TOPIC
Mathematical Connections and Problem Solving

KEY QUESTION
How can you devise an optimal amusement park schedule for a class of 22 students that have to be placed in five groups based on their ride preferences, location of the rides, and availability of quick ride tickets?

LEARNING GOALS
Students will:
• Use numeric data to divide 22 students into five groups and create an optimal schedule according to wait time and preference
• Consider how to use and exclude data
• Make decisions about whether or not a solution meets the needs of a client
• Communicate the solution clearly to the client

GUIDING DOCUMENTS
This activity has the potential to address many mathematics and science standards, as well as address engineering principles. Please see pages 4-5 for a complete list of mathematics and science standards.

RECOMMENDED SUPPLIES FOR ALL MODEL-ELICITING ACTIVITIES
It is recommended to have all of these supplies in a central location in the room. It is recommended to let the students know that they are available, but not to encourage them to use anything in particular.

- Overhead transparencies and transparency markers/pens, whiteboards and markers, posterboards, or other presentation tools such as a document camera.
- Calculators
- Rulers, scissors, tape
- Markers, colored pencils, pencils
- Construction paper, graph paper, lined paper
- Paper towels or tissues (for cleaning transparencies)
- Manila folders or paper clips for collecting the students’ work
- Optional: Computers with programs such as Microsoft Word and Excel

WHAT ARE MODEL-ELICITING ACTIVITIES (MEAs)?
Model-Eliciting Activities are problem activities explicitly designed to help students develop conceptual foundations for deeper and higher order ideas in mathematics, science, engineering, and other disciplines. Each task asks students to mathematically interpret a complex real-world situation and requires the formation of a mathematical description, procedure, or method for the purpose of making a decision for a realistic client. Because teams of students are producing a description, procedure, or method (instead of a one-word or one-number answer), students’ solutions to the task reveal explicitly how they are thinking about the given situation.

THE Amusement Park MEA CONSISTS OF FOUR COMPONENTS:
1) Newspaper article: Students individually read the newspaper article to become familiar with the context of the problem. This handout is on page 7.
2) Readiness questions: Students individually answer these reading comprehension questions about the newspaper article to become even more familiar with the context and beginning thinking about the problem. This handout is on page 8.
3) Problem statement: In teams of three or four, students work on the problem statement for 45 – 90 minutes. This time range depends on the amount of self-reflection and revision you want the students to do. It can be shorter if you are looking for students’ first thoughts, and can be longer if you expect a polished solution and well-written letter. The handouts are on pages 9-12.
4) **Process of sharing solutions:** Each team writes their solution in a letter or memo to the client. Then, each team presents their solution to the class. Whole class discussion is intermingled with these presentations to discuss the different solutions, the mathematics involved, and the effectiveness of the different solutions in meeting the needs of the client.

In totality, each MEA takes approximately 2-3 class periods to implement, but can be shortened by having students do the individual work during out-of-class time. The Presentation Form can be useful and is explained on page 4 and found on page 14.

**RECOMMENDED PROGRESSION OF THE Amusement Park MEA**

While other implementation options are possible for MEAs, it is recommended that the MEA be implemented in a cooperative learning format. Numerous research studies have proven cooperative learning to be effective at improving student achievement, understanding, and problem solving skills. In this method students will complete work individually (Newspaper article and readiness questions; as well as initial thoughts on the problem statement) and then work together as a group. This is important because brainstorming works best when students have individual time to think before working as a group. Students can be graded on both their individual and group contributions. Social skills’ discussion at the beginning of the MEA and reflection questions at the end of the MEA are also essential aspects of cooperative learning.

**Social Skills (3 -5 minutes)**

Students must be taught how to communicate and work well in groups. Several social skills that are essential to group work are decision-making, asking questions, and communicating and listening. The teacher can show part of a YouTube video and discuss aspects of these skills before beginning the MEA.

(http://www.youtube.com/user/flowmathem)

**Newspaper Article and Readiness Questions:**

The purpose of the newspaper article and the readiness questions is to introduce the students to the context of the problem.

(10 minutes): Give the article and the questions to the students the day before for homework. Then, in the next class, discuss as a class the answers to the readiness questions before beginning to discuss the problem statement.

**Problem Statement:**

You may want to read the problem statement to the students and then identify as a class: a) **the client that the students are working for** and b) **the product that the students are being asked to produce**. Once you have addressed the points above, allow the students to work on the problem statement. Let the students know that they will be sharing their solution to the rest of the class. Tell students you that you will randomly pick a group member to present for each group. Tell the students that they need to make sure that everyone understands their group’s solution so they need to be sure to work together well. The group member who will present can be picked by assigning each group member a number.

**Working on the Problem Statement (35-50 minutes):** Place the students in teams of three or four. Students should begin to work by sharing their initial ideas for solving the problem. If you already use teams in your classroom, it is best if you continue with these same teams since results for MEAs are better when the students have already developed a working relationship with their team members. If you do not use teams in your classroom and classroom management is an issue, the teacher may form the teams. If classroom management is not an issue, the students may form their own teams. You may want to have the students choose a name for their team to promote unity.

**Teachers’ role:** As they work, your role should be one of a facilitator and observer.
Avoid questions or comments that steer the students toward a particular solution. Try to answer their questions with questions so that the student teams figure out their own issues. Also during this time, try to get a sense of how the students are solving the problem so that you can ask them questions about their solutions during their presentations.

**Presentations of Solutions** (15-30 minutes): The teams present their solutions to the class. There are several options of how you do this. Doing this electronically or assigning students to give feedback as out-of-class work can lessen the time spent on presentations. If you choose to do this in class, which offers the chance for the richest discussions, the following are recommendations for implementation. Each presentation typically takes 3 – 5 minutes. You may want to limit the number of presentations to five or six or limit the number of presentations to the number of original (or significantly different) solutions to the MEA.

Before beginning the presentations, encourage the other students to not only listen to the other teams’ presentations but also to a) **try to understand the other teams’ solutions** and b) **consider how well these other solutions meet the needs of the client**. You may want to offer points to students that ask ‘good’ questions of the other teams, or you may want students to complete a reflection page (explanation – page 4, form – page 14) in which they explain how they would revise their solution after hearing about the other solutions. As students offer their presentations and ask questions, whole class discussions should be intermixed with the presentations in order to address conflicts or differences in solutions. When the presentations are over, collect the student teams’ memos/letters, presentation overheads, and any other work you would like to look over or assess.

**ASSESSMENT OF STUDENTS’ WORK**
You can decide if you wish to evaluate the students’ work. If you decide to do so, you may find the following Assessment Guide Rubric helpful:

**Performance Level Effectiveness: Does the solution meet the client’s needs?**

- **Requires redirection**: The product is on the wrong track. Working longer or harder with this approach will not work. The students may need additional feedback from the teacher.

- **Requires major extensions or refinements**: 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.

- **Requires editing and revisions**: The product is on a good track to be used. It still needs modifications, additions or refinements.

- **Useful for this specific data given, but not shareable and reusable OR Almost shareable and reusable but requires minor revisions**: No changes will be needed to meet the immediate needs of the client for this set of data, but not generalized OR Small changes needed to meet the generalized needs of the client.

- **Share-able or re-usable**: The tool not only works for the immediate solution, but it would be easy for others to modify and use in similar situations. OR The solution goes above and beyond meeting the immediate needs of the client.
IMPLEMENTING AN MEA WITH STUDENTS FOR THE FIRST TIME

You may want to let students know the following about MEAs:

• MEAs are longer problems; there are no immediate answers. Instead, students should expect to work on the problem and gradually revise their solution over a period of 45 minutes to an hour.

• MEAs often have more than one solution or one way of thinking about the problem.

• Let the students know ahead of time that they will be presenting their solutions to the class. Tell them to prepare for a 3-5 minute presentation, and that they may use overhead transparencies or other visuals during their presentation.

• Let the students know that you won’t be answering questions such as “Is this the right way to do it?” or “Are we done yet?” You can tell them that you will answer clarification questions, but that you will not guide them through the MEA.

• Remind students to make sure that they have returned to the problem statement to verify that they have fully answered the question.

• If students struggle with writing the letter, encourage them to read the letter out loud to each other. This usually helps them identify omissions and errors.

OBSERVING STUDENTS AS THEY WORK ON THE Amusement Park MEA

You may find the Observation Form (page 13) useful for making notes about one or more of your teams of students as they work on the MEA. We have found that the form could be filled out “real-time” as you observe the students working or sometime shortly after you observe the students. The form can be used to record observations about what concepts the students are using, how they are interacting as a team, how they are organizing the data, what tools they use, what revisions to their solutions they may make, and any other miscellaneous comments.

PRESENTATION FORM (Optional)

As the teams of students present their solutions to the class, you may find it helpful to have each student complete the presentation form on page 14. This form asks students to evaluate and provide feedback about the solutions of at least two teams. It also asks students to consider how they would revise their own solution to the Amusement Park MEA after hearing of the other teams’ solutions.

STUDENT REFLECTION FORM

You may find the Student Reflection Form (page 15) useful for concluding the MEA with the students. The form is a debriefing tool, and it asks students to consider the concepts that they used in solving the MEA and to consider how they would revise their previous solution after hearing of all the different solutions presented by the various teams. Students typically fill out this form after the team presentations.

STANDARDS ADDRESSED

NCTM MATHEMATICS STANDARDS

Numbers and Operations:

• Understand and use ratios and proportions to represent quantitative relationships

• Judge the reasonableness of numerical computations and their results

Algebra

• Represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic rules

• Relate and compare different forms of representation for a relationship

• Model and solve contextualized problems using various representations, such as graphs, tables, and equations

• Use symbolic algebra to represent and explain mathematical relationships

• Identify essential quantitative relationships in a situation and determine the class or classes of functions that might model the relationships

• Draw reasonable conclusions about a situation being modeled
Geometry
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture

Measurement
- Solve simple problems involving rates and derived measurements for such attributes as velocity and density
- Analyze precision, accuracy, and approximate error in measurement situations

Data Analysis and Probability
- Find, use, and interpret measures of center and spread, including mean and interquartile range
- Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatter plots
- Use observations about difference between two or more samples to make conjectures about the populations from which the samples were taken;
- Use proportionality and a basic understanding of probability to make and test conjectures about the results of experiments and simulations
- Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions

Problem Solving
- Build new mathematical knowledge through problem solving
- Solve problems that arise in mathematics and in other contexts
- Apply and adapt a variety of appropriate strategies to solve problems
- Monitor and reflect on the process of mathematical problem solving

Reasoning and Proof
- Develop and evaluate mathematical arguments and proofs

Communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Analyze and evaluate the mathematical thinking and strategies of others

Connections
- Recognize and use connections among mathematical ideas
- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole
- Recognize and apply mathematics in contexts outside of mathematics

Representation
- Use representations to model and interpret physical, social, and mathematical phenomena

NRC SCIENCE STANDARDS
Inquiry
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence
- Think critically and logically to make the relationships between evidence and explanations
- Recognize and analyze alternative explanations and predictions
- Communicate scientific procedures and explanations
- Use mathematics in all aspects of scientific inquiry

Common Core Math Standards

4. MD.2 Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.

7.G. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
## Standards for Mathematical Practices integration with MEAs

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<tr>
<th>Mathematical Practice</th>
<th>How it occurs in MEAs</th>
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<tr>
<td>1. Make sense of problems and persevere in solving them.</td>
<td>As participants work through iterations of their models they continue to gain new insights into ways to use mathematics to develop their models. The structure of MEAs allows for participants to stay engaged and to have sustained problem solving experiences.</td>
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<td>2. Reason abstractly and quantitatively</td>
<td>MEAs allow participants to both contextualize, by focusing on the real world context of the situation, and decontextualize by representing a situation symbolically.</td>
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<td>3. Construct viable arguments and critique the reasoning of others.</td>
<td>Throughout MEAs while groups are working and presenting their models.</td>
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<td>4. Model with mathematics.</td>
<td>This is the essential focus of MEAs; for participants to apply the mathematics that they know to solve problems in everyday life, society, or the workplace. This is done through iterative cycles of model construction, evaluation, and revision.</td>
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<td>5. Use appropriate tools strategically.</td>
<td>Materials are made available for groups as they work on MEAs including graph paper, graphing calculators, computers, applets, dynamic software, spreadsheets, and measuring devices.</td>
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<td>6. Attend to precision.</td>
<td>Precise communication is essential in MEAs and participants develop the ability to communicate their mathematical understanding through different representations including written, verbal, symbolic, graphical, pictorial, concrete, and realistic.</td>
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<td>7. Look for and make use of structure.</td>
<td>Participants in MEAs can use their knowledge of mathematical properties and algebraic expressions to develop their solutions.</td>
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<td>8. Look for and express regularity in repeated reasoning.</td>
<td>As participants develop their models the patterns they notice can assist in their model development.</td>
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A World of Fun and Adventure

The dog days of summer have settled in and area residents are finding ways to stay cool.

The town of Smithville is helping people stay cool with special rates for its new tourist attraction.

Since opening on May 26, Adventure World has had approximately 50,000 people pass through its gates.

According to Lupita Carmona, spokeswoman for the park, Adventure World’s turnstiles have been going crazy. “With the warm weather, our affordable prices and our great attractions, it’s no wonder why we’re seeing such huge crowds this early in the season.”

The new park contains 28 rides and attractions in three sections named Challenge Island, Thrill Park and Fantasy World. A wide variety of rides satisfy everyone’s interests.

The main attractions at the park are the two new roller coasters.

One of the most popular rides at the park is The Monster, which is highlighted by a 200 foot, 60 degree drop. The other roller coaster that is turning Central Indiana upside down is The Spiral. On this looping coaster, riders are turned upside down four times.

Long lines have plagued the Monster and the Spiral. Throw in the fact that these two rides are on the opposite sides of the park and you have people running over each other and quite impatient while standing in line.

To help with these long lines, the park has created the Quick Ticket system. With a Quick Ticket, guests are able to avoid long lines by “making reservations” at each ride.

At each Quick Ticket ride there are two separate lines, one for Quick Ticket recipients and the other is the regular entrance for those who did not obtain a Quick Ticket.

A Quick Ticket is very easy to get. At each ride, there is a machine that prints free tickets with times for the riders. By hitting a button, a Quick Ticket is printed with the time the guest should return to the ride, which is normally 30 minutes from the time that the ticket is printed.

Amanda Jennings of Mansfield, Iowa, used the new system to ride the Monster. “When I first walked up to the ride, I noticed that there was a 60 minute wait. I didn’t want to wait in line, so I decided to get a Quick Ticket.”

When she came back, there was only a five-minute wait, said Jennings. “Instead of standing in line for the Monster, I was able to enjoy the rest of the park.”

According to Carmona, the park is one of several in the nation that is using this system. “The system makes sense because people hate standing in line for 45 minutes just to ride a 3 minute ride,” said Carmona.

“We’re very pleased about how the system works and that the customers love it. I’ve had people come up to me and say they were going to come back just because the system made their visit more enjoyable.”
Readiness Questions:

1. When did Adventure World Open? How many people have visited Adventure World?

2. What is the Quick Ticket system? How does this system compare to waiting in the normal line? Do you have to buy the Quick Tickets?

3. How did the Quick Ticket system help Amanda Jennings?

4. What rides are the most popular?

5. What times of the day are the rides the busiest? How did you come to this conclusion?

6. According to the chart listing line wait times at Adventure World, what is listed in a column with a Q? What is listed in a column with an R? What does it mean if a box is gray?

7. Which ride has the longest regular wait time? Which ride has the longest Quick Ticket wait time?

8. How does the wait time for the Monster change throughout the day?
Amusement Park Problem

Information: Wendy Thompson and her sixth-grade class have been chosen to give a musical performance at Adventure World. When they aren't performing, they can explore the rides and entertainment at the amusement park. They will be arriving at 8 a.m. and will be leaving at 5:30 p.m. From 12:30 p.m. to 2 p.m., they will be at the Amphitheater in Fantasy World for their performance and eating lunch. From 9:30 a.m. to 10:30 a.m. they are going to watch the movie at the IMAX theatre in Thrill Park. The students and their chaperones have the rest of the day to explore the park's rides, shops and restaurants.

The Problem:

There are 22 students in her class and four parents to help chaperone. The students need to stay with a chaperone at all times. Wendy wants to group the students in five groups according to their ride preferences. A few weeks ago, she asked each of her students to list their five favorite rides (the list of their favorites is attached) to help her do this.

So each group is sure to get on as many rides as possible, Wendy wants to decide when each group should go on each ride. The park is large and some of the rides are far apart so the schedule needs to be made very carefully in order to allow the groups to ride as many attractions as possible.

Please write a letter to Wendy and her students providing a schedule for each of the five groups' day at Adventure World and describe the method you used to divide the class into groups and create the schedule so she can share it with other teachers taking students to Adventure World that day for performances.
Line Wait Times at Adventure World

This chart shows how long it takes to wait in line at the different rides at Adventure World. For each time of day, it shows how long you have to wait in a Quick Ticket line and how long you have to wait in a regular line.

**Key:**

- **Q** = Quick Ticket Line Time in minutes
- **R** = Regular Line Time in minutes

A gray box indicates the Quick Ticket Line is unavailable.

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