TOPIC
Statistical Reasoning, Mathematical Connections and Problem Solving

KEY QUESTION
How do you create a method to compute an estimated price of condominiums based on features such as square footage, number of bedrooms, floor level in the building, and river view?

LEARNING GOALS
Students will:
• Use numeric and categorical data to create a predicting and estimating scheme
• 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. Please see pages 4-7 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
• Markers, colored pencils, pencils
• 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 Fathom, TinkerPlots, Excel, or Microsoft Word

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 CONDO PRICING 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 8.
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 10-11.
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 13.

**RECOMMENDED PROGRESSION OF THE CONDO PRICING 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/flowmathematics)

**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 CONDO PRICING MEA

You may find the Observation Form (page 12) 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 13. 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 Condo Pricing MEA after hearing of the other teams’ solutions.

STUDENT REFLECTION FORM

You may find the Student Reflection Form (page 14) 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:

• Work flexibly with fractions, decimals, and percents to solve problems

• Understand and use ratios and proportions to represent quantitative relationships

• Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation

• Understand the meaning and effects of arithmetic operations with fractions, decimals, and integers

• Develop and analyze algorithms for computing with fractions, decimals, and integers and develop fluency in their use

• Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases

• 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
• Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations
• Use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships
• Model and solve contextualized problems using various representations, such as graphs, tables, and equations
• Use graphs to analyze the nature of changes in quantities in linear relationships
• Generalize patterns using explicitly defined and recursively defined functions
• Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior
• Understand and compare the properties of classes of functions, including exponential, polynomial, rational, logarithmic, and periodic functions;
• Use symbolic algebra to represent and explain mathematical relationships
• Use a variety of symbolic representations, including recursive and parametric equations, for functions and relations
• 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
• Approximate and interpret rates of change from graphical and numerical data

Geometry
• Use Cartesian coordinates and other coordinate systems, such as navigational, polar, or spherical systems, to analyze geometric situations
• 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
• Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit
• Use conjectures to formulate new questions and plan new studies to answer them
• Understand and use appropriate terminology to describe complementary and mutually exclusive events
• Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each
• Know the characteristics of well-designed studies, including the role of randomization in surveys and experiments;
• Understand the meaning of measurement data and categorical data, of univariate and bivariate data, and of the term variable
• Compute basic statistics and understand the distinction between a statistic and a parameter
• For bivariate measurement data, be able to display a scatterplot, describe its shape, and determine regression coefficients, regression equations, and correlation coefficients using technological tools
• Display and discuss bivariate data where at least one variable is categorical
• Recognize how linear transformations of univariate data affect shape, center, and spread
• Identify trends in bivariate data and find functions that model the data or transform the data so that they can be modeled
• Use simulations to explore the variability of sample statistics from a known population and to construct sampling distributions
• Understand how sample statistics reflect the values of population parameters and use sampling distributions as the basis for informal inference
• Understand how basic statistical techniques are used to monitor process characteristics in the workplace

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

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Condo Pricing Model-Eliciting Activity 5
• Develop and evaluate mathematical arguments and proofs

Communication
• Organize and consolidate their mathematical thinking through communication
• Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
• Analyze and evaluate the mathematical thinking and strategies of others
• Use representations to model and interpret physical, social, and mathematical phenomena

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
• Create and use representations to organize, record, and communicate mathematical ideas
• Select, apply, and translate among mathematical representations to solve problems
• Use representations to model and interpret physical, social, and mathematical phenomena

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

ABILITIES OF TECHNOLOGICAL DESIGN
• Identify appropriate problems for technological design.
• Design a solution or product.
• Evaluate completed technological designs or products.
• Communicate the process of technological design.

UNDERSTANDINGS ABOUT SCIENCE AND TECHNOLOGY
• Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.
• Creativity, imagination, and a good knowledge base are all required in the work of science and engineering

COMMON CORE MATH STANDARDS

6.RP.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. For example, “The ratio of wings to beaks in the bird house at the zoo was 2:1, because for every 2 wings there was 1 beak.” “For every vote candidate A received, candidate C received nearly three votes.”

6.EE.9 Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

8.SP.1 Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

HS.A-SSE.1 Interpret expressions that represent a quantity in terms of its context

HS.A-CED.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
# Standards for Mathematical Practices

## integration with MEAs

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<thead>
<tr>
<th>Mathematical Practice</th>
<th>How it occurs in MEAs</th>
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<tbody>
<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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<tr>
<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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<tr>
<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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<tr>
<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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<tr>
<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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<tr>
<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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New Condominiums Bring Jobs, Controversy

Murphy and Hamilton Building Associates formally announced their next construction project on Monday. Morgan Place, a thirty-story complex of luxury condominiums, will be built in the Downtown East of Minneapolis. The Morgan Place Condominiums will be marketed towards executives and professionals who prefer not to be responsible for the maintenance involved in owning their own home.

A condominium is essentially an apartment that is purchased and then owned by the tenant. The tenant usually pays a monthly fee to the homeowner’s association for the building, which in return is responsible for the upkeep of the property’s exterior and common areas. Luxury condos in the city are often built as high rises. Owners pay extra money for living in the upper stories, since they enjoy a panoramic view of the city. In addition, some condominiums in the building could have a view of the Mississippi River. If the condominium has a view of the river, it will cost more money. The condominium could have a full view of the river or only a partial view of the river depending on where it is located in the building or if there are other buildings that block the view.

Usually, there are condominiums of different sizes and with different numbers of bedrooms within the same building. The size of the condominium is described by the square footage which is the area of the condominium in square feet. Within the building, there will be different condominiums that have different layouts. The area is determined by the amount of floor space in the condominium. The developers will offer three luxury upgrade packages to owners. Murphy and Hamilton has not formally announced the packages yet, but they often include such luxury items as deluxe appliances, marble fireplaces or foyers, garage parking, heated floors, double-paned windows, and luxury lighting.

Not everyone is thrilled with the impending construction project. Morgan Place reflects the changing composition of many Minneapolis neighborhoods. As expensive real estate is constructed in a neighborhood, and people in a high-income bracket move in, the neighborhood becomes more desirable. The high demand for housing increases the property value of surrounding houses and land. Additionally, property taxes increase for current residents. This forces low- and middle-income residents to sell their homes and search for more affordable accommodations elsewhere. However, the property tax income for the city can increase. Minneapolis has tried various plans to increase the development of low- and middle-income housing within the city. The city is also attempting to design mixed income neighborhoods with various types and sizes of home. Murphy and Hamilton is committed to involvement in such community development projects after the completion of Morgan Place.

Morgan Place is expected to have many positive effects on the Downtown East neighborhood. It will bring increased income to existing local businesses and attract new commerce. In addition, the condominium construction will provide jobs for local workers.
Readiness Questions

1. Why would some condominiums in the same building cost more than others? Justify your answer.

2. Why would someone want to purchase a condominium on a higher floor in a building?

3. How is the square footage determined for each condominium?

4. By looking at the sample data table, approximately how much does a one bedroom condominium cost?

5. By looking at the sample data table, what are the range of prices for condominiums on the 31st floor? Why do you think those condominiums have different prices?

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<tr>
<th>Unit type</th>
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<th>Floor</th>
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6. Read the memo and answer the following questions
   a. Who is the client?
   b. What solution (mathematical model) does the client need?
   c. What does the client need to be able to do with the solution (mathematical model)?
INTEROFFICE MEMORANDUM

TO: ENGINEERING 106 TEAM
FROM: ALEX LIAO, REAL ESTATE DIVISION DIRECTOR, MURPHY AND HAMILTON BUILDING ASSOCIATES
DATE: 02/23/04
RE: UNIT PRICES FOR MORGAN PLACE COMPLEX

To move forward with the project, our investors need a minimum estimate of our anticipated profits. Your task is to generate a method that management can use to estimate the price of each condominium in Morgan Place. Data from Skyline Manor (the other new building in the area) will be provided to help you develop your method.

Please create a reusable method that allows us to enter features and compute a price estimate. You may include the following base features in your model: square footage, number of bedrooms, floor level in the building, and river view. Then write a report describing how your pricing model works which describes how the condominium prices are computed in your model and the procedure you used to develop your pricing model (so we can use your procedure for future projects in the area). Be sure to note any features you chose NOT to consider when creating your model.

Thank you,

Alex Liao
## Skyline Manor Apartment Data

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OBSERVATION FORM FOR TEACHERS - Condo Pricing MEA

Team: ________________________________

STEM (Science, Technology, Engineering, & Mathematics) Concepts Used:
What STEM concepts and skills did the students use to solve the problem?

Team Interactions:
How did the students interact within their team or share insights with each other?

Data Organization & Problem Perspective:
How did the students organize the problem data? How did the students interpret the task? What perspective did they take?

Tools:
What tools did the students use? How did they use these tools?

Miscellaneous Comments about the team functionality or the problem:

Cycles of Assessment & Justification:
How did the students question their problem-solving processes and their results? How did they justify their assumptions and results? What cycles did they go through?
PRESENTATION FORM – Condo Pricing MEA

Name________________________________________

While the presentations are happening, choose TWO teams to evaluate. Look for things that you like about their solution and/or things that you would change in their solution. You are not evaluating their style of presenting. For example, don’t write, “They should have organized their presentation better.” Evaluate their solution only.

Team _____________________________

What I liked about their solution:

What I didn’t like about their solution:

Team _____________________________

What I liked about their solution:

What I didn’t like about their solution:

After seeing the other presentations, how would you change your solution? If you would not change your solution, give reasons why your solution does not need changes.
STUDENT REFLECTION FORM – Condo Pricing MEA

Name ___________________________ Date______________________________

1. What mathematical or scientific concepts and skills (e.g. ratios, proportions, forces, etc.) did you use to solve this problem?

2. How well did you understand the concepts you used?

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<th>A little bit</th>
<th>Some</th>
<th>Most of it</th>
<th>All of it</th>
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Explain your choice:

3. How well did your team work together? How could you improve your teamwork?

4. Did this activity change how you think about mathematics?