Using Model Eliciting Activities (MEAs) in the Engineering Classrooms

July 19-20, 2012

Workshop Facilitators

- Larry Shuman, University of Pittsburgh
- Brian Self, Cal Poly San Luis Obispo
- Heidi Diefes-Dux, Purdue
- Tamara Moore, University of Minnesota
- Eric Hamilton, Pepperdine
- Karen Bursic, University of Pittsburgh
- Ron Miller, Colorado School of Mines
- Mary Besterfield-Sacre, University of Pittsburgh
Workshop Goals

• Acquaint faculty to the MEA concept and pedagogical background

• Engage participants in discipline specific MEAs such that they are equipped to:
  – Implement these MEAs in their own classroom
  – Assess aspects of student learning

• Build on participants’ knowledge base to further prepare faculty to incorporate and potentially develop future MEAs

REVIEW OF THE AGENDA
Welcome and Logistics

- Welcome
- Logistics
  - Computer accounts
  - Release form for photos/videos
  - Hotel, travel to/from AP, etc.
  - Honorarium paperwork

Eric Hamilton, Pepperdine

INTRODUCTION TO MEAS
Common questions

- What are they? What aren’t they?
- Do they “work”? 
- Can they be assessed?
- Is this problem-based learning?
- From Oakland PA to Oakland CA

One way to think of them

- Tools to help understand how knowledge and complex reasoning evolve and grow
- Tools to help knowledge and complex reasoning evolve and grow
Two important axioms

- Knowledge and competencies are structure and interconnected – they are not additive.
- Knowledge and competencies can represented with models that are expressed orally, visually, or in countless other ways.

The most important tool a [researcher][professor] has

- ...is to understand the models that learners possess.
Elicitation

• The best way to understand or work with models is to elicit them, to draw them out
• Not the same as pounding them in
• Sort of a “reverse polarity”

Elicitation part 2

• Elicitation – drawing out – is essential for understanding cognition. And it needs to be done carefully, in a way that preserves structure.
• Years of research produced the six principles for elicitation.
• Not just elicitation though...but testing, revision and transformation
A funny, symmetrical thing happened

• ...on the road to understanding conceptual evolution
• Elicitation implies translation and representation
• Testing implies representational manipulation and adaptation
• Revision implies re-adaptation

Multiple change levels

• Students
• Teachers
• Professors
Two more comments

- Local developmental shifts: mini-Piagets....
- MEAs, as much as anything, are about how to interpret what is seen
  - PBL versus MEA is not as productive as – what allows me to see my students thinking more...

From Moneyball to Volleyball

- [https://www.dropbox.com/s/023x50tt3w6rj9e/VolleyballProblem.doc](https://www.dropbox.com/s/023x50tt3w6rj9e/VolleyballProblem.doc)
LET’S DO A MEA

6 MEA PRINCIPLES
Model-Eliciting Activities

- Model-Eliciting Activities (MEAs) are client-driven, open-ended, realistic problems that involve the development or design of mathematical/scientific/engineering models.
- These are broadening engineering classroom experiences that tap the diversity of learning styles and strengths that "all" students bring to the classroom.
- Intended to make advanced engineering and science content and substantive problem-solving experiences accessible to a diversity of (or "all") students.

Introduction to Model-Eliciting Activities

- MEAs are Instructional Tools
  – Meant to compliment the content of a course
  – For use in conjunction with other instructional tools
  – Address higher-order thinking skills
  – Address multiple educational objectives
Model-Eliciting Activities

Nature of MEAs:

- **Realistic** problems with a client
- Require team of problem solvers
- Product is the process for solving the problem
  - End product is a mathematical model that the client can use

Parts of a Typical MEA

- **Individual Component**
  - “Getting Settled, Oriented to the Context, and Started Thinking”
- **Individual to Team Work Transition**
  - Building consensus: terminology, concepts, what the task is all about (understanding client’s needs)
- **Team Component**
  - General Solution (Mathematical Model)
  - Applied Solution (Solution to the “Test Case”)
  - Evaluation of the Model (Iteration)
MEA Design Principles

• **Model-Construction**
  
  **Description:** Ensures the activity requires the construction of an explicit description, explanation, or procedure for a mathematically significant situation
  
  What is a model?
  
  • Elements
  • Relationships among elements
  • Operations that describe how elements interact

  What models are the students developing when they solve this MEA?

• **Reality**

  **Description:** Requires the activity be posed in a realistic engineering context and be designed so that the students can interpret the activity meaningfully from their different levels of mathematical ability and general knowledge.

  **Realistic** contexts are constructed by:
  
  • Gathering information from actual sources
  • Making simplifying assumptions when information is conflicting, missing, or difficult for students to use

  What knowledge do students bring to this problem?
MEA Design Principles

• **Self-Assessment**
  
  — **Description:** Ensures that the activity contains criteria students can identify and use to test and revise their current ways of thinking
  
  • Students recognize the need for model
  • Students use the client’s criteria to inform refinements to their model
  • Students must judge for themselves when they have met the client’s needs

  *What is provided in this MEA that students can use to test their ways of thinking?*

• **Model-Documentation**
  
  — **Description:** Ensures that the students are required to create some form of documentation that will reveal explicitly how they are thinking about the problem situation

  *What documentation are the students being asked to produce in this MEA?*
“Thought-Revealing”

What can student documentation tell us?

- What information, relationships, and patterns does the solution (mathematical model) take into account?
- Were appropriate ideas and procedures chosen for dealing with this information?
- Were any technical errors made in using the preceding ideas and procedures?

MEA Design Principles

- **Construct Share-Ability and Re-Usability**
  - **Description**: Requires students produce solutions that are shareable with others and modifiable for other engineering situations
  - **Biggest challenge for students**
    - Tendency is to create a solution only for the situation as given and only readable by the creators
    - We are looking for the students to construct a model that:
      - Someone else can pick up and use
      - Could be used to solve similar problems
    - Extent to which students can achieve this can be used in feedback and assessment strategies
Construct Share-Ability and Re-Usability

Think about the MEA you looked at:

• Who is the client?
• What solution (mathematical model) does the client need?
• What does the client need to be able to do with solution (mathematical model)?

Does the product meet the client’s needs?

<table>
<thead>
<tr>
<th>Performance Level</th>
<th>How useful is the product?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Requires redirection</td>
<td>The product is on the wrong track. Working longer or harder won’t work.</td>
</tr>
<tr>
<td>2 Requires major extensions or revisions</td>
<td>The product is a good start toward meeting the client’s needs, but a lot more work is needed to respond to all of the issues.</td>
</tr>
<tr>
<td>3 Requires only minor editing</td>
<td>The product is nearly ready to be used. It still needs a few small modifications, additions or refinements.</td>
</tr>
<tr>
<td>4 Useful for this specific data given</td>
<td>No changes will be needed to meet the immediate needs of the client, but this is not generalizable to new but similar situations.</td>
</tr>
<tr>
<td>5 Sharable or reusable</td>
<td>The tool not only works for the immediate situation, but it also would be easy for others to modify and use it in similar situations.</td>
</tr>
</tbody>
</table>
MEA Design Principles

• Effective Prototype
  – Description: Ensures that the solution generated must provide a useful prototype, a metaphor, for interpreting other situations
    • Want the situations or concepts used in creating the mathematical model to be useful in future coursework & practice

MEA Design Principles

• Effective Prototype
  What are the underlying concepts that students are working with to solve the MEA we worked on?
  – Ideas:
    • ??
Model-Development Sequences

- Raising the potential to address more educational objectives (e.g. ABET Cr. 3 a-k)
- Model-Exploration Activities
  – Comparison of student generated models to engineering models to solve problem
- Model-Adaptation Activities
  – Adapting engineering or student generated models

Karen Bursic, Brian Self, Heidi Diefes-Dux and Mary B-Sacre

INSTRUCTOR PERSPECTIVES #1
Scheduling

- Incorporate into your syllabus
- Significant class time is required
- Plan for feedback (more later...)
- Think through the logistics
- Timing the individual and group parts

Implementing

- Your first implementation will not go perfectly. Neither will your second!
- May need one class period to “practice”
- Keep it simple
- Link with other activities
Implementing continued

• Manage student groups
• Individual accountability
• MEAs work well in labs and recitations
• Active learning!
• Website for MEA management

Coaching

• Effectively guiding students is a challenge
• Not necessarily one “right” answer
• Engineers and Writing?
• Self-assessment
Feedback

- Provide feedback on individual part before the group part is due
- Postmortem after final memos are due
- Survey the students – what can be done to improve the experience

ASSESSMENT OF STUDENT WORK

Mary B-Sacre and Heidi Diefes-Dux
Assessments

- Go to:
  - Modelsandmodeling.net
  - Assessment tab
- Reflection tools
- Rubrics used at Pitt
- Student solution maps
- ABET 2000 end-of-course student evaluation

Authentic Assessment of Student Work on MEAS

Heidi Diefes-Dux
Engineering Education
Purdue University
Together we will:

- Look at a sample open-ended problem
- Consider the idea of “authentic assessment”
- Learn about a four-dimension model for assessing student work on open-ended problems
- Apply the assessment model to sample student work
- Think about how this model can be applied to open-ended problems you use with your students

Challenges of Assessment

What is challenging about assessing student work on open-ended problems?

- X
- X
Travel Mode Choice MEA

From: Ollie Fiji, Executive Director, E3 Trans Consultants

Our firm has been hired by the UCF’s Department of Physical Facilities Management which is working with the UCF Board of Trustees to develop the next Campus Master Plan.

UCF…wants to improve transportation facilities and services…

Now the Planners Group needs a model developed that they can use to predict students’ travel mode choice on this and other university campuses.

Your team is responsible for creating and evaluating a general procedure to predict the most likely travel mode for a given student. Your model must be able to predict the travel mode choice of additional non-surveyed students for whom similar data can be obtained.

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th>Value or units</th>
</tr>
</thead>
<tbody>
<tr>
<td>car</td>
<td>Car ownership</td>
<td>y=yes, n=no</td>
</tr>
<tr>
<td>timewalk</td>
<td>Travel time for walking</td>
<td>Minutes</td>
</tr>
<tr>
<td>ttimeauto</td>
<td>Travel time for driving</td>
<td>Minutes</td>
</tr>
<tr>
<td>costauto</td>
<td>Cost of parking</td>
<td>$ per semester</td>
</tr>
<tr>
<td>ttimebus</td>
<td>Travel time for bus or shuttle</td>
<td>minutes</td>
</tr>
<tr>
<td>costbus</td>
<td>Bus or shuttle fare</td>
<td>$ per one way ticket</td>
</tr>
<tr>
<td>freqbus</td>
<td>Frequency of bus, time between buses</td>
<td>Minutes</td>
</tr>
<tr>
<td>busstop</td>
<td>Distance from home to bus/shuttle stop</td>
<td>blocks (1 block = 1/8 mile)</td>
</tr>
<tr>
<td>mode_used</td>
<td>Mode selected by the student</td>
<td>bus, walk, or drive</td>
</tr>
</tbody>
</table>

Authentic Performance-Based Tasks
(Wiggins & McTighe, 2005)

• Realistic contexts
• Engage students in applying content knowledge to address problems like those found in engineering practice
• Identified audience (stakeholders & direct user)
• Assessment centers on knowledge and skills appropriate for engineering practice
• Multiple opportunities for feedback and iteration
Assessing Student Work on Authentic Problems

• What do practitioners attend to in others’ work?
  – What learning do we care about?

• What is the quality of student work?
  – What learning trajectories do we want to speed/nudge students along?

What to attend to:

• X
  • X
ABET Program Outcomes

Engineering programs must demonstrate that their students attain the following 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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Forms of Assessment for Open-Problem Solving (Jonassen, 2004)

• (Elements of) problem-solving performance
• Domain knowledge
• Argumentation and justification
Four-Dimension Model for Authentic Assessment

Assessment Model Development

• Engineering (practitioner) panel assessed and gave feedback on sample student work
  – Looked at the elements of student work they attended to
• TA panel used to debug rubric
• Refined over iterations of classroom use with TAs
  – Helped differentiate rubric items
Authentic Assessment Model

1. **Mathematical Model Complexity** –
   *(Domain Knowledge & Problem-Solving Process)*
   Does the math model address the complexity of the problem?
   
   – What makes the TMC problem complex?

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**Generalizability** *(Communication)*

2. **Share-ability** *(Problem-Solving Process)* – Can the intended audience successfully apply the model as written to replicate results?

3. **Re-usability** *(Problem-Solving Process)* – Is it clear what the purpose of the model is and under what conditions it can be used?

4. **Modifiability** *(Argumentation)* – Are sufficient rationales provided so that the others can understand the model enough to modify it for their needs?
Overall Purpose of Feedback

- Narrow the gap between actual performance and reference level performance to encourage improvement across each dimension from drafts to final response. **Reference level never changes from start to finish.**
- Enable better performance in subsequent problem solving activities.

High Quality Feedback

- Focused on the specifics of the task, not on short-comings of students themselves
- Response-specific - related to the students’ current response
- Clear and simple, but elaborate enough
- Praise is NOT always effective
Travel Model Choice - Mathematical Model

Mathematical Model Complexity – A High Quality Model

- Quantitative or logical model to predict travel mode AND quantitative method for assessing accuracy of the model
- Accuracy >= 80% with simple and elegant model
- Clear articulation of variables used in model,
  - Importance and/or equality of variables is described
- Correct handling of data types
  - Similar data types are treated in a similar fashion
  - Units are converted when data types are combined
- Means of eliminating drive choice when no car is owned
- Means of incorporating “Proximity to Bus Stop” and “Bus Frequency” data types into the model does not overly penalize the bus option (or dis(advantage) the walk or drive options

Travel Model Choice - Generalizability

Re-usability
- Identifies who the direct user is and what the direct user needs in terms of the deliverable, criteria for success, and constraints
- Provides an overarching description of the procedure
- Clarifies assumptions and limitations concerning the use of procedure

Modifiability
- Explains selection of model type
- Contains evidence-based rationales for critical steps in the procedure
- Clearly states assumptions associated with individual procedural steps

Share-ability
- Results are presented in form requested (included assessment of model)
- All steps in the procedure are clearly and completely articulated
- No extraneous information
Memo Format

TO: Name, Title
FROM: Team #
RE: Subject

I. Introduction (Re-usability)
   A. In your own words, describe the problem. (~2-3 sentences)
      This should include your team’s consensus on who the direct user is and what the direct
      user needs in terms of the deliverable, criteria for success, and constraints.
   B. Provide an overarching description of what the procedure is designed to do or find – be
      specific (~1-2 sentences)
   C. State your assumptions about the conditions under which it is appropriate to use your
      procedure. Another way to think about this is to describe the limitations of your
      procedure.

II. List the steps of your procedure (Mathematical Model). Provide clear rationales for the
    critical steps, assumptions associated with individual procedural steps (Modifiability), and
    clarifying explanations (e.g. sample computations) for steps that may be more difficult for
    the direct user to understand or replicate (Shareability).

III. Present results of applying the procedure to the specified data in the form requested.
    (Shareability)

IV. Other requested information

Re-usability – for whom, for what, and when the mathematical model is intended
Mathematical Model – generalizable procedure that addresses the complexity of problem
Modifiability – arguments for decisions made about the model
Shareability (Results) – demonstration that the mathematical model works using data
provided or created
Overall Assessment Strategy

TO: Name, Title
FROM: Team #
RE: Subject

Re-usability – for whom, for what, and when the mathematical model is intended

Mathematical Model – generalizable procedure that addresses the complexity of problem

Modifiability – arguments for decisions made about the model

Shareability (Results) – demonstration that the mathematical model works using data provided or created

Shareability (Apply & Replicate; No Extraneous Information) – Ease of use and clarity

MEA Feedback and Assessment –

Team Sample 1

Mathematical Model
To: Ollie Fiji / From: Engineering Team / Re: Student Travel Mode Choice

Our procedure will be used by the Planners Group. They will use it to predict which mode of transportation students will use at UCF. The prediction is based on survey data. Not counting a person’s attitude towards a particular mode of transportation, we have decided to use a point system in determining the mode of choice.

- For all modes of transportation, one point is given per 10 minutes of travel time. This relates all modes equally.
- Next, for travel via bus, the points are as follows: one point per one dollar in ticket cost, one point per 1/8 of a mile to the nearest stop, one point per 15 minutes of bus frequency.
- For the drive your own car, one point is given per 25 dollars in parking costs. Obviously, if the student does not own a car then this option is out.
- For walking, one extra point is given because it is the slowest mode of travel. Therefore, its point value is based solely on time + 1.

The way of deciding which mode is best suited for each student then becomes very simple: which mode has the lowest score? In this model, more points are bad. This is because higher costs = more points, longer travel time = more points, greater distances to a bus stop = more points . . . This is because these are all consequences of the convenience of a bus ride or driving oneself.

So, our results for the students are as follows:

Student 1: walk(4 pts), drive(4 pts), bus(4 pts)  
Student 3: walk(19 pts), drive(5 pts), bus(8 pts)  
Student 5: walk(6 pts), drive(3 pts), bus(3 pts)...

Student 1: TIE Walk/Drive/Bus  
Student 3: Drive - match to survey  
Student 5: TIE Drive/Bus...

Overall, for the 15 students, we are getting 40% accuracy with this procedure.
Travel Mode Choice
Team Sample 1

Re-Usability

**Summarize the information provided in the procedure that contributes to its re-usability.**

The direct user is identified. One of the two deliverables (procedure) and its function are stated. The criteria for success is stated as the prediction of a travel mode only. Constraints are mentioned in terms of survey data only. An overview statement of the procedure mentions a point system.

<table>
<thead>
<tr>
<th>Re-Usability Item</th>
<th>Travel Mode</th>
<th>Yes (2 pts)</th>
<th>Sort Of (1 pt)</th>
<th>No (0 pt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of direct user</td>
<td>E3 Trans Consultants Planners Group</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deliverable</td>
<td>Procedure AND quantitative assessment of accuracy of model</td>
<td></td>
<td>Only 1 X</td>
<td></td>
</tr>
<tr>
<td>Criteria for success</td>
<td>Predict the student travel mode choice (bus, drive, walk) AND the goal value for the quantitative assessment of accuracy of model</td>
<td></td>
<td>Only 1 X</td>
<td></td>
</tr>
<tr>
<td>Constraints</td>
<td>Given survey concerning cost (for bus ticket and cart parking), travel time (in minutes for each option), proximity to bus stop (in miles), bus frequency (in minutes), and actual travel mode choice</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Overarching Description</td>
<td>Should provide an overview of how student travel mode is predicted AND how the accuracy of the model is determined</td>
<td></td>
<td>Only 1 X</td>
<td></td>
</tr>
<tr>
<td>Assumptions and limitations concerning the use of procedure</td>
<td>What, if anything, limits the use of the procedure? Depends on the details of the procedure. Some statement must be present.</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Travel Mode Choice MEA
Team Sample 1

Re-Usability

**Provide constructive recommendations on how to make the procedure more re-usable.**

- The criteria for success need to clarify the travel mode choices being predicted.
- Another deliverable and its criteria for success concerns the quantitative assessment of the accuracy of the model. This is not mentioned.
- Constraints need to specifically list the data types available.
- An overview of the quantitative assessment method is needed.
- A statement regarding limitations to using the procedure needs to be made, even if there are none.

1. No
2. X
3. X
4. X

2. The procedure is not re-usable because multiple pieces are missing or need clarification.
3. The procedure might be re-usable, but it is unclear whether the procedure is re-usable because a few pieces are missing or need clarification.
4. The procedure is clearly re-usable.
So, our results for the students are as follows:

<table>
<thead>
<tr>
<th>Student</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>walk(4 pts), drive(4 pts), bus(4 pts)</td>
<td>walk(4 pts), drive(4 pts), bus(4 pts)</td>
<td>walk(4 pts), drive(4 pts), bus(4 pts)</td>
</tr>
<tr>
<td>Student 2</td>
<td>walk(1 pts), no car!, bus(5 pts)</td>
<td>walk(1 pts), no car!, bus(5 pts)</td>
<td>walk(1 pts), no car!, bus(5 pts)</td>
</tr>
<tr>
<td>Student 3</td>
<td>walk(19 pts), drive(5 pts), bus(8 pts)</td>
<td>walk(19 pts), drive(5 pts), bus(8 pts)</td>
<td>walk(19 pts), drive(5 pts), bus(8 pts)</td>
</tr>
<tr>
<td>Student 4</td>
<td>walk(2 pts), drive(4 pts), bus(3 pts)</td>
<td>walk(2 pts), drive(4 pts), bus(3 pts)</td>
<td>walk(2 pts), drive(4 pts), bus(3 pts)</td>
</tr>
<tr>
<td>Student 5</td>
<td>walk(6 pts), drive(3 pts), bus(3 pts)</td>
<td>walk(6 pts), drive(3 pts), bus(3 pts)</td>
<td>walk(6 pts), drive(3 pts), bus(3 pts)</td>
</tr>
</tbody>
</table>

Student 1: TIE Walk/Drive/Bus
Student 2: Walk - match to survey
Student 3: Drive - match to survey
Student 4: Walk - match to survey
Student 5: TIE Drive/Bus...

Overall, for the 15 students, we are getting 40% accuracy with this procedure.
Mathematical Model
Assessment Strategy

- Summarize the mathematics used
- Apply the model to the data provided
- Provide constructive feedback with the intention to move a student team towards a high quality model
Travel Mode Choice
Team Sample 1

Summarize the mathematics used in the procedure.
A point system is used to predict the bus, drive, walk travel mode options. Option with the lowest number of points is the predicted mode.

Apply the procedure / Describe any problem(s)

Some sample computations:

<table>
<thead>
<tr>
<th>Student</th>
<th>Walk (pts)</th>
<th>Drive (pts)</th>
<th>Bus (pts)</th>
<th>Predict</th>
<th>MATCH?</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>19</td>
<td>5</td>
<td>8</td>
<td>Drive</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>Walk</td>
<td>no</td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Walk</td>
<td>yes</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>Drive</td>
<td>yes</td>
</tr>
</tbody>
</table>

Overall, I am getting 47% accuracy.
I had to assume that fractions of points would not be added for travel time. For instance, travel time of 7 min got 0 points. Travel time of 15 minutes got 1 point. Your procedure is generating a lot of ties – these ties need to be resolved.
Travel Mode Choice
Team Sample 1

Provide constructive recommendations ...

- The point system translates the data into a single type that can be worked with. However, the way points are distributed is not equitable for similar data types.
  - Why is $1 for parking not equivalent to $1 for a bus ticket in the point system? So, cost data types are not being treated equally.
  - Why is walking penalized extra when time data is available?

Grouping of data types into clearly defined factors that impact the travel mode choice (rather than grouping by travel mode option) might help your team assign points more equitably. Then, your team will need to address whether one factor is more important than another (or are they all equal?)

Travel Mode Choice
Team Sample 1

Provide constructive recommendations ...

- The accuracy of your model is too low to be of use to the direct user; part of this is due to the ties. Your team needs to assess the accuracy of your model in a way that could lead to improvements. What are the mismatches between your predicted and the actual travel mode? Are there patterns in these mismatches that can be addressed? It appears your model over predicts the Walk option. An analysis of why your model is failing needs to be presented in the memo.
- The model needs a mechanism for breaking ties.
Travel Mode Choice
Team Sample 1

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The procedure fully addresses the complexity of the problem.</td>
</tr>
<tr>
<td>3</td>
<td>The procedure moderately addresses the complexity of the problem and/or contains embedded errors.</td>
</tr>
<tr>
<td>2</td>
<td>The procedure only somewhat addresses the complexity of the problem and/or contains embedded errors.</td>
</tr>
<tr>
<td>1</td>
<td>The procedure does not address the complexity of the problem and/or contains significant errors.</td>
</tr>
<tr>
<td>0</td>
<td>No progress has been made in developing a model. Nothing has been produced that even resembles a poor mathematical model. For example, simply rewriting the question or writing a “chatty” letter to the direct user does not constitute turning in a product.</td>
</tr>
<tr>
<td>4</td>
<td>The procedure takes into account all types of data provided to generate results OR reasonably justifies not using some of the data types provided.</td>
</tr>
<tr>
<td>3</td>
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TMC Team Sample 1
Modifiability – Where is it in the text?

... -For all modes of transportation, one point is given per 10 minutes of travel time. **This relates all modes equally.** -Next, for travel via bus, the points are as follows: one point per one dollar in ticket cost, one point per 1/8 of a mile to the nearest stop, one point per 15 minutes of bus frequency. -For the drive your own car, one point is given per 25 dollars in parking costs. Obviously, if the student does not own a car then this option is out. - For walking, one extra point is given because it is the slowest mode of travel. Therefore, its point value is based solely on time+1. The way of deciding which mode is best suited for each student then becomes very simple—which mode has the lowest score? In this model, more points are bad. This is because higher costs = more points, longer travel time = more points, greater distances to a bus stop = more points, ... This is because these are all consequences of the convenience of a bus ride or driving oneself. ...
Travel Mode Choice MEA
Team Sample 1

Modifiability

*Summarize the rationales and assumptions provided*

- Time is treated equally across modes.
- Cost & inconvenience (time) is assigned point values.

*Provide constructive recommendations...*

- Why is a point system an appropriate method for this procedure? Did you consider other methods? What happened?
- Implicit assumptions are being made when point values are assigned - but the reason why point values are selected is not clear. How did you come up with hardcoded value like 10 min of travel time, 15 min for bus frequency, 1/8 mile to bus stop? These need to be justified, preferably using resources beyond your personal experience.

<table>
<thead>
<tr>
<th>Modifiability</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>The procedure is clearly modifiable.</td>
<td>4</td>
</tr>
<tr>
<td>The procedure is lacking acceptable rationales for a few critical steps in the procedure, and/or a few assumptions are missing or need clarification.</td>
<td>3</td>
</tr>
<tr>
<td>The procedure is lacking acceptable rationales for multiple critical steps in the procedure, and/or multiple assumptions are missing or need clarification.</td>
<td>3</td>
</tr>
</tbody>
</table>

Travel Mode Choice
Team Sample 1

Share-ability (Apply & Replicate)

*Provide constructive recommendations on how to make the procedure easier for the direct user to use and replicate.*

- RESULTS: My bus points and yours do not always match. Are you applying all of the bus points consistently?
- PROCEDURE: While the model has problems, the procedure as written is reproducible by the direct user.
Travel Mode Choice
Team Sample 1

Share-ability (Extraneous Info)

<table>
<thead>
<tr>
<th></th>
<th>There is no extraneous information in the response.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>There is extraneous information in the response, including but not limited to discussions of software tools, issues beyond the scope of the problem, and/or excessive wordiness.</td>
</tr>
</tbody>
</table>

Out of 80 points. Remaining points tied to other MEA-related activities.
Grade assigned is the lowest LEVEL assigned to any of the MEA Rubric items.
MEA Feedback and Assessment –

**Team Sample 2**

Mathematical Model

---

**TMC Team Sample 2**

**TO:** Fiji, Ollie  /  **FROM:** Team #30  /  **RE:** Student Travel Mode Choice

The Planners Group of E3 Trans Consultants needs our team to develop a model that can be used to predict students’ travel mode on UCF and other university campuses. A successful model will accurately predict a student’s method of travel based on given criteria. This model uses if/elseif/else logical statements to categorize a student’s mode of travel. In order to develop this model, our team did a thorough analysis of the variables involved for each student. These variables include the cost, travel time, and distance for the student using different transportation options. We assume that the user is a student of the university that lives off-campus and is limited to driving, busing, or walking as their three types of transportation to campus. It is also assumed that the students using the bus will not need to be traveling to or from campus during times that the bus is not running. Our group didn’t use bus frequency as a constraint because it has miniscule effect on someone’s decision of transportation due to the ease of synchronizing class schedules with busing. We incorporated time, distance, and cost in the development of our MEA. The student will not change throughout the process once he/she has a method of travel defined. The procedure is as follows:

1. Initially, students will not have the opportunity to take a car if one is not owned.
2. If no car is owned and the time to walk is ≤ 10 min they will walk.
3. If the time to walk is ≥ 15 min, or the walk to the bus stop is ≥ 2 blocks, then the student will drive.
4. If the difference between driving and busing is < 10 min, then the student will choose to bus.
5. A student will choose to walk if the cost of driving is > 75 dollars.
6. All other students will choose to drive.

The cutoff value for a walking time of 10 min, as stated in step two, was decided because a 10 min walk is not considered strenuous. The time to walk and distance to the bus stop were considered as cutoffs because if either value is excessive, the desire to drive will increase. The reason for taking a difference between driving and busing is because driving is consistently a more expensive choice than busing, therefore making it a less desired choice. Lastly, the student’s choice to walk if the cost of driving is > 75 dollars is a clear choice because of the financial burden. We applied our algorithm to students 3, 11, 13, and 15, and found that they chose to: drive, bus, walk, and drive, respectively. Using our procedure, these results exactly match the data set.
TMC Team Sample 1
Math Model – Where is it in the text?

...  
1. Initially, students will not have the opportunity to take a car if one is not owned.  
2. If no car is owned and the time to walk is ≤ 10min they will walk.  
3. If the time to walk is ≥ 15min, or the walk to the bus stop is ≥ 2 blocks, then the student will drive.  
4. If the difference between driving and busing is < 10min, then the student will choose to bus.  
5. A student will choose to walk if the cost of driving is > 75 dollars.  
6. All other students will choose to drive.  
...

Travel Mode Choice
Team Sample 2

What mathematics are used in this procedure?

A logic model is used. Uses ownership of car, walk time, distance to bus stop, difference between drive and bus time, and car cost to make travel mode prediction.
Travel Mode Choice

Team Sample 2

What happened when I tried to use this procedure...

<table>
<thead>
<tr>
<th>Student</th>
<th>1st true statement</th>
<th>Choice</th>
<th>Actual</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>#3 walk time 180 min</td>
<td>Drive</td>
<td>Drive</td>
</tr>
<tr>
<td>11</td>
<td>#4 $</td>
<td>\text{timeauto-timebus}</td>
<td>= 5 \text{ min}$</td>
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<tr>
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<td>#2 walk time 10 min</td>
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<td>Walk</td>
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<tr>
<td>15.</td>
<td>#3 walk time 20 min</td>
<td>Drive</td>
<td>Drive</td>
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</table>

The decision tree is very difficult to follow. I get an accuracy of 67% for the 15 student survey responses.
Travel Mode Choice

Team Sample 2

Math Model Feedback ...

• Logic statements:
  – May not cover the space of possible combinations
  – Difference between variables – absolute?
  – Rarely use busstop>=2 logic
• No accounting for bus cost
• No discussion of how model is failing

4 The procedure fully addresses the complexity of the problem.
3 The procedure moderately addresses the complexity of the problem and/or contains embedded errors.
2 The procedure only somewhat addresses the complexity of the problem and/or contains embedded errors.
1 The procedure does not address the complexity of the problem and/or contains significant errors.
0 No progress has been made in developing a model. Nothing has been produced that even resembles a poor mathematical model. For example, simply rewriting the question or writing a “chatty” letter to the direct user does not constitute turning in a product.

4 The procedure takes into account all types of data provided to generate results OR reasonably justifies not using some of the data types provided.
DISCIPLINE BREAKOUT #1
MODELSANDMODELING.NET

All workshop facilitators

What, Who, and Where

• MEA – Facilitator – Room
  – Participant a
  – Participant b
  – Participant c
• MEA – Facilitator – Room
  – Participant d
  – Participant e
  – Participant f
• MEA – Facilitator – Room
  – Participant g
  – Participant h
• MEA – Facilitator – Room
  – Participant i
  – Participant j
  – Participant k
  – Participant l
All workshop facilitators

DISCIPLINE BREAKOUT #2
MODELSANDMODELING.NET

What, Who, and Where

- MEA – Facilitator – Room
  - Participant a
  - Participant b
  - Participant c

- MEA – Facilitator – Room
  - Participant d
  - Participant e
  - Participant f

- MEA – Facilitator – Room
  - Participant g
  - Participant h

- MEA – Facilitator – Room
  - Participant i
  - Participant j
  - Participant k
  - Participant l
Tamara Moore

THINKING ABOUT CREATING YOUR OWN MEA?

Karen Bursic, Brian Self, Ron Miller and Mary B-Sacre

INSTRUCTOR PERSPECTIVES #2
Grading and Assessment

• You or a TA?
• Rubrics help
• Make a list of common feedback that you are giving
• Strategies often emerge over time

What you can expect...

• Students will have trouble with the word “model”
• Implementation issues to be resolved over time
• Your views on teaching and student learning will evolve in unexpected ways
• A very useful assessment tool
Designing

• Don’t reinvent the wheel
• Discover, Reinforce, or Integrate?
• Add social relevance
• Use your research interests for ideas
• Bounce ideas off of other instructors
• Vary the audience for the memos
• Use previous results to inform change
• Vary the MEAs you use in each class

Larry Shuman, Brian Self and Ron Miller

ETHICS, LABS AND MISCONCEPTIONS
Physical Models

Brian Self

Cal Poly
Physical – MEAs
Physical MEAs

- Using laboratory experiments to collect data for the models
- As a method to provide self-assessment of the student models
- As a reinforcement tool to help students better understand the concepts being covered in the MEA.

Transducer Design MEA
- 400 level class
- Sizing program
- Build the transducer
Sizing the Transducer

- Spreadsheet created to size the transducer based on the force applied
- Dimensions are varied at each force level until the strain is large enough for reliable measurement (1000-1500με)

<table>
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</table>

Our Transducer and Wiring

- Four gages across middle section of ring
- Outside/inside gages wired in opposite sides of bridge
- Axial strains cancel, bending strains multiply by 4 to give high sensitivity
Some Different Designs

Catapult MEA

- Historical reenactment
  - Peterborough Museum in England
  - Competition for 6th form students

- Instructions for students to predict how far their catapults will fire

- Self assessment – launch raw eggs using scaled down catapults
Catapult Measurement Day

Catapult Launch Day
Catapult Launch Day

• UNIVERSITY OF PITTSBURGH • UNIVERSITY OF MINNESOTA • PURDUE UNIVERSITY • UNITED STATES AIR FORCE ACADEMY
• COLORADO SCHOOL OF MINES • CAL POLY SAN LUIS OBISPO • PEPPERDINE UNIVERSITY
• MODELSANDMODELING.NET
Catapult Launch Day

Electricity Rebate MEA

- Develop financial incentives to make homes more efficient
- Use electricity meter, your bill, and the Kill A Watt meter
- Develop rebate program
Gyroscopic Motion

- Simulation program written which includes calculation of moments
- Small model to look at coordinate systems
- Reinforce concepts with a 50 minute laboratory experience
\[ \vec{M} = I \vec{\Omega} \times \vec{p} \]

Gyroscopic Motion
Physical MEAs

Data collection, self-assessment, reinforcement

Identifying and Repairing Student Misconceptions Using MEA’s

Ron Miller
Categories of Knowledge

- Meta-cognitive knowledge (thinking about thinking)
- Conceptual knowledge (fundamentals)
- Algorithmic knowledge (problem-solving)
- Information-based knowledge (recall facts)

Anderson and Krathwohl, 2001

What is a Concept?

Concepts are mental categories of objects, events, or ideas that have a common set of features.

or

Concepts are units of thought or elements of knowledge that allow us to organize experience.
From Cognitive Psychology

➢ In terms of a constructivist view of learning and knowledge, students create mental models describing their view of the world.

➢ Students come to your classes with at least partially developed mental models which we may term prior knowledge.

Prior knowledge is often formed using everyday experience and may be incorrect. These incorrect conceptions are often called:

✓ misconceptions
✓ pre-conceptions
✓ alternate conceptions
How Can Conceptual Knowledge be Assessed?

- **Research methods**
  - interviews; “think-aloud” problem-solving; verbal protocol analysis

- **Concept inventories**
  - multiple choice instruments with conceptual questions
  - answer choices include common misconceptions as distractors

---

How Can Conceptual Knowledge be Assessed?

- **Model eliciting activities**
  - Structured open-ended problems designed to identify (and repair?) presence of misconceptions
Why are Some Concepts so Difficult?

- Students’ knowledge of everyday life conflicts with the knowledge we would like them to construct
  - Example: Things that feel warm have a higher temperature than things that feel cold. Therefore a carpet has a higher temperature than a tile floor.

- Students have no “schema” for the processes we are trying to teach
  - Example: Students may think of Force as a “substance” and therefore attribute to Force the properties of a substance (can be used up, contained, pushed or pulled) [Reiner, Slotta, Chi & Resnick, 2000].

Some Robust Misconceptions

- energy = temperature
- temperature = heat rate (temperature sensation)
- rate of transfer = amount of transfer
- steady-state = equilibrium
- energy quantity = energy quality
Example: Human Thermometer

- Students develop physical and mathematical models to predict the interface temperature and sensation felt when touching the surface of different materials.
- Includes hands-on work to study the temperature sensation of different materials (which are at room temp.).

Quantitative Results

- 5 concept questions focused on temperature sensation administered before and after MEA.
- Post-test scores were higher on all 5 questions with improved results ranging from 4.7% to 16.9%.
- However, other activities occurred between pre- and post-testing.
Qualitative Results

- Video and audio taping of 16 3-4 student teams in chemical engineering heat transfer course
- Focus on how students use multiple representations (e.g. pictorial, symbolic, language, concrete, realistic) to describe their understanding of heat transfer while developing models

Misconceptions about temperature vs. sensation persisted

“They could be [at the same temperature] but I think they asymptotically approach that. Technically they are really close.”

Most groups eventually worked it out

“Ok they are at the same temperature but draw heat differently.”
Summary

- MEA’s represent a rich context for helping students become better modelers and confront their strongly-held misconceptions
- More misconception-MEA’s and more pilot testing needed to better understand the impact

Introducing an Ethical Component

Larry Shuman
Rationale

• Can students
  – First recognize and then
  – Resolve an ethical dilemma

• Dilemma should be a “gray” issue, and not black or white.

• Should require students to choose between two alternatives (or more).

• Should relate to a workplace situation.

Where to find dilemmas

• Look in the newspaper – what you find will also be timely!

• Look at ethics cases –
  – Ethics Education Library (IIT)
    http://ethics.iit.edu/eelibrary/?q=node/2395
  – Online Ethics Center (NAE)
    http://www.onlineethics.org/
  – Texas AM – Introducing Cases into UG Courses
    http://ethics.tamu.edu/

• Personal experience
How to setup

• Upfront: The dilemma must be recognized and should be addressed as part of resolving the MEA; must provide sufficient feedback if team does not recognize dilemma.

• Near or at end of the process: introduce dilemma once the team has begun resolving the MEA, or come up with a result.
Two Examples

• Vehicle roll-over: once team has discovered that a particular vehicle-tire combination creates a significantly higher number of accidents, must decide what to do with that information.

• Eliminating data – the team reaches a conclusion that is different than what the boss wanted – what do they do next?