AC 2009-1277: E-MEAS: INTRODUCING AN ETHICAL COMPONENT TO MODEL ELICITING ACTIVITIES

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E-MEAs: Introducing An Ethical Component to Model Eliciting Activities

Abstract
We are using *models and modeling,* specifically model eliciting activities (MEAs), to enhance upper-level engineering students' vertical skills integration and problem solving capacity. The MEAs we are introducing also are challenge students to develop an additional professional engineering skill - an ability to recognize and resolve ethical dilemmas. This MEA extension - ethical MEA (E-MEA) - requires students to resolve ethical dilemmas embedded within a larger, unstructured engineering problem. Engineering scenarios are being designed that elicit differing perspectives on ethical issues, for example confidential information versus public safety or employee loyalty versus whistle blowing. We are extending MEAs in this fashion in order to study the strategies that engineering teams use to resolve complex ethical dilemmas, using process-level assessments of their MEA problem solving activities.

Our approach begins with the key engineering concept or idea (model) that we wish to target (e.g., ANOVA, multiple linear regression, or decision modeling). We then adapt either an existing ethical case or develop our own, identifying a scenario with appropriate data that both targets the particular engineering concept but also introduces the ethical dilemma that must be addressed by the student team as part of the problem solution. The use of context-based case studies provides ideal subject material for the development of these modeling exercises, which are designed to require the synthesis of intangible concepts such as environmental or societal justice. We present several E-MEAs that we have developed and pilot tested, including our results to date in analyzing both the problem solving process the student team used and an assessment of the outcome. We also describe our various data collection methods and our future plans.

1. Introduction

It has now been more than decade since what was then the Accreditation Board for Engineering and Technology and is now simply ABET added to its previously implicit set of "hard" engineering outcomes a second, equally important set of six outcomes which we, among others have designated "professional" skills[1]. Included among these latter skills are communications, teamwork, and understanding ethics and professionalism, which we have denoted as process skills, and three others - engineering within a global and societal context, lifelong learning, and a knowledge of contemporary issues - which we have termed awareness skills.

We propose that in what Freidman is now calling a "hot, flat and crowded world[2]" these professional skills can no longer be neglected by engineering educators in favor of the more traditional "hard skills." This is especially true as the current economic downturn has further caused industry to view larger and larger portions of the science and engineering labor pool as a commodity rather than a profession. In fact, companies have become transnational, no longer limited by national borders as they seek the best talent from any number of lower cost countries including India, China, Russia and Vietnam[3, 4]. As a result, U.S. engineering educators must now focus on ensuring that our graduates will continue to bring value to a market place in which their salary may be three to five times greater than their international competitors[5, 6].

Combine this with the growing interest in sustainability and current, worldwide recognition that the planet's resources are limited, and it is also becoming clear that our graduates also must possess a social consciousness. Now more than ever they need to understand the implications of their work, especially any long-term impact on the people affected by their engineering designs and decisions[7].

Hence, engineering educators now face a new challenge: how do we produce graduates that are better problem solvers, and possess the important "process" and "awareness" professional skills. To do this, we also have to develop the tools to better assess learning to determine if we have achieved these desired outcomes. We believe that one very fruitful approach is to focus on models and modeling, especially the development and use of model eliciting activities or MEAs[8-10]. We propose that this construct, developed initially by mathematics educators, can be both an important learning intervention, as well as a research tool, and can be tightly coupled with other assessment tools. To that extent, under funding from National Science Foundation (CCLI Phase 3) - *Collaborative Research: Improving Engineering Students' Learning Strategies Through Models and Modeling* - we are leading a seven university study to do exactly that[11]. Below we describe the MEA methodology, provide an overview of the project, and discuss our particular progress to date including the development of what we are calling ethical MEAs or E-MEAs.

2. The MEA Construct - Background

We are rigorously investigating the use of *models and modeling* as a foundation for undergraduate engineering curriculum and assessment. Our approach builds upon and extends model-eliciting activities (MEAs), which originated in the mathematics education community[12]. MEAs are built around carefully constructed open-ended scenarios that simulate authentic, real-world problems. The construct has been designed to better develop systems thinking in problem-solving. A typical MEA requires a student team to apply mathematical or other structural interpretations (a model) to situations that cut across multiple disciplines and constraints. The team may need to make new connections, combinations, manipulations, predictions or look at the problem in other ways in order to resolve the posed MEA scenario. MEAs differ from "textbook" problem-solving activities in terms of length of time, access to information resources, number of individuals involved in the problem-solving process, and type of documentation required. However, the most important difference is the emphasis on building, expressing, testing and revising conceptual models. In examining this construct, we felt that it could be extended to cover the recognition and resolution of ethical dilemmas**.**

Mathematics education researchers developed MEAs to observe the development of student problem-solving competencies and the growth of mathematical cognition [13]. What started as a tool to assist researchers in studying problem solving soon morphed into a methodology to assist students in becoming better problem solvers[14-16]. Concomitantly, MEAs became a tool for both instructors and researchers to not only observe but also design situations that engaged learners in productive mathematical thinking[17, 18].

Recently MEA research has shifted to undergraduate engineering education, specifically at Purdue University[19-22]. Diefes-Dux and her colleagues introduced Purdue's first-year engineering to MEAs, and demonstrated that not only could they be effectively used to introduce concepts in engineering contexts, but also increased women's interest in engineering[23, 24].

Another relevant MEA extension has been provided by Lesh, Hamilton and their colleagues in developing a series of reflection tools (RTs) that, following an MEA activity, help students record significant aspects about what they have done (e.g., strategies used, or ways the team functioned) so that later they could use this information to engage in reflections and discussions about the effectiveness of various roles, strategies, and levels and types of engagement[25]. RTs offer the potential to be an important research observational tool, while helping students better develop conceptual frameworks for thinking about learning and problem-solving.

2.1 The Six Principles of Model-Eliciting Activities

As noted above, MEAs are client-driven, open-ended problems designed to be both model-eliciting and thought-revealing. As simulations, careful design and refinement is critical to their effectiveness. MEAs require students to mathematize (e.g., quantify, organize, dimensionalize) information and structure in context. Six principles for designing model-eliciting activities[26] have been adapted to the development of contextual mathematical modeling activities for engineering courses[27-29].

Model Construction: student teams must create a mathematical system to reasonably address the analytically significant needs and purposes of a given client. A mathematical model is defined as a system that is used to describe, make sense of, explain, or make predictions about a system.

Reality: the problem must be set in a realistic, authentic engineering context that requires the development of a mathematical model for solution. In a well-designed MEA students must resolve a complex scenario by extending their knowledge of and experience with concepts and models. Realistic assumptions should be used by the students to assess the quality of their solutions. The MEA must create the need in the minds of the students for problem resolution, ideally making them behave like professional engineers.

Generalizability: students must create models that are sharable, transferable, easily modifiable, and/or reusable in similar situations. The model must be generally useful to the client and not just apply to the particular situation. For example, it must be capable of being used by other students in similar situations, and robust enough to be used repeatedly as a tool for some purpose.

Self-Assessment: students must perform self-evaluation of their work as they progress. The criterion for "goodness of response" is partially embedded in the activity by providing a specific client with a clearly stated need. This criterion should encourage students to test and revise their models by pushing them past their initial thinking to create a more robust model that better meets the client's needs.

Model Documentation: the model must be documented; typically students write a memo to the client describing their model. Hence, the MEA is both model-eliciting, and thought-revealing. That is, students' mathematical approach to the problem is revealed in the client deliverable. This enables students to examine their progress, assess the evolution of the mathematical model, and reflect about the model. It provides a window into students' thinking, which can inform instruction.

Effective Prototype: the MEA's solution should provide a useful prototype for interpreting other situations. One or more important engineering concepts should be embedded in the MEA; long after solving the problem, students should be able to think back to a given MEA when they encounter other, structurally similar situations. In this manner, students should better retain concepts.

2.2 Expanding the Construct

The MEA construct has considerable potential for engineering education - it allows for multiple perspectives to be brought to bear on a situation, includes a realistic setting that enables students to feel that they are doing engineering, and permits student teams to assess their own progress towards solution by including carefully crafted data sets. Given this potential, extensions to other types of models and applications hold much promise. In particular, we are extending the MEA framework to the various engineering disciplines as well as extending the construct to ethical models. Relative to the former, we are extending the MEA construct to a format in which the student team must integrate prior knowledge and concepts in order to solve the problem at hand, thus enforcing conceptual understanding. Relative to the latter, by introducing an ethical component, we are better preparing students to become more socially conscious.

We have hypothesized that well-designed MEAs at the junior and senior level can lead to heightened conceptual understandings by requiring students to engage a particular concept or concepts as a key step in the solution process. Further, at this level a well designed MEA should also create an opportunity where skills such as communication, verbalization, and collaboration are combined with mathematical and engineering concepts to resolve the posed problem. It should also encourage students to acquire or develop necessary new knowledge. Hence, a well constructed MEA should support the development of teams of critical thinkers who can evolve their engineering knowledge into fully-tested, refined modeling solutions. They should educate prospective professionals to clearly document their work. They should support the development of the abilities and skills as stated in ABET criterion 3 a to k[30]. These features of MEAs and their implementations are clearly aligned with *how people learn*[31] recommended pedagogies.

3. From MEA To E-MEA – Introducing an Ethical Component to Engineering MEAs

One goal in developing MEAs for upper-level engineering courses has been to motivate students to integrate concepts covered previously in their curriculum into their developing model. In this way, fundamental engineering and science concepts should be reinforced, while exercising complex reasoning and creative thinking skills. We first tested a series of pilot MEAs and accompanying assessment tools during summer 2007 in an elective industrial engineering problem solving course using seven pilot MEAs as shown in Table 1. Since then we have introduced MEAs in a range of courses: engineering statistics (I and 2), sustainability, human factors, and engineering ethics. In addition, ethical MEAs (E-MEAs) were also piloted in these latter courses and continue to be developed.

3.1 Ethics And Global MEAs

The use of context-based case studies provides ideal subject material for the development of modeling exercises. This is particularly true in the case of ethics-based models, which often require the synthesis of intangible concepts such as environmental justice, international policy, and resource conservation during solution, as does the *Trees* MEA shown in Table 1. We have developed several ethics cases that have global and/or societal aspects including ethanol versus food production[32] and a situation similar to the Ford Explorer – Firestone Tire "roll-over" accidents[33]. We believe that these particular E-MEAs should motivate students to better understand the global context within which engineering decisions are made. For example, the Gown Manufacturing MEA focuses on a U.S. company's offshoring decision. Students must incorporate multiple types of information, including economic and demographic data, about three possible countries in developing and testing a decision methodology.

Table 1: Description of MEAs

	MIA	Description and Skills Targeted	Origin
Probability, Statistics and Data Analysis			
1	Supplier Development	• Comparison of alternative suppliers • ANOVA techniques	Inspired by Just-in-Time MEA (Purdue)
2	Quality Improvement	• Quality plan to reduce variance and scrap • Quality improvement process • Decision flow chart using SPC tools	Inspired by Process Control MEA (Purdue)
3	Compressor Reliability	• Central Limit Theorem applied to time to failure • Confirmation of wear-out vs burn-in failure • Distribution fitting – use of Chi Square	Inspired by Tire Reliability (Purdue)
Operations Research			
4	CD Compilation	• Optimization heuristic; 0-1 integer programming	Extension of Purdue MEA
Decision Modeling			
5	Disaster Decision Modeling	• Modeling natural disaster responses • Using real-time data • Decision tree and influence diagram/Bayesian network	Developed by U. of Pittsburgh researchers
Engineering Ethics			
6	Trees	• Recognizing and resolving ethical dilemma • Reducing auto accidents vs. preserving old growth trees	Modification of Harris, Pritchard, Rabins case[34].
Global Decision Making			
7	Outsourcing Gown Manufacturing	• Deciding whether or not to outsource • Deciding where to outsource	Developed by U. of Pittsburgh researchers

In brief, our objective is to utilize the E-MEAs to better understand the various strategies student teams use to resolve complex ethical dilemmas. Consequently, we have developed a series of E-MEAs (which are discussed below). Some of these have resulted from adapting existing ethical cases to E-MEAs, while others are our own creation. Our cases are designed to bring out differing perspectives on ethical issues, e.g., employee loyalty as opposed to whistle blowing. We then use MEA reflection tools to facilitate data collection.

3.2 Example E-MEAs

The Ford-Firestone case has provided material for an E-MEA that requires the students to first utilize conceptual knowledge, and then address an ethical dilemma. Specifically, we present the students with the following situation: A major insurance carrier has noticed a relatively large number of claims involving SUVs that have rolled over after tire tread has separated. The carrier contacts an engineering testing firm to design a series of potentially destructive tests on a combination of vehicles and tires to identify a potential problem with either a vehicle or tire model in various environmental conditions. Students are given costs for conducting the experiment, a budget, and are then asked to provide a design for the experiment – i.e., identify each combination of vehicle and tire to test, and the particular replications (if any). A simulator then provides each student team with a unique set of test results based on their design so that they can then conduct a more thorough statistical analysis. However, in making their final report, the team must address the sensitivity of the results they have just found. Specifically, what should they (the testing company) do with the results (that the carrier has asked them to keep confidential). That is, they must consider issues related to non-disclosure versus the safety of the public; at what point does public welfare trump non-disclosure? Hence, this E-MEA requires students to address three types of problems:

1. An experimental design with a cost constraint
2. A statistical analysis
3. An ethical dilemma.

Students were given two weeks to resolve this particular E-MEA. In going over possible solutions, the instructor led a discussion on the ethical issue. In addition, a case study of the actual Ford-Firestone rollover problem was given to the students, in which several other actual dilemmas that the engineers from both companies faced were presented. In the next section we will review the student results and our assessment methods.

Other E-MEAs that we have developed include:

CNC Machine Purchase: In Part 1, a manufacturing plant has an opportunity to replace an older CNC machine with a newer model. The plant manager views this as a significant opportunity for the plant, especially since the purchase would not come from his budget. The plant manager requests that the team prove that the new machine will outperform the current one as measured by unit production time, cost, and quality, in order to build the best case for purchase. In Part 2, the team is asked to re-do its analysis in order to now show that the replacement is, in fact, better (assuming the team originally concluded that it was not), or provide more specific details about how it proved the replacement is better. This was designed for a first semester engineering statistics course.

Ethanol: In Part 1, the team is asked to create a procedure for determining whether a "green," socially-conscious Midwest agricultural company should become an ethanol producer or remain solely in grain production for food and livestock. The team's procedure must include a method for evaluating various sites in the U.S. for the development of an ethanol production facility, which could be fueled by any one of several feed stocks. In Part 2, the company has decided to move forward and locate its ethanol production facility in Ames, Iowa. The producer will need one or more distribution points in the U.S. for its ethanol. Should it pursue a centralized or de-centralized distribution scheme, given a set of potential distribution center locations? In addition to resolving issues of facility choice and location, the team must also address serious ethical issues involving ethanol use and production. This has been used in two courses: renewable energy resources and supply chains.

Hazmat: This E-MEA involves a decision with ethical implications concerning possible investment in countermeasures for reducing or preventing hazardous materials spills. The team is asked to create a procedure for deciding whether a small, rural Pennsylvania county with a major highway running through it and faced with a series of hazard material spills, should invest $2 million in countermeasures that should lead to a reduction in such accidents. The team must address unknown material costs and the values attached to accidents in which injuries and fatalities could occur. The students are given a relatively large data base of accidents occurring in the areas, although there is missing data. This E-MEA was designed for an advanced engineering statistics course.

Pilotless Airplane: This MEA involves a NASA sponsored student competition in which the entrants must design and test a "pilotless plane." The teams are judged on accuracy, flight time, and distance flown. In the past there have been objections over how the winner is chosen. As a result, the team must also develop a fair procedure for selecting an overall winner for this year's and future contests. The team must also propose a method for dealing with potential rule violations related to using last year's designs; i.e., does the design have to be original? This MEA was used in an introductory engineering statistics course.

Trees: Part 1 of this MEA concerns possible removal of old growth trees along a road through a public forest. There have been a series of accidents although many may be due to excessive speed. Although the county's department of transportation has decided to remove the trees, and a citizen environmental group is protesting. The student team is asked to resolve the dispute. Part 2 involves a similar scenario reset in a California State Park that contains redwood trees. This MEA has been pilot tested in both undergraduate and graduate Engineering Ethics classes. As noted in Table 1, it is based on a case initially developed by Harris, Pritchard and Rabins[34]. In addition to these new MEAs, we have also enhanced six previously developed MEAs for use in various Industrial Engineering courses in conjunction with Tamara Moore (University of Minnesota). These MEAs are: Supplier Development, CD Compilation, Quality Improvement, Compressor Reliability, Gown Manufacturing Outsourcing, and Disaster Modeling. The first four were originally developed at Purdue University; the last two at the University of Pittsburgh (see Table 1).

4. Developing an E-MEA

An MEA or E-MEA should be created for a specific purpose, typically as a learning exercise to introduce or reinforce one or more concepts. First steps include:

- Determining the conceptual issue(s) that will be presented to the students,
- What other fundamental concepts will be involved or required?

- How will the E-MEA be used (e.g., within the lecture, as part of a recitation exercise, or in a workshop.)?
- When it is to be introduced.

Once these are decided, a storyline must be developed that describes a realistic situation in which the concept(s) will be embedded. We have developed a number of our storylines from incidents in the news, as well as from personal experience, and the experience of colleagues in industry.

Once the storyline has been developed, the ethical dilemma can then be introduced. The dilemma also could be taken from personal experience or adapted from a text book or classic case. Ideally, it should not represent a "black or white" issue, but rather lie in a gray area. Its resolution might require a creative "win-win" situation. The dilemma should be written in a way that requires the students to carefully read the case in order to recognize it. We have learned to frame the case first, and then have the students address the dilemma once they have obtained their results. See Table 2 for possible dilemmas and MEA topics that deal with global and societal issues. It is anticipated that we will continue to develop MEA around some of these topics.

We have learned from experience that the MEA should consist of two parts. The first part serves to get the student thinking about the concept and the situation to be presented in the second part; it is typically done individually. The second part, which is the actual MEA, is done by the team. For example, we modified an MEA originally developed by colleagues at Purdue – Tire Reliability. There version was intended for freshmen in an introduction to engineering course. Our version is designed for an introductory engineering statistics course in which we are focused on concepts related to data plotting and measures of central tendency, in this case data to determine the life of a tire. For this MEA, the first part asks about the concept of reliability and why it is important; they are also asked to sketch a reliability curve (similar to what our colleagues at Purdue have done). The second part asks the team to develop a method for determine given a set of data on tire life, and whether or not that particular tire meets the manufacturer's reliability criteria.

Note that an MEA could be designed to address several possible factors: understanding of an engineering concept, Improvement in working in teams, or preparation for professional life. The latter could focus on improved documentation and reporting; improvement in communication and writing skills; improvement in problem solving. In addition, it can provide a better understanding of real world issues, engineering problems, and challenges. If an ethical component is added, it then also would address improvement in recognizing and resolving an ethical dilemma (e.g., better ethical reasoning ability).

5. Assessing Problem Solving Processes

In order to best assess problem solving progress through use of MEAs, we have been the using a variety of evaluative methods including performance rubrics, reflection tools, and behavioral observation to assess students' problem solving achievement and strategies. Behavioral observation enables us to monitor and observe how our participant teams engage in the E-MEAs, noting issues such as team dynamics, decisions, and communication[35]. Effective assessment will then enable us to address our research questions on the impact of MEAs on problem solving by analyzing the various performance data.

Table 2: Framework for Adding Ethical Issues to MEAs

Dilemma Domain	Common Dilemmas	Example – Issues
Environmental	Harm to Land/ water/natural resources	• Pollution in air • waste in rivers • Decreasing usable land for farming
	Harm to Plants	• Cutting trees
	Harm to Animals	• Destroying a natural land of animals • Killing animals for testing / experimenting
	Harm to climate	• Adding to global warming
Societal	Harm to individual or public health for economic, personal, political reasons	• Selling drugs
	Racism / gender	• Not assigning the project to a woman
	Harm to public welfare	• Creating a monopolist environment through illegal ways, tacit collusion
Economical	Waste of capital	• Creating extra cost for the firm for personal reasons, etc.
	Waste of labor effort	• Making employees work extra due to lack of manager capability in decision making
	Waste of manufactured goods or other resources to obtain personal or group advantages	• Using a resource that is almost about to be extinct to gain economic advantages
Political	Creating political issues between agencies, countries,	• Selling goods to a country with international embargo
Quality Related	Creating low quality work/ end goods to harm people, society, firm, nature	• Selling goods before testing for quality or imperfections in manufacturing or design stage • Providing goods that are low quality- to provide a threat to society
Agency Issues/ Employers, Employees	Creating extra work, changing results, manipulating objectives etc. to gain personal advantages by a manager	• Changing results of a project to gain extra salary or bonus • Report results in an untruthful manner to get promoted • Delegate work and responsibility to another worker to make sure he is not going to be risking his own status or income
	Wasting employer's resources for personal use	• Ordering extra tools to use them at home at employer's cost
Historical Heritage	Creating harm to historical heritage	• Building a dam on historical ruins

5.1 Performance Assessment Using Rubrics.

We have developed an MEA performance assessment rubric which assesses solutions based on the four (of six) MEA principles: 1) Generalizability, 2) Self Assessment/Testing, 3) Model Documentation, and 4) Effective Prototype. Supporting elements have been delineated together with expectations for each solution-related principle. For example, for Effective Prototype, we have expanded the principle to include refinement and elegance of the solution. Each dimension is graded on a 5-point scale, indicating the degree to which the solution achieves or executes the principle. The scores across the four dimensions can be averaged to obtain an overall score. The current version of the rubric includes:

- Generalizability: Assesses the degree to which the model is a working solution for the particular problem and future similar cases. Is the model robust, and can it be easily "handed over" to others to apply in similar situations?
- Self-Assessment/Testing: Assesses the extent to which the solution has been tested and reflects thought and procedural revision. Have nuances or special conditions in the data or problem been uncovered and accounted for in the procedure?
- Model Documentation: Evaluates the level of detail and explicitness in the written procedure. Clarity of expression, correct grammar, and ease of reading are also assessed. Have the assumptions that were made been clearly stated? Has all information specifically requested by the client been included?
- Effective Prototype: Measures the refinement and elegance of the solution procedure. Is the procedure based on thorough application of engineering concepts and principles? Have appropriate engineering ideas been used? Is the solution accurate and of high quality?

A score of a "1" on any given dimension indicates that the principle was not achieved or executed in the solution. A score of "2" indicates some, but insufficient, achievement or execution. A "3" indicates sufficient, or minimum, level of achievement and satisfaction of the base requirements. A score of a "4" indicates that the solution embodies the principle for the most part and that the solution has gone beyond the requirements; the team has achieved more than expected and has generally done a good job. In order to achieve a "5" on any given dimension, the principle must be executed in an outstanding and exceptional manner as delineated in the rubric. The ethics component are scored using the Pittsburgh-Mines Ethics Assessment Rubric (P-MEAR) previously developed and validated[36]. Figure 1 shows a partial view of our scoring sheet.

5.2 Reflection Tools.

To date, reflection tools serve as an observational device for research; however, they have the potential to be used as an assessment tool to analyze the problem solving process. RTs can indicate when or if certain strategies were used during a particular MEA/E-MEA as well as over the course of multiple MEAs. Hence, reflection tools provide a window into how students were thinking and planning while problem solving and provide a means to study the developmental process surrounding problem solving in engineering students. In essence, they serve as a type of "process" assessment of the problem solving activity, in addition to outcomes assessment (based on the rubric or other form of scoring). We are investigating the effectiveness of reflection tools in studying students' developmental process. To do this, we are building upon our behavioral observation expertise, conducting behavioral observations in conjunction with the use of the reflection tools. In this way, we supplement data obtained from these new tools and use the observational data to validate the RTs and rubrics by triangulating the results.

<table>
<tr><td colspan="3">Class:</td><td colspan="2"></td></tr>
<tr><td>Concepts</td><td colspan="2">Categories
(Bold faced letters are for coding)</td><td>1</td><td>2</td></tr>
<tr><td rowspan="4">1. Iteration
(See Lesh, Adams, Hjalmarson)

Express-test-revise</td><td rowspan="3">Types of iteration
(Proof of)
(See Hamilton 2006)</td><td>Versions (Wiki edits)
(count)</td><td></td><td></td></tr>
<tr><td>Drafts (Docs)
(Preservation of good ideas)
(count)</td><td></td><td></td></tr>
<tr><td>Difference between steps
(Shifts in Work)
(Bad ideas left behind)
(yes/no)</td><td></td><td></td></tr>
<tr><td colspan="2">Challenge to students (evidence through iteration) (Adams 2003: <u>Transformative</u>-processes in which new understandings were generated and synthesized into the design task)
(yes/no)</td><td></td><td></td></tr>
<tr><td rowspan="5">2.
Engineering
Ethics
Assessment</td><td>Recognition of dilemma</td><td>Rate 1 – 5 (Use PGH-Mines)</td><td></td><td></td></tr>
<tr><td>Information</td><td>Rate 1 - 5</td><td></td><td></td></tr>
<tr><td>Analysis</td><td>Rate 1 -5</td><td></td><td></td></tr>
<tr><td>Perspective</td><td>Rate 1 -5</td><td></td><td></td></tr>
<tr><td>Resolution</td><td>Rate 1 - 5</td><td></td><td></td></tr>
</table>

Figure 1: Scoring Sheet

To record and assess student problem solving processes, we are using programmable PDAs. Each member of the student team is given a PDA. When the student is working on the assigned MEA, he/she is prompted by the PDA at set intervals (e.g., every 15 minutes). The student then enters the particular problem solving activity that he/she is engaged in at that time. This type of sampling enables us to obtain a valid, statistical description of the process[37].

5.3 Example

Below we provide an example of the SUV Rollover E-MEA noted above. For this exercise, the student team assumes the role of consulting engineering team who is being asked to first design an experiment involve a set of SUVs and a set of tires. The objective is to see if there is a relationship between tire damage and SUV for one or more of the possible combinations. The students are given a budget constraint, but cost depends on whether or not the test vehicle is totaled. If it isn't then a relatively high salvage cost would enable them to conduct more experiments. Figure 2 shows a portion of the "assignment" given to the students in the form of a memorandum.

To: Thomas K. Richards
Richards Automotive Consulting (RAC)
From: John McCray
CountryWide Insurance Company (CWI)
Re: Tire accident analysis
Date: 1/28/08

Dear Tom:

We are requesting your expert opinion as automotive accident consultants with respect to a potentially serious situation that facing CountryWide. As you know, we are one of the largest automobile insurers in the U.S. Over the past several years we have received claims from more than 100 customers who have experienced vehicle rollover accidents that appear to be the result of tire separation. Too many of these claims have resulted in serious injury and a few have also resulted in death. Interestingly, the large majority of these claims involve a SUV.

Our claims investigators feel that we may be dealing with multiple problems. First, the SUV design may present a serious safety hazard. The National Highway Traffic Safety Administration (NHTSA) has pointed out that the high frame results in a high center of gravity, and, for certain SUVs can create an unstable design. Consequently, these SUVs may have a greater tendency to rollover. Combine this with a weak roof and inadequate crash protection, and a SUV rollover can be deadly. Consequently, NHTSA has estimated that while 22 percent of passenger car occupant fatalities are attributable to rollover, the number jumps to 61 percent for SUVs. An estimated 7,000 people are killed or seriously injured annually when their vehicle rolls over and the roof collapses into the occupant survival space. The drawing below illustrates this problem:

Figure 2: Partial Assignment Memorandum for the SUV Rollover E-MEA

The ethical dilemma for this E-MEA is set with the following line:

> On a more personal level, because of the sensitivity of this information, I am also concerned about our obligations given certain findings, even though CWI has requested that we give the results only to them. Consequently, please provide me in a separate memorandum your professional opinion concerning what we should do with this information if the results do point to particular companies

Once the student team submits their design, a simulator is then used to return each team's individual results (but from the same underlying distribution), which they then must analyze. One very good student team's partial response was:

> *The Tukey's test follows the ANOVA table in the output. The first section of the Tukey's is most noteworthy. The mean number of cracks for the Wilderness SUV is assumed to be at zero and you can see that the confidence intervals for the mean of other three SUVs lie far below this at -14.0 and below in comparison to the Wilderness. The next two Tukey's sections just tell us that the other three SUVs have means that are the same. The Wilderness is the only SUV whose mean is not equal to the others.*

Another team's partial responses to the ethical dilemma was:

> *We understand that this is a very serious issue for you because CWI has requested that the results be given only to them and that for obvious reasons they have interests in keeping this information concealed from the public.* ***You have a duty to CWI*** *because they paid you to conduct this study, but you* ***also have a duty to the public*** *based on fundamental ethical principles. Before giving the results to CWI, make a copy of them to save in your files. Ask CWI if they would be able to have a meeting in which the information is exchanged, and tell them your concerns regarding the danger of Stonehead Tires. If they do not volunteer to take any direct action with the findings of that have been presented to them, or if they suggest acting unethically and keeping the information private,* ***then we feel it is your professional responsibility to bring the matter to the attention of an authoritative motor vehicle establishment*** *(such as the American Association of Motor Vehicle Administrators).*

6. Conclusions

We have provided an overview of the MEA construct and how we are expanding that construct to junior and senior level students. We have also described how we have constructed MEAs that also present students with ethical dilemmas to resolve, and, where possible, are set within a global context. In addition, our E-MEAs require upper division (junior and senior) students to recall and integrate concepts covered across the curriculum into a representative model that can generate a set of feasible solutions. In this way, fundamental engineering and science concepts are reinforced, while students exercise complex reasoning and creative thinking skills. We are using field-based case studies that require the synthesis of intangible concepts such as environmental justice, international policy, and resource conservation during solution as subject matter for developing ethical MEAs (E-MEAs). Further, we are using MEAs to develop improved tools for assessing student learning. In contrast to formulaic problem-solving approaches commonly employed in the current assessment setting, observing students during in-class, peer-group work will facilitate the examination of the student's fundamental understanding of engineering and science concepts in an applied setting, their ability to integrate these concepts during model formulation, and their capacity to communicate complex engineering thoughts to a group of peers (e.g., peer-to-peer debriefing).

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