THE MODEL ELICITING ACTIVITY (MEA) CONSTRUCT: MOVING ENGINEERING EDUCATION RESEARCH INTO THE CLASSROOM

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ABSTRACT

A growing set of “professional skills” including problem solving, teamwork, and communications are becoming increasingly important in differentiating U.S. engineering graduates from their international counterparts. A consensus of engineering educators and professionals now believes that mastery of these professional skills is needed for our graduates to excel in a highly competitive global environment. A decade ago ABET realized this and included these skills among the eleven outcomes needed to best prepare professionals for the 21st century engineering world. This has left engineering educators with a challenge: how can students learn to master these skills?

We address this challenge by focusing on models and modeling as an integrating approach for learning particular professional skills, including problem solving, within the undergraduate curriculum. To do this, we are extending a proven methodology - model-eliciting activities (MEAs) - creating in essence model integrating activities (MIAs). MEAs originated in the mathematics education community as a research tool. In an MEA teams of students address an open-ended, real-world problem. A typical MEA elicits a mathematical or conceptual system as part of its procedural requirements. To resolve an MEA, students may need to make new connections, combinations, manipulations or predictions. We are extending this construct to a format in which the student team must also integrate prior knowledge and concepts in order to solve the problem at hand. In doing this, we are also forcing students to confront and repair certain misconceptions acquired at earlier stages of their education.

A distinctive MEA feature is an emphasis on testing, revising, refining and formally documenting solutions, all skills that future practitioners should master. Student performance on MEAs is typically assessed using a rubric to measure the quality of solution. In addition, a reflection tool completed by students following an MEA exercise assists them in better assessing and critiquing their progress as modelers and problem solvers.

As part of the first phase a large, MEA research study funded by the National Science Foundation and involving six institutions, we are investigating the strategies students use to solve unstructured problems by better understanding the extent that our MEA/MIA construct can be used as a learning intervention. To do this, we are developing learning material suitable for upper-level engineering students, requiring them to integrate concepts they’ve learned in foundation courses while teasing out misconceptions. We provide an overview of the project and our results to date.

1. INTRODUCTION

In developing its new criteria almost a decade ago, the then Accreditation Board for Engineering and Technology and now simply ABET reaffirmed a set of “hard” engineering outcomes that all B.S. graduates should possess while introducing, a second, equally important set of six outcomes which we, among others have designated “professional” skills [1]. ABET has included among these latter skills communications, teamwork, and understanding ethics and professionalism, which we have designated as process skills, and three others - engineering within a global and societal context, lifelong learning, and a
knowledge of contemporary issues - which we have denoted as awareness skills.

We propose that in today’s “flat world” [2] these professional skills have become as important as the more traditional “hard skills.” This is especially true as industry appears to be viewing an increasingly larger portion of the science and engineering labor pool as a commodity rather than a profession. Today a growing number of less developed countries, with lower wage rates and an abundance of young, intellectual capital are competing for work that in the past decade was performed by highly paid professionals, many of whom were then in short supply [3, 4]. While we do not know the extent of this shift in work from the US (and the other developed nations) to offshore locations, we agree with others that the trend is, for the most part, permanent and irreversible.

Hence, a new issue that is confronting engineering educators is how to best ensure that our graduates will continue to bring value to a market place in which their salary demands are three to five times greater than their international competitors [5, 6].

However, there is more – the growing interest in sustainability and recognition, even in the US, that the planet’s resources are limited, has also mandated that our graduates also possess a social consciousness – they must understand the implications of their work, especially its long-term impact on the people affected by it [7].

To us, the challenge is clear: how do we educate engineers to not only be better problem solvers, but to also acquire the important “process” and “awareness” professional skills at the same time? And, how do we assess their learning, so that we are assured that our students have, in fact, achieved these desired outcomes? We suggest that one way to help achieve this is the development and use of model eliciting activities or MEAs [8-10]. Developed initially by mathematics educators, we propose that the MEA construct can be used as a learning intervention, a research tool, and an assessment methodology.

To that extent, under funding from National Science Foundation (CCLI Phase 3), we are leading a six university study of models and modeling [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

Specifically, our six university team of researchers is addressing models and modeling as a foundation for undergraduate engineering curriculum and assessment. Our approach builds upon and extends model-eliciting activities (MEAs). As noted above, MEA research originated in the mathematics education community [12]. It uses open-ended case study forms to 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 are distinctly different 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.

Mathematics education researchers developed MEA theory and practice 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 was increasingly documented as a methodology that helped students become better problem solvers [14-16]. Concomitantly, MEAs also became a tool for helping both instructors and researchers become more observant and sensitive to the design of situations that engaged learners in productive mathematical thinking [17, 18].

Recently, MEA research has shifted to undergraduate engineering education, initially at Purdue University [19-22]. These initial modeling activities that were introduced into Purdue’s first-year engineering course (approximately 1800 students per year) demonstrated that the use of engineering contexts and concepts to develop instructional settings (tasks and pedagogy) also accomplished the goal of increasing women’s interest, and simultaneously enhanced the interest of international students as well as traditional populations of engineering undergraduates [23]. Beside their integration into the introductory engineering education curriculum at Purdue, additional implementations are underway at the University of Minnesota, University of Pittsburgh, the US Air Force Academy (USAFA), and Indiana University [24].

We propose that a models and modeling approach is a powerful vehicle for some of the most compelling undergraduate education goals, especially in connection with the increasingly important problem-solving and creativity competencies. Modeling when applied to unstructured problems may require crossing disciplinary boundaries and complex, heterogeneous competencies to identify, organize and represent structure. It also demands connected reasoning ability to create new knowledge structures and the capacity to document, generalize and transfer solution paths.

Also of relevance here is the work of Lesh, Hamilton and colleagues in developing a series 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 can use this information to engage in reflections and discussions about the effectiveness of various roles, strategies, and levels and types of engagement [25]. These RTs serve as an observational device for research, and have the potential to help students develop important conceptual frameworks for thinking about learning and problem-solving. As modelers become more sophisticated in how they think about problem-solving, one would expect that they become more sophisticated in thinking about problems.
2.1 The Six Principles of Model-Eliciting Activities

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: Requires students to 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 another system, to make sense of a system, to explain a system, or to make predictions about a system.

Reality: The activity is set in a realistic, authentic engineering context and requires the development of a mathematical model for solution of an actual problem. A well-designed MEA requires students to make sense of a complex scenario by extending their existing knowledge and experience. Realistic assumptions can 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 engineers working for the particular organization.

Generalizability: Requires that students 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. Thus, 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: As the model develops, students must perform self-evaluation of their work. 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 also encourage students to test and revise their models by pushing them past their initial ways of thinking to create a more robust model that better meets the needs of the client.

Model Documentation: Requires that the model be documented; typically students write a memo to the client describing their model. Hence, the MEA is not only model-eliciting, but thought-revealing. That is, students’ mathematical approach to the problem is revealed in the client deliverable. This process 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 solution to an MEA provides a useful prototype, or metaphor, for interpreting other situations. The activity needs to encourage the students to create simple models for complex situations. The underlying concepts from the activity must be important ideas in STEM education; long after solving the problem, students should be able to think back on a given MEA when they encounter other, structurally similar situations.

2.2 Objective – From MEA to MIA

The MEA construct is very powerful - 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. Because of the power of this construct, a natural extension is to extend it to other types of models and applications. In our case, we are extending the MEA framework to the various engineering disciplines as well as extending the construct to two other models - ethical models and models that elicit misconceptions. In doing this, we are also expanding the construct to focus on model integrating activities or MIAs.

That is, we are extending the MEA construct to a format in which the student team must also integrate prior knowledge and concepts in order to solve the problem at hand. We believe that a well-designed MIA should also force students to confront and repair certain misconceptions acquired at earlier stages of their education. Finally, to better prepare students to think as world citizens, we are adding global and societal context to our MIAs.

In investigating the impact of the rigorous use of collaborative, team-based modeling on student abilities and growth in engineering problem solving, including skills and concept integration, we are addressing three questions:

First, can MIAs enable us to assess problem solving processes, achievement, and growth in an upper-level engineering course, using a combination of performance measurement rubrics and reflection tools for modeling? If so, to what extent? Second, does the use of MIAs and accompanying reflection tools in an upper-level engineering course promote the development of unstructured-problem solving processes and skills integration, and if so, how? And third, what degree of effectiveness do MIAs have in addressing key aspects or components of the engineering problem solving process, including skills transfer and integration, resolution of misconceptions, and ethical and global perspectives?

Insight provided by these questions can inform engineering educators in providing instruction that will set our graduates apart in the emerging global engineering environment.

2.3 What is a good MIA?

Like an MEA, an MIA provides the students with a realistic problem from an identifiable client. The solution requires the development of a problem solving procedure involving mathematical, scientific, and engineering concepts that are unspecified by the problem statement. Students must integrate their existing knowledge to develop a generalizable mathematical model. It is hypothesized that this should lead to heightened conceptual understandings. Students should be involved in the initial ideas underlying the concept or system, thus establishing the motivation to go through cycles of testing and refining them. A well designed MIA should create an environment where skills such as communication, verbalization, and collaboration must be combined with mathematical and engineering thought about the problem. It should also require
students to acquire new knowledge on a just-in-time basis while reinforcing previously obtained knowledge. Well constructed MIA s should challenge students to communicate and work effectively in teams; to create and adapt conceptual tools; and to describe, explain, and cope with complex systems. They should support the development of the abilities and skills as stated in abet criterion 3 a to k [30]. In short, MIA s 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. The features of MEAs and MIA s and their implementations are clearly aligned with how people learn [31] recommended pedagogies.

3. MIA RESEARCH – WHERE WE ARE HEADED
The MIA construct is very powerful, allowing for the multiple perspectives of the team members to be brought to bear on a situation. It includes a realistic setting that enables students to feel that they are doing “real” engineering even in the classroom’s artificial environment, and permits student teams to assess their own progress towards solution using carefully crafted data sets. Because of its value as both an intervention and education research tool, we have begun to extend the construct and existing MEAs to MIA s for upper-level students.

In extending the construct to MIA s, our focus has been on integration including the transfer of skills and concepts from prior coursework. In addition, where possible we are designing our MIA/MIA s to also identify misconceptions, introduce ethical dimensions, and, where possible, provide a global or societal context. We are in the process of testing a series of pilot MIA/MIA s (and accompanying assessment tools). Our testing began in summer 2007 in an elective industrial engineering problem solving course using the pilot MEAs/MIA s in Table 1, and continues now in an advanced engineering statistics course. Ethical MEAs (E-MEAs) were also piloted in two engineering ethics courses and continue to be developed.

Our goal in developing a series of MIA/MIA s for upper-level courses is for students to better recall and integrate concepts covered across the curriculum into models that can be tested to generate a solution that meets the client’s need. In this way, fundamental engineering and science concepts are reinforced, while complex reasoning and creative thinking skills are exercised. Given the potential promise of MEAs for engineering education, we have begun the process of refinement, testing, and validation of the pilot MIA s in Table 1, which provides descriptions and skills targeted. Developed for upper-level (industrial) engineering students, all have been used as in-class exercises. For example, the CD compilation MIA has been extended to better challenge upper-level students by requiring that they use LP concepts and tools from prior operations research coursework.

### Table 1: DESCRIPTION OF MEAs/MIA s

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<tr>
<th>MIA</th>
<th>Description &amp; Skills Targeted</th>
<th>Origin</th>
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<td>Probability, Statistics &amp; Data Analysis</td>
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| 1   | Supplier Development | * Quantitative comparison of multiple suppliers.  
|     |                    | * ANOVA techniques. | Inspired by Purdue’s JIT MIA. |
| 2   | Quality Improvement | * Quality investigation plan to reduce variation & scrap.  
|     |                    | * Overall product quality improvement process.  
|     |                    | * Decision flow chart incorporating SPC tools. | Inspired by Purdue’s Process Control MIA. |
| 3   | Compressor Reliability | * Central Limit Theorem - application to failure time data.  
|     |                    | * Confirmation of Wear-out vs. Burn-in failure.  
|     |                    | * Distribution fitting (chi square). | Inspired by Purdue’s Tire Reliability MIA. |
|     | Operations Research |       |
| 4   | CD Compilation | * Optimization: heuristic algorithm or 0-1 integer LP. | Developed by Purdue.  
|     |                    | Content added by U Pittsburgh. |
|     | Decision Modeling |       |
| 5   | Disaster Decision Modeling | * Decision modeling of events associated with a hurricane and other disasters.  
|     |                    | * Includes a real-time information source.  
|     |                    | * Decision tree and influence diagram/Bayesian network. | Developed by U Pittsburgh. |
|     | Engineering Ethics |       |
| 6   | Trees | * Resolution of ethical dilemma: reducing auto accidents versus preserving old growth trees, including redwoods. | Developed by U Pittsburgh. |
|     | Global Decision Making |       |
| 7   | Gown Manufacturing Outsourcing | * Incorporation of multiple factors for a global outsourcing choice. | Developed by U Pittsburgh. |

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 MIA shown in Table 1. We are currently considering several ethics cases that have global and/or societal aspects such as ethanol versus food production [32]; electrification in South Africa, damn construction in Ghana, and bio-prospecting and intellectual property in India [33]. As described below, a second E-MEA...
will involve a situation similar to the Ford Explorer – Firestone Tire “roll-over” accidents [34].

If designed properly, these particular MEA/MIAs should motivate students to better understand the global context within which engineering decisions are made. For example, the Gown Manufacturing MIA 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.

The Ford-Firestone case is providing the material for an MEA/MIA 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 an SUV that has rolled over after the tread on a tire 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 the variables to test, and the particular combinations and replications (if any). A simulator has been developed that will provide each student team with unique 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 question: what should the carrier do with the results? That is, they must consider issues related to non-disclosure versus the public welfare; at what point does the public welfare trump non-disclosure? This particular E-MEA is currently being tested; results will be reported at the conference.

### 3.2 Identifying Student Misconceptions.

We are particularly interested in extending MEAs to conceptual (or mis-conceptual) understanding of engineering topics, including statistical methods and concepts. The problem of misconceptions is widespread through STEM disciplines, with nearly 7000 reported studies of student misconception in the literature [35]. Researchers have found that senior-level chemical and mechanical engineering students retain a significant number of robust misconceptions even after completing courses in fluid mechanics, heat transfer, and thermodynamics. Over 40% consistently cannot distinguish between the rate and amount of heat transfer between two bodies at different temperatures and approximately 50% cannot distinguish between the quantity and quality of energy as described by the second law of thermodynamics. Nearly 30% cannot logically distinguish between temperature and energy in simple engineering systems and processes. [36-37]

We are particularly interested in addressing misconceptions about basic statistical concepts. Research related to how students apply statistical procedures and develop a system of data analysis is still emerging, particularly as related to engineering students and the application of statistics to engineering problems. As a result four of the pilot MEA/MIAs center on the application of statistical methods. They have been formulated to tease out particular misconceptions that could then be “repaired” by the instructor. Similarly, the Ford-Firestone MEA has also been designed to identify possible misconceptions, especially relative to interactions and normality.

### 3.3 Discipline-Related MIAs for Skills Transfer and Integration

The issue of skills transfer and integration is one of the most important and least specified phenomena in STEM education. All engineering disciplines require graduates to be able to transfer skills they learned in courses to situations that they encounter in their professional careers. Thus, fundamental engineering and science concepts must be reinforced throughout the curriculum; students must be challenged to integrate such concepts into working models. For example, we added content to the CD Compilation MEA that requires students to apply integer programming optimization tools. Students must first evaluate a situation, and then recognize that it could be solved or modeled using a methodology learned in an earlier course. This is an example of an MIA that now addresses skills transfer. Another MIA - Disaster Decision Modeling - requires students to integrate skills from probabilistic decision analysis into a disaster decision modeling methodology. In our pilot test, we included a real-time information source in the form of a simulated expert on the scene. This led to interesting results, as a few teams asked unanticipated questions to the expert and used the information as well as their decision trees to make a decision.

### 4. ASSESSING PROBLEM SOLVING PROCESSES

In order to best assess problem solving progress through use of MIAs, we are investigating the use of various evaluative methods as part of design experiments conducted in the classroom. “Design experiments,” introduced by Collins [38], describes an educational research experiment carried out in a complex learning environment that explores how a technological innovation (here, engineering problem solving using MEA/MIAs) affects student learning and educational practice [39-41]. The goal of design experiments is to create innovative learning environments and simultaneously understand important aspects of cognition and learning. Design experiments as a research approach have been used in partnerships with teachers and educational researchers. They are similar to experimental studies that examine a particular intervention, but address more directly the question and issues that practitioners face in an iterative manner; hence they are formative in nature. They try to accommodate both variation inherent in classrooms and the need to adapt interventions in response to the relevant variation. We are conducting several design experiments to assess growth in problem solving ability and skills integration. In doing this, we are using 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 MEA/MIAs, noting issues such as team dynamics, decisions, and communication [42]. Effective assessment will then enable us to address our research questions on the impact of MIAs on problem solving by analyzing the various performance data.

4.1 Performance Assessment Using Rubrics.
We have developed an MEA/MIAs performance assessment rubric. In extending MEAs to MIAs for use with upper-level students, we are assessing 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 MIAs are also scored using the Pittsburgh-Mines Ethics Assessment Rubric (P-MEAR) previously developed and validated [43]. We are also considering a second instrument that would allow triangulation of results. Data would then be analyzed using cluster and statistical methodologies to classify students according to performance. Several instruments exist; e.g., the DIT-2 [44] to assess moral reasoning or the Intercultural Development Index (IDI) [45] to measure sensitivity to cultural differences.

4.2 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/MIAs as well as over the course of multiple MIAs. 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 problem solving activity, in addition to outcomes assessment based on the rubrics. 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.

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 [46].

We will also supplement the reflection tools with a web-based assessment and feedback system to measure group functioning - the Professional Developer [47]. This tool was created to help students grow and develop as team members by providing a mechanism for obtaining feedback from other team members, instructors, friends, and supervisors. The format allows all team members to communicate concerns and evaluations in a constructive manner, thereby enhancing individual learning and team communication and performance.

4.3 Structural Analysis of Reflection Data
In order to better understand the relationship of the problem solving processes used by students during MEA/MIAs exercises and the ultimate performance outcome, we are using structural equation modeling (SEM). This serves as another method by which we are able to assess the impact of using MEA/MIAs to improve problem solving competency. FIGURE 1 shows an example of a possible influence diagram that would provide the
basis for a structural equation model. Here the quality of the solution as determined by the rubric score is used as the dependent variable or performance outcome measure. Individual-level variables, including individual roles, engagement, and problem solving strategies, are hypothesized to influence group-level functioning, which is hypothesized to directly influence the quality of the team’s problem solving process. This model hypothesizes that the group’s problem solving process is an intermediate outcome, which directly impacts ultimate solution quality, as determined by the rubric.

![Influence Diagram](image)

**FIGURE 1: INFLUENCE DIAGRAM**

We will employ data modeling to better understand the relationship of the process-level variables to ultimate solution quality during an MIA activity. There are various techniques we may employ depending on the data types, including factor analysis (FA); latent class analysis (LCA) [48,49]; and structural equation modeling (SEM), including its categorical variant termed the Modified LISREL approach [50-52]. SPSS, Latent Gold, and LISREL software will be used for these analyses. We will use LCA or FA Analysis to develop latent variables for the unobservable constructs such as individual engagement. The latent and observed variables can be used to develop systems-level models using SEM. We have this modeling experience [53].

5. CONCLUSIONS

We have provided an overview of the MEA construct and how we are expanding that construct to model integrating activities, or MIAs, targeted at junior and senior level students. We have also briefly described how we will be constructing MEA/MIAs that not only tease out misconceptions, but also present students with ethical dilemmas to resolve, and, where possible, set within a global context. As we are in the first few months of a four year project that involves six partner institutions, by necessity, this paper must lay out more plans than accomplishments. It should be viewed as the first of a series of papers that will detail our findings and educational research.

As noted, our overall educational objective is to replace short, synthetic classroom exercises with extended MEA/MIAs that require upper division (junior and senior) students to recall and integrate concepts covered across the curriculum into a representative model that can be tested to 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, as described above, 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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7. REFERENCES


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