Lesson Number: 1 of 1

Subject Area(s): Algebra, Math Models, Geometry

Lesson Dependency: Review of evaluating functions, independent and dependent variables

Keywords
wind load, pressure, angle (theta), exposure, independent variable, dependent variable, height

Time Required: 90 minutes

Summary
Students will investigate the impact of wind loads on building structures. By examining features such as building exposure, building height, wind gusts, roof pitch, etc., the student will calculate associated pressures and determine the relationship between roof angle measures, building height and wind load in building design.

Engineering Connection
Wind gusts such as hurricanes and tornadoes can cause major damage to building structures and its occupants. Although, it is possible to design very secure buildings, the design may not be cost effective. Hence, the student will investigate Wind-Force Resisting Systems that can be designed and constructed to resist wind loads within specific parameters.

Engineering Category: Category 2 (Civil Engineering, Building Structures)
This lesson connection mathematics to civil engineering by using equations that calculate the stress a building may face during a wind storm such as a hurricane or a tornado.
Educational Standards
Texas Essential Knowledge and Skills (TEKS):

- (M.1) The student uses a variety of strategies and approaches to solve both routine and non-routine problems.
- (M.2) The student uses graphical and numerical techniques to study patterns and analyze data.
- (M.3) The student develops and implements a plan for collecting and analyzing data in order to make decisions

TAKS Objectives:
Objective 1: The student will describe functional relationships in a variety of ways
Objective 2: The student will demonstrate an understanding of properties and attributes of functions
Objective 5: The student will demonstrate an understanding of quadratic and other nonlinear functions.

Learning Objectives: Sheltered Instruction Observation Protocol (SIOP) is a research-based lesson planning and instructional delivery model designed to improve student learning and engagement. SIOP was initially designed to help English language learners acquire language proficiency and develop critical thinking skills while also learning academic content. Research has shown that the implementation of this model of instruction can help to increase achievement for all learners.

(Reproduction of this material is restricted to use with Echevarria, Vogt, and Short, 2008. Making Content Comprehensible for English Learners: The SIOP® Model.)

Content Objective: The student will investigate how to evaluate a function using calculations of wind load and graph the function using independent and dependent variables. In subsequent lessons, the student will determine slope, find the slope of parallel and perpendicular lines, practice the Pythagorean Theorem, and investigate trigonometric functions. The student will be able to build a type of truss and determine angle measures using these metrics.

Language Objective: The student will be able to write an essay based on ethics of building design and structure. Over the course of the project, the student will produce a PowerPoint presentation of wind load analysis.

Objective using Blooms taxonomy and SIOP (SWBAT – Student will be able to)

SWBAT:
(Level 1)
- Recall the story of the Three Little Pigs
- Identify the types of exposures when designing a building structure
- Relate types of exposure to the nursery story

(Level 2)
- Predict the effect of change in wind gust to the windward pressure on a roof

(Level 3)
- Calculate, collect and chart data of wind loads
Introduction / Motivation

Activity 1: Facilitation questions: Building background

1. Has anyone experienced being in a dangerous storm such as a tornado or a hurricane? Ask to share.
2. When there is a warning of a impending storm, what safety measures do you take? Why?
3. Why do you think some building structures survive some storms while others are destroyed? Make a list on chart paper
4. Use the KWL chart and write what you KNOW and WHAT you would like to learn.

The students will view the story of the Three Little Pigs.
http://www.bbc.co.uk/cbeebies/tweenies/storytime/stories/3littlepigs/

The student will review a PowerPoint on Exposure.: (see Appendix)

Building background: Allow students to use graphic organizer (Venn diagram) to brainstorm about their knowledge of wind gusts and what could happen to buildings:

Exposure B                      Exposure C                     Exposure D

Facilitation questions:
See Appendix A.

If you had to match a type of Exposure with one of the Three Little Pigs, which one would you match and why?

Video montage:

After watching video, add items to list that students may have brainstormed.

Lesson Background & Concepts for Teachers

Today, investigate parameters that effect potential damage on buildings during storm
- Exposure
- Building height
- Wind Load
- Internal pressure
- Effective Area

**Vocabulary / Definitions**

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Gust and Load</td>
<td></td>
</tr>
<tr>
<td>Exposure</td>
<td></td>
</tr>
<tr>
<td>Internal pressure</td>
<td></td>
</tr>
<tr>
<td>External Pressure</td>
<td></td>
</tr>
<tr>
<td>Roof pitch</td>
<td></td>
</tr>
<tr>
<td>Angle</td>
<td></td>
</tr>
<tr>
<td>Effective Area</td>
<td></td>
</tr>
</tbody>
</table>

**Parameter 1:** Surface Roughness and Exposure
Cooperative Learning: Descriptions of Exposure and group must build.  
(see Types of Exposure .ppt file)
Assessment: Have students use LEGOs to build the types of exposures. Explain wind gusts and tunneling effect

**Parameter 2:** Building Pressure (Internal and External) Draw sketches of pressure.

**Parameter 3:** Roof Pitch and Angle

**Part I:** Review of Parent Functions
The student will complete analysis of parent functions using the graphing calculator.  
(see Resources at the end of lesson)

**Part II:** Calculation of Wind Load
Map of Wind Gusts
Formula of Wind Load

Graphing Function: Independent vs Dependent Variable
- Table of Values
- Calculations
- Using Graphing Calculator to plot Graph
- Develop equation

Wind Load calculation Powerpoint

Associated Activities

Building Design: Roof Trusses

Lesson Closure

ETHICS IN CONSTRUCTION: Take A Stand (Temporary Structures)
Suppose you had to design a temporary structure that would only last for two years. Would you design it with the wind loads of a more permanent structure, or would you alter your calculations? Why?

EXTENSION: Extend calculations and modeling of equations to roof pitch, angle, and effective area (include Geometry TEKs and TAKS Objective)

References

Attachments

Exposure Powerpoint

Types of Exposure

Surface Roughness
- Surface Roughness B
  - Urban, suburban and wooded areas or other terrain with numerous closely spaced obstructions having the aspect a single family dwellings or larger
- Surface Roughness C
  - Terrain with scattered obstructions having heights generally less than 30 ft.
- Surface Roughness D
  - Flat, unobstructed areas and water surface outside hurricane prone regions includes smooth mud flats, salt flats and unbroken ice

Exposure
- Exposure B
  - Where ground surface roughness condition B prevails for a distance of at least 200 ft or 20 times the height of the building
- Exposure C
  - Where effect of exposure B and D do not apply
- Exposure D
  - Where ground surface roughness condition D prevails for a distance greater than 5000 ft or 20 times the building height
Wind Load Calculation Powerpoint

Main Wind-Force Resisting System (MWFRS)

Formula

\[ p = qGC_p - q_i(GC_{pi}) \]

- \( q = q_z \) for windward wall at height \( z \) above the ground
- \( q_i = q_z \) for all walls and roofs of enclosed buildings
- \( G \) = gust effect factor
- \( C_p \) = external pressure coefficient
- \( GC_{pi} \) = internal pressure coefficient

Wind Gust

Gust factor, building height, external and internal building pressure

Constant Values to Substitute

\[ q = 0.0256 \times 0.83 \times V^2 \]

- \( G = 0.8 \)
- \( C_p = 0.8 \)
- \( GC_{pi} = 18 \)

Sample Calculation: Find wind load on a building that has a height of 15 feet when velocity is 50 mph.

\[ p = qGC_p - q_i(GC_{pi}) \]
### Parent Functions for Modeling Data

Three functions commonly used to model scatter plots of data that increase or decrease are:

The following parent functions represent these three general models. Complete the following information about the parent functions to generate a quick reference sheet for future use.

<table>
<thead>
<tr>
<th>Parent Function</th>
<th>Graph</th>
<th>Increases or Decreases</th>
<th>Concave Up or Concave Down</th>
<th>Intercepts</th>
<th>Asymptotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y = e^x )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = x )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = \ln(x) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = -\ln(x) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = x^2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = x^{-\frac{1}{2}} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y = x^2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Building background: brainstorm about their knowledge of wind gusts and what could happen to buildings:

Exposure B
Exposure D

If you had to match a type of Exposure with one of the Three Little Pigs, which one would you match and why?
## TABLE of WIND LOAD CALCULATIONS

- Exposure C
- Building Height = 15
- Roof Pitch < 25 degrees

<table>
<thead>
<tr>
<th>Wind Gust</th>
<th>LOAD (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SCATTERPLOTS

How to enter data into TI Graphing Calculator:

1. Hit STAT button and highlight EDIT
2. Hit ENTER button
3. Put values of Wind Gust in X column
4. Put values of Load in Y column
5. Turn on STATPLOT
6. Graph Points.

Determine which function would be the best fit.
1. Hit STAT button and highlight CALC
2. Enter desired function and press ENTER twice.
3. Copy equation
4. Enter equation into Y=.
5. Compare continuous graph to discrete graph
What mathematical models might be used to describe this data? Why?

Use the regression capabilities of your graphing utility to fit each of the following models to the data. Which is the better model? How do you know?
## Appendix A:

### BOARD NOTES:

#### Objectives:

<table>
<thead>
<tr>
<th>Process</th>
<th>Content</th>
<th>Format</th>
<th>Materials Needed</th>
</tr>
</thead>
</table>
| **Eye Opener** | Each student will complete a KWL table on what students know about wind load  
Fairy tale:  
Video of the three Little Pigs | Individual | KWL table  
Projector, Internet Access ,  
Overhead, TI-84 overhead screen |
| **Engage “hook”** | Reality:  
Video of Fort Worth tornado.  
Facilitation Questions:  
What type of damage do you see regarding building structure?  
What you were to design a building, what things would you consider? | Teacher-lead | Chart paper to record student answers. |
| **Explore Activity 1** | SWBAT:  
After group identifies exposure, review with powerpoint  
(Types of Exposure)  
Define exposure and relate it to the Three Little Pigs story? | Cooperative Learning (complete Venn diagram) | Groups of 5: Wind Gust PowerPoint  
1. Each group will read a description of “Exposure”. The students will highlight words that they don’t understand.  
2. Each group will use LEGO’s to build landscape to represent exposure.  
3. The group will orally share data with class using highlighted words.  
Graph of Wind Gusts in Texas. |
<table>
<thead>
<tr>
<th>Activity 3</th>
</tr>
</thead>
</table>
| - Corpus Cristi  
In each group, determine the wind gust in your city.  

The students will calculate wind load based on wind gust.  
- Put equation on back of multi-layer foldable.  
- Each quantity will be placed on the foldable.  
- Calculate wind load |

- PowerPoint on Calculating Wind Load: (foldables for Notes)(Paper)  
- Construction paper with pictures  
- Chart Paper (wind gust vs. wind load)  
  1. What are the independent and dependent variables?  
  2. As volume increases, what happens to pressure?  
  3. Graph this function with your scatter plot. Does your function seem to model the relationship?  
  Use graphs of parent functions to compare |
<table>
<thead>
<tr>
<th>Explain “lecture”</th>
<th>Math Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student will enter the data</td>
<td></td>
</tr>
<tr>
<td>• Into a class table</td>
<td></td>
</tr>
<tr>
<td>• in his/her graphing calculator and make a scatter plot.</td>
<td></td>
</tr>
<tr>
<td>The student will be able to compare data to the parent functions of certain types of graphs to determine best fit.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call on students using popsicles to sketch each graph</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluate “assess”</th>
<th>Calculate the wind load of wind gust of 150.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete KWL chart (learned). Write a quick write about what you learned about wind loads.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elaborate “extend”</th>
<th>Ethics in Construction : Temporary structure: How would you calculate wind load for a building to last two years? Consider costs, labor and safety.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call on students using popsicles to sketch each graph</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chart Paper (wind gust vs. wind load)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What are the independent and dependent variables?</td>
</tr>
<tr>
<td>2. As volume increases, what happens to pressure?</td>
</tr>
<tr>
<td>3. Graph this function with your scatter plot. Does your function seem to model the relationship?</td>
</tr>
</tbody>
</table>

Use graphs of parent functions to compare

Use table from function determine equation of function. How does it compare to the points on the graph? (see below)
Follow-up using roof pitch, angle measure, effective area, and wind gusts and compare graphs of functions and find equations of best-fit

Extension: (see above suggestions)

Activity 1: (Cooperative Learning) Roofing types: Discuss the similarities and differences of the roofing types found on website using Venn diagram. Students will be paired and given a particular type of roof and will be asked to describe the roof. Output: vocabulary list

Activity 2: (Teacher-lead) we will review the slope formula and (rise over run). We will practice using the formula on roof pitches (reinforce flat roof (zero slope) and what a roof with an undefined slope would look like.) worksheet

Activity 3: Discuss the concept of a truss. Using a sample of a truss, discuss parallel and perpendicular lines and the transversal (brace). Reinforce properties of parallel lines. Students will sketch a simple truss on patty paper, and then use scaling (proportions) to build simple truss based on specified angle measurements. (Maybe use dilations on the coordinate plane for geometric applications) Pre Calculus: students may investigate the function of the roof pitch versus the angle measurement of the brace.

Closure: Student produce a paragraph describing how to change the pitch of a roof and how the pitch is related to the roofing angle.

Day Two:
Building background: What is a wind gust? Is a hurricane a type of wind gusts. The student will investigate wind gusts and landscape exposures. The student will speculate on which type of roof and pitch would be better given a certain type of wind gust and exposure. The student will derive simple calculations of wind gusts to support their analysis. The analysis will be a project that will be completed at the end of the grading period. The student will be guided through the project with a given timeline to complete certain stages (contents in an envelope) Vocabulary

Need example to give to students: Work a couple of problems; offer solution.

The student will compare two different types of exposure and predict how exposure effects wind loads (wind tunnels). The students will use data to develop functions:

- Change in pitch affects wind load
- Change in angle affect change in pitch
- Number of braces in truss affects stability (wind load)
Set-up (to set the stage and motivate the students to participate)

1. Introduce the lesson by having students complete Activity A, emphasizing that the lesson focuses writing observations in a clear and concise form.

2. Give students an overview of Activity B via the Guiding Questions. Review calculator procedures for making scatter plots, determining regression models, and graphing the regression model on the scatter plot.

3. Have students complete Activity B in their teams, followed by Whole Group Discussion via the Summary Questions.

Teacher Notes (to personalize the lesson for your classroom)

Guiding Questions for Day 2 (to engage students in mathematical thinking during the lesson)

- What is the domain for a function that might model the situation? Why is it important to consider this? (c.1.B) The domain for the modeling function may include values for the independent variable that do not make sense in the contextual situation. By determining the domain for the situation, you know more about what restrictions there are on the independent variable. What about affects on range? Make sure that a table is given to student.

- What decisions must you make in order to construct a scatter plot that accurately pictures the data? (c.1.B) You need to decide which variable you want to be independent and which to be dependent. The range of values you see for each variable gives you an idea about how to set the calculator ranges and scales.

- What do you think the scatter plot will look like? Linear or non linear

- What mathematical models for the scatter plot would be appropriate to consider? (c.1.D, E; c.3.A) linear, quadratic, exponential (pre calculus).

- What does the regression correlation coefficient, r, tell you about a mathematical model for a scatter plot? (c.3.B) The r-value tells you how well the model fits the data. The closer abs(r) is to 1, the better the fit.
Student Name:
Write three comments, statements, or questions you want to know about wind gusts

<table>
<thead>
<tr>
<th>What I KNOW about wind gusts</th>
<th>What I WANT to Know about wind gusts</th>
<th>What I Learned about wind gusts</th>
</tr>
</thead>
</table>

Answer to facilitation questions.

Hook: What type of damage do you see regarding building structure?

What you were to design a building, what things would you consider?
Activity 1: Define exposure and relate it to the Three Little Pigs story?

Closure: Ethics in Construction:

TAKE A Stand (SIOP Activity):

Suppose you had to design a temporary structure that would only last for two years. Would you design it with the wind loads of a more permanent structure, or would you alter your calculations? Why? Consider costs, labor and safety.

Owner Susan Y. Patterson

Version: January 2009