00	57	3.72	1.05	39
c	Design	**0.050**	2.37	1.25	57	2.84	1.41	38
d	Team	**0.018**	3.66	0.81	58	4.03	0.85	38
e	PS	0.222	3.58	1.05	59	3.76	1.17	38
k	Equip	0.331	1.34	0.87	58	1.53	0.94	36
	Soft	0.191	2.61	1.27	59	2.31	0.98	39
	CAD	0.064	1.08	0.38	59	1.38	0.95	40
f	Ethics	**0.043**	3.10	1.11	59	3.50	1.13	40
g	Write	**0.031**	3.27	0.83	59	3.62	0.94	39
	Oral	0.941	3.00	0.81	59	2.72	0.89	39
h	Risks	**0.003**	3.39	1.00	57	3.97	0.96	39
j	Issues	0.181	3.76	0.96	58	3.95	1.04	40
i	LLL	0.327	3.45	1.01	58	3.55	1.13	40

[1] one-tailed; null is equal means; alternative is that experimental group mean is larger than comparison group

Table 4: Fall 2009 Probability and Statistics Course Results

Outcome		p-value[1]	Comparison Group 1 (no MEAs)			p-value[1]	Comparison Group 2 (no MEAs)			Experimental Group (MEAs)		
			Mean	Std. Dev.	n		Mean	Std. Dev.	n	Mean	Std. Dev.	n
a	Math	**0.007**	3.60	1.01	50	**0.000**	3.31	0.97	54	4.09	0.79	34
	Chem	0.198	1.16	0.47	50	0.217	1.17	0.47	52	1.28	0.74	36
	Physics	0.571	1.34	0.75	50	0.876	1.53	0.95	47	1.31	0.76	35
	Engr	**0.012**	2.66	1.22	50	**0.008**	2.67	0.97	46	3.19	0.92	36
b	Exp	0.456	2.54	1.15	50	0.833	2.84	1.20	49	2.57	1.29	35
	Data	0.768	3.69	1.19	49	0.886	3.80	1.09	46	3.51	1.04	35
c	Design	0.593	2.06	1.17	50	0.532	2.02	1.12	51	2.00	1.15	36
d	Team	**0.000**	2.24	1.04	50	**0.008**	2.77	1.08	48	3.33	0.99	36
e	PS	**0.016**	2.84	1.25	50	**0.005**	2.82	0.96	50	3.31	0.75	36
k	Equip	0.425	1.46	0.97	50	0.114	1.27	0.68	48	1.50	0.97	36
	Soft	0.384	2.27	0.91	49	1.000	3.45	1.22	51	2.33	0.93	36
	CAD	0.138	1.18	0.67	49	0.193	1.22	0.62	49	1.36	0.80	36
f	Ethics	**0.003**	2.06	1.28	50	**0.009**	2.20	1.06	51	2.75	1.02	36
g	Write	**0.000**	1.44	0.95	50	**0.000**	1.54	1.01	50	2.75	1.11	36
	Oral	0.095	1.26	0.69	50	0.088	1.25	0.70	48	1.49	0.85	35
h	Risks	**0.001**	1.86	1.07	50	**0.050**	2.18	1.15	49	2.58	1.05	36
j	Issues	**0.002**	2.00	1.08	49	**0.014**	2.19	0.99	49	2.67	0.96	36
i	LLL	0.063	2.54	1.22	50	0.437	2.90	1.13	50	2.94	1.14	35

[1] one-tailed; null is equal means; alternative is that experimental group mean is larger than comparison group

Finally, we consider the results from comparing the fall 2009 experimental group and spring 2010 section of the engineering statistics course, both of which incorporated E-MEAs. The fall course consisted only of industrial engineering students, while the spring course was a mix of students from various engineering disciplines. The purpose of this comparison was to determine whether the difference observed in the fall experiment might be due to the experimental groups consisting of only IE students while the comparison groups were a mix of students from the other engineering disciplines. As can be seen, only one item showed a significant difference between the fall experimental group and the spring group, which also incorporated the MEAs. This does provide some evidence that differences in the fall sections were not attributed to differences in the types of students in the three sections of the course.

Table 5: Comparing IEs with non-IEs

Outcome		**Experimental Group (MEAs)**			**p-value**[1]	**Non IEs (MEAs)**		
		Mean	**Std. Dev.**	**n**		**Mean**	**Std. Dev.**	**n**
a	Math	4.09	0.79	34	0.766	4.15	0.77	27
	Chem	1.28	0.74	36	0.395	1.15	0.46	27
	Physics	1.31	0.76	35	0.791	1.26	0.71	27
	Engr	3.19	0.92	36	0.940	3.21	1.15	29
b	Exp	2.57	1.29	35	0.109	3.15	1.43	26
	Data	3.51	1.04	35	**0.023**	4.18	1.19	28
c	Design	2.00	1.15	36	0.900	1.96	1.28	26
d	Team	3.33	0.99	36	0.776	3.26	0.94	27
e	PS	3.31	0.75	36	0.106	2.78	1.53	27
k	Equip	1.50	0.97	36	0.394	1.30	0.87	27
	Soft	2.33	0.93	36	0.063	2.79	0.99	28
	CAD	1.36	0.80	36	0.115	1.11	0.42	27
f	Ethics	2.75	1.02	36	0.482	2.96	1.26	27
g	Write	2.75	1.11	36	0.875	2.79	0.92	28
	Oral	1.49	0.85	35	0.100	1.19	0.56	27
h	Risks	2.58	1.05	36	0.400	2.85	1.38	27
j	Issues	2.67	0.96	36	0.892	2.63	1.27	27
i	LLL	2.94	1.14	35	0.621	2.78	1.34	27

1 two tailed, null is equal means; alternative is unequal

Discussion

Further evidence of the benefits of MEA can be seen when a deeper look at the student solutions is taken. Nearly all of the student teams at least identified the ethical and societal issues in the given situations and most groups specifically addressed the issues in their solutions and made recommendations to the client regarding them. Without the MEAs, the comparison groups are not given the opportunity to consider these issues in addressing engineering problems. For example, one group in the engineering economy course stated the following in their solution to the Dams, Earthquakes, and Budget Cuts E-MEA:

> *"Another angle which needs to be viewed when trying to select the best option is the impact of safety and the environment that it will have. Earthquakes are common in the area, and decreasing safety of a project that costs this much and putting the entire thing at risk once constructed is not a good idea. You also want to limit the environmental effects of your choice. Finally, you must consider all other consequences not dealt with above, such as how it may affect relationships with surrounding nations and how much it will alter the dam's performance and capacity…..These safety measures far outweigh the other alternatives. A dam which is susceptible to earthquake damage in an earthquake prone area is simply unacceptable. If an earthquake were to damage one of the other dams, thousands of people could potentially die. Preventing this potential loss of life is the most important thing to any ethically responsible company. Human lives are valued more than anything else."* -Team 11

Another group stated the following:

> *"Next, an organized list would need to be formed to analyze each alternative. Each list should include benefits, and costs, operating and maintenance costs, of the alternative. A benefit-cost ratio would useful in calculating economic implications of the alternative to evaluate which is more attractive. Additionally, in projects of this nature, there is more to analyze than just the economic costs. Societal implications may be a more important focus when determining the correct alternative. Factors to consider would include the region's people, the environment, archeological sites, and most importantly international relations."* – Team 12

A team in the spring 2010 probability and statistics course made the following statement in regards to the ethical dilemma posed in the Tire Reliability E-MEA:

> *"Peterson's request to not share the results of our analysis is understandable when considering confidentiality. However, there are certain circumstances that require one to violate this request. These circumstances would occur if it is found that the tires present a detriment to public safety. If Safety Plus refuses to act to solve the problem in a timely fashion, it is the obligation of those performing the analysis to take action. Actions can include making the public aware by reporting to media. A more acceptable strategy, with consider to the corporation, would be to notify a regulatory committee such as the department of transportation. The results from the 25 K grade tires fall into this category."*- Team 7

While the self-reported results found in the teaching evaluations are useful in initially identifying differences between the E-MEA and non E-MEA sections, other assessments are also used. The grading rubric used by the instructors includes points specifically given for identifying and addressing the ethical, environmental, and/or other societal issues in the group solutions to the E-MEAs. For the first two E-MEAs in the engineering economy course, only 76% of the student groups received full credit for these points. By the third E-MEA, 93% of the groups received full credit. This was consistent in both the industrial engineering section of the course as well as the section that included students in various engineering majors. Overall scores on the E-MEAs continued to show improvement in students' ability to recognize and understand the importance of the professional skill areas. Students were beginning to understand that real problems typically require the decision-maker to go beyond the rational, analytical, and mathematical solutions to problems and recognize the impact on such non-quantifiable factors as safety, environmental effects, and ethical dilemmas. Increases in successful teamwork and improvement in students' communications skills (via the written memos) have also been observed. When reviewing the "reflection" data, we have also observed an increase in the percentage of students that recognized and addressed the ethical issues as new E-MEAs were introduced to the same group of students (see [20] in these proceedings).

Conclusions

Because of the success with using E-MEAs in improving these outcomes, the instructors for these courses continued to incorporate E-MEAs in all sections of their courses in the 2010-2011 academic year. Specifically, in the engineering economy course, both fall 2010 sections were assigned three E-MEAs throughout the semester.

While the use of E-MEAs requires effort on the part of the instructor if they are to be implemented properly – e.g., selecting and adapting appropriate MEAs or E-MEAs to a particular course, organizing student groups, grading, and so forth - we have found that this teaching methodology is ideal for engaging students in applying course concepts to realistic, client-based problems that are generally much richer than textbook problems. If used correctly, we have shown that they can be very effective in reinforcing and integrating course concepts as well as increasing student knowledge and understanding of various professional skills related to ABET program outcomes. We are now focusing additional research on the modeling aspects of implementing MEAs in engineering courses as well as student "reflective" surveys being used to measure life-long learning and further benefits of MEAs.

In summary, we have found that the proper use of MEAs can result in substantial learning gain, certainly as much as the more traditional instructional methods that use "back-of-the-book" problems as the sole homework exercises. However, with the E-MEAs, we have found something else – in addition to assessing problem solving skills as originally suggested by

Besterfield-Sacre and Shuman – we found that they could also improve students' abilities to better acquire almost all of the professional skills. Hence, we propose that when used in combination with the concept inventories, grading rubrics, and reflection tools, they offer engineering faculty not only a learning intervention but an assessment method for a large portion of the ABET outcomes as well. By utilizing MEAs or E-MEAs in a select set of courses, faculty can obtain a comprehensive set of assessments for ABET while enhancing student learning.

To close, engineering faculty must be able to address weaknesses in program outcomes and, while schools often find they have no difficulty with the so called "hard skills" (e.g., apply math, science and engineering science, design and conduct experiments) it is in teaching and assessing the professional skills where they more often fall short. By introducing realistic problems such as the ones contained in the E-MEAs, faculty are able to assess and improve students' knowledge and skills in these areas. For additional examples of MEAs and E-MEAs as well as guidelines for their use please see http://modelsandmodeling.net/Home.html.

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