Big Blow Can Blow The Budget

A data literacy activity on costs associated with natural hazards

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DIMACS
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Summary: This module is a mathematical and quantitative literacy activity on interpreting data. This activity examines information from the Federal Emergency Management Agency's National Risk Index tool, the National Oceanic and Atmospheric Administration's Historical Hurricane Tracks tool, and the Natural Hazards Research and Applications Information Center's Children and Disasters Special Collection of research.

Target audience: The intended audience for this activity includes undergraduate freshmen enrolled in general education / introduction to research classes and elementary pre-service teachers.

Prerequisites: Mathematical content knowledge includes elementary and middle school level content standards including rounding whole numbers to specified place values, multiplying by powers of ten, writing equivalent ratios, and representing data as histograms or pie charts.

Number of class periods: If the entire activity is conducted in class, this may take 2 hours of class time. We may encourage completing Part 1 synchronously during class time, and having students complete Parts 2-4 asynchronously.

Topics Included: Whole number place value concepts, whole number addition / subtraction / multiplication / division computation, decimal and percent concepts and computation; ratios, proportions, and proportional reasoning; data analysis.

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Appendix C: High school level mathematical explorations

Acknowledgement: This module was developed as a part of the *Reconnect 2023 Workshop on Risk Assessment* held in Providence, Rhode Island from June 19 – 23, 2023 organized and funded by the Department of Homeland Security (DHS), the Center of Discrete Mathematics and Theoretical Computer Science (DIMACS), and SENTRY (Soft-target Engineering to Neutralize the Threat RealitY). The authors would like to thank Dr. Midge Cozzens for her valuable suggestions and continued support.

Learning Goals:

Goal 1: Students will answer data literacy problems related to Department of Homeland Security public resources that can be solved using grade school level mathematics, and identify and select relevant quantities to consider in the problem solving process.

Goal 2: Students will formulate mathematical models and data representations to show their solution processes while investigating the problems posed about the Department of Homeland Security resources.

Goal 3: Students will interpret the results of their mathematical investigations and connect them to ideas related to communities' recovering from the effects of natural hazards.

Student Learning Objectives:

At the conclusion of this module it is expected that the student will have the following knowledge/skills:

- Investigate monetary effects of natural hazards
- Read and describe a data visualization
- Identify types of quantities being used in given situations
- Round numbers to indicated place values
- Add and subtract mixed numbers (whole numbers and decimals)
- Examine columns of variables and identify higher and lower ranked or valued items within the column
- Cross-compare between data sources
- Answer data literacy questions

Learning Outcomes

Common Core State Standard (2010)	Learning Outcome in this Module
4.NBT.2 Use place value understanding to round multi-digit whole numbers to any place.	Expected Annual Loss (EAL) Values are being rounded to the nearest thousands place and ten-thousands place.
4.MD.2 Use the four operations to solve word problems involving ...money, including problems involving simple fractions or decimals...	Addition, subtraction, multiplication, and division can be used to solve the word problems in this activity.
4.NBT.4 Fluently add and subtract multi-digit whole numbers using the standard algorithm.	EAL-Values are multi-digit whole numbers that will be added and subtracted to respond to the questions in the activity.
6.RP.3 Use ratio and rate reasoning to solve real-world and mathematical problems	We ask students to use the rate (over 10 years) at which hurricanes occur to estimate an annual budget for a selected county.
6.SP.3 Display numerical data in plots...	The distribution of EAL-Values will be displayed in a visual form.
Standard for Mathematical Practice 2: Reason abstractly and quantitatively	Quantitative reasoning involved in this activity includes attending to the meanings of the various quantities presented in the data tables downloaded from the FEMA website and how to interpret them.
Standard for Mathematical Practice 4: Model with mathematics.	Students might write equations to describe the situations of interest pertaining to the natural hazards and estimated costs associated with addressing them.

Introduction

In an effort to increase the data literacy of our country's citizens, educators have recommended for grade school teachers to use mathematical modeling and real-life contexts in their lessons (Boaler et al., 2021; Common Core State Standards Initiative, 2020). Selecting contexts which could relate to students' lives can increase their engagement in the lessons and their motivation to learn more mathematical content, which can in turn empower students to have a sense of agency (Hirsch & Roth McDuffie, 2016; Berry, et al, 2021; Conway et al, 2023). This module uses publicly available digital tools from the Department of Homeland Security's Natural Risk Index (NRI) to help students examine the predicted costs associated with recovering from natural hazards, the National Oceanic and Atmospheric Administration's Historical Hurricane Tracks tool to help students determine how frequently hurricanes are expected to occur for given geographic regions, and articles from the Natural Hazards Research and Applications Information Center to help students better understand the processes involved in communities' recovering from natural hazards. We hope that by using these resources as a basis for mathematical explorations, more citizens will become aware of the many resources that are available publicly to help us better assess the financial and community-based risks involved with natural hazards.

Notes for instructors and sample solutions:

Part 1: Guided Interpretation of Expected Annual Loss Ratings and Values

The ratings describe how likely the hazard type will affect the county being researched. The Expected Annual Loss (EAL) Value provides an estimate of how much it will cost the county to repair the damage associated with the listed hazard type. The data used below is related to the county in which Towson University is situated, Baltimore County (zip code 21252).

After downloading the data related to zip code 21252 (see Appendix A for instructions), complete the table about Baltimore County's hazard types and their associated EAL dollar values. For each hazard, round the EAL dollar values to the nearest thousands place.

A blank spreadsheet can be accessed here:

https://docs.google.com/spreadsheets/d/1sawBDLaYgIhLcxjga6a0055GqAcZgMAvEU-gV84oUj0/edit#gid=0

Risk Level	Hazard Type	EAL Value (in thousands)	EAL Value (in ten thousands)
High	Hurricane	61862	6186
	Heat Wave	26452	2645
	Strong Wind	2499	250
	Winter Weather	670	67
	Ice Storm	413	41
Moderate	Tornado	3851	385
	Riverine Flooding	1218	122
	Cold Wave	406	41
	Drought	298	30
	Lightning	214	21
	Landslide	158	16
Low	Earthquake	1190	119
	Coastal Flooding	87	8.7
	Wildfire	47	4.7
	Hail	17	1.7

Number classification questions:

A. Which column contains nominal data? (Hazard Type) (note: nominal data is naming data, the categories are mutually exclusive)
B. Which column contains interval data? (EAL Value) (note: interval data consists of numerical data that can be measured along a numerical scale, each point is placed equally from the other points)
C. Which column contains ordinal data? (Risk Level) (note: ordinal data is ranking data)

Data literacy questions:

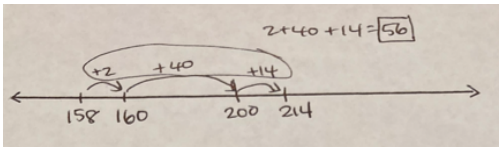
D. What is the hazard type that is the highest risk of occurrence? (hurricane)
E. What is the hazard type that is expected to cause the most costly damage? (hurricane)
F. Identify the hazards of moderate risk to the county. (Tornados, Riverine Flooding, Cold Wave, Drought, Lightening, Landslide)
G. Hazards that have a high risk of occurrence may not always be more costly to address. Find a high risk hazard which has a lower EAL value than a moderate or low risk hazard,

and explain. (cross-reference columns of data… earthquake costs more than several high risk hazards: winter weather & ice storms)

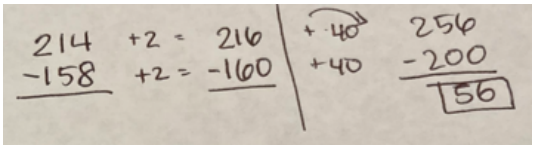
Addition and subtraction questions: Show at least two different ways to solve problems H & J, aside from the standard algorithm. You are encouraged to use virtual manipulatives (e.g., base ten blocks, number lines), and/or drawings.

H. Approximately how much more money (in thousands of dollars) should Baltimore County allocate this year towards repairing damage from lightning than landslides?

(214-158= 56. Solution 1: I would start with 158 and see how much I need to add to arrive at 214. 158+2=160, 160+40=200, 200+14=214. Then 2 + 20 + 14 = 56.



Solution 2: Since this problem involves regrouping in the ones place, I will add 2 to both the minuend and subtrahend, which is the equal addends approach. Minuend: 214+2=216. Subtrahend: 158+2=160. My revised subtraction problem is 216-160. If I want to avoid regrouping in the tens place as well, then I would need to add 40 to the minuend and subtrahend in the revised subtraction problem. Then I would solve 256-200 = 56.

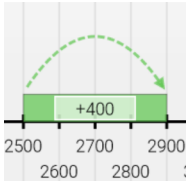


)

J. Baltimore County would like to allocate money towards both repairing effects of Strong Winds and Ice Storms in a given year, based on the EAL Value estimates. Approximately how much money should be budgeted for both Strong Winds and Ice Storms?

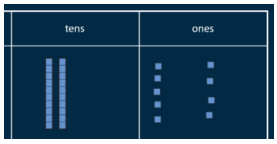
(2499+413, estimate 2500 + 400 = 2900)

Solution 1: Number line



The above image was created using MathLearningCenter's Number Line app: https://apps.mathlearningcenter.org/number-line/

Solution 2:



The above image was created assuming that one unit cube represents $100K. The technology tool used was: https://www.didax.com/apps/base-ten-blocks/

H) How much money should Baltimore County allocate towards all of the hazard types in the Low risk category?

($1341K is the sum of the earthquake, coastal flooding, wildfire, and hail EAL-values. Acceptable answers can range from lowest to highest dollar amount listed for the low risk category, but students should be able to indicate which hazards they included in their calculation.)

Open-ended question:

Assuming that Baltimore County has $5 million to allocate towards addressing their anticipated natural hazards:

1) Identify five hazards to prioritize for the upcoming year.

The five high risk hazards listed are hurricanes, heat waves, strong winds, winter weather, and ice storms. Other hazards from the list are acceptable with adequate justification.

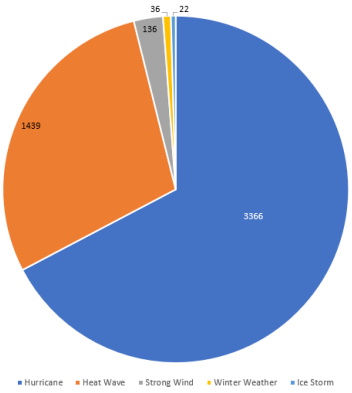
2) Describe how much money they should allocate towards those five hazards. Explain.

In the sample table below, I found the total amount of money suggested for distribution towards the high hazards ($91,896K) and found the suggested percentage of this total for each of the five high hazards. For example, the hurricane EAL-Value is $61,862K and this represents 61826/91896 ~ 67.3% of the total. I then used the same percentage of the total allocated amount, which was given as $5 million or $5,000K. For hurricanes, this would be 0.673*$5000K = $3366K. Dollars allocated to the five Hazards should add up to the full amount.

High Hazard Type	EAL Value (in thousands)	% of Total	% * 5,000 thousand
Hurricane	61862	67.3%	3366
Heat Wave	26452	28.8%	1439
Strong Wind	2499	2.7%	136
Winter Weather	670	0.7%	36
Ice Storm	413	0.4%	22
Total	**91896**	**100.0%**	**5000**

3) Create a visual representation (such as pie chart or bar graph) to illustrate the allocation.

The allocation in thousands of dollars is shown below in a pie chart. The five categories have a total allocation of $500K.



Extension to Part 3: Estimate Average Yearly from Hurricanes

Search for your region: https://coast.noaa.gov/hurricanes/

A) How many hurricanes have hit your county in the past 10 years?

(Baltimore County has had 3 hurricanes)

B) Assume that the EAL Values found in the previous activity is the cost associated with one hurricane. If the county wants to be able to spread out the total cost for recovering from all its expected hurricanes over ten years, how much money should the county allocate each year?

($61862K * 3 hurricanes / 10 years =$ 18,559K per year)

Part 2: Guided Interpretation of Expected Annual Loss Ratings and Values

Download the Expected Annual Loss Ratings and Values for another county of interest and answer questions #A-E for that county.

A) What is the hazard type that is the highest risk of occurrence? (will depend on the county selected)

B) What is the hazard type that is expected to cause the most costly damage? (will depend on the county selected)

C) If A and B have different responses, why do you think they differ? (will depend on the responses to A and B above)

D) Identify the hazards of moderate risk to the county. (will depend on the county selected)

E) Hazards that have a high risk of occurrence may not always be more costly to address. Find a high risk hazard which has a lower EAL value than a moderate or low risk hazard, and explain. (cross-reference columns of data… earthquake costs more than several high risk hazards: winter weather & ice storms)

Develop five additional questions that can be answered from your data table using mathematics. Examples of questions are provided below:

(1) If your selected county was going to allocated all of the needed funds, identify the percentage that would be allocated to each of the three risk categories: (a) high risk, (b) moderate risk, (c) low risk.

(This response will vary depending on the county selected, but to solve the student will need to first need to total all the EAL values, then (i) add all the high risk EAL values and divide by the total EAL value, (ii) add all the moderate risk EAL values and divide by the total EAL value, and (iii) add all the low risk EAL values and divide by the total EAL value. Important note: percentages should have a sum of 100%.

2. Create a table showing the EAL values by risk category (the data in the table will vary based on the county selected, but the table design should resemble the example provided below:

Risk Category	**EAL Value %**
High risk	
Moderate risk	
Low risk	
Total	(should add up to 100%)

Note: students should be instructed to round up their answers to eliminate decimal points in their percentages

3. Create a graphic to illustrate the percentages identified in the Table in #2 above (note: it is recommended that a pie chart be developed to illustrate this answer)

4. What is the dollar value of the difference between the most costly EAL value and the lowest EAL value? (The response will vary depending on the county selected. The answer is derived by subtracting the lowest EAL value from the highest EAL value. The answer represents the EAL value **range** for all hazards in that county.)

5. If you have $1 million, which hazards would you address and why? (this will vary depending on the county selected. However, the students should list the hazards they will be addressing. The total funded EAL values cannot exceed $1 million)

Part 3: Comparison of two counties' data

Compare two counties' data using three different ways and report your findings.

We would expect students to make comparisons answering questions such as:

- If both counties were to allocate all of the money towards risks categorized as being at a high risk of occurrence, what is the difference between the amount of money that County 1 and County 2 would need to budget?
- County 1 would need to budget how much more (or less) money for winter weather than County 2?
- If both counties were to budget according to the suggested amounts for all hazards, how much more (or less) money would County 1 need to budget compared to County 2?

Part 4: Connection to social justice

A. Find a data-driven resource about supporting communities recovering from the effects of natural hazards. Cite your resource. You may use articles selected from the Natural Hazard Center's Research Counts collection, or other resources. https://hazards.colorado.edu/news/research-counts/special-collection/children-and-disasters

   (Questions and responses developed below are from the article located here: https://hazards.colorado.edu/news/research-counts/special-collection/lessons-learned-helping-students-and-school-personnel-recover-from-disaster)

B. Write at least five data literacy questions (and provide their solutions) to help readers of the article learn more about the recovery process. Provide sample solutions to your questions and show your work.

Refer to the article's "Table 1: Perceived support provided to students and educators in the aftermath of Hurricane Matthew" to respond to the following questions:

(1) According to school personnel, what were the top three perceived supports available to students and personnel? (Adjustment to the school calendar, personal supplies, and school supplies)

(2) What was the area ranked lowest for perceived support available to students and personnel (Students - mental health providers; Personnel - Transportation)

(3) Why do you think there was a difference in the lowest ranked perceived support available for students and personnel? (This is a thought question, responses will vary)

(4) Why don't the percentages in each column add up to 100%? Does this mean the percentages given are wrong? (The percentages do not add up to 100% because the variables are not being compared to each other. Instead each variable is being compared to itself.)

(5) If 35.5% of survey respondents perceived that free meals were available to students, what percentage of respondents did not perceive that free meals were available to students? (64.5% of survey respondents did not perceive that free meals were available to students. This answer was obtained by subtracting 35.5% from 100%. Note: consideration of the non-perception percentage may cause the students to view the variable in a different manner.)

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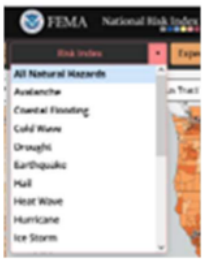
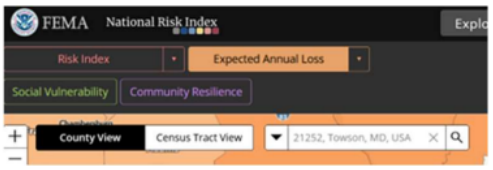
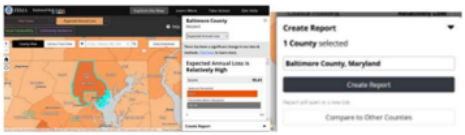
Cover Image generated by https://fotomedley.com/

Appendix A: Instructions for downloading National Risk Index data

To download a county's report from the National Risk Index (NRI) https://hazards.fema.gov/nri/map#:

Steps	Screen Shots
Step 1: Select your Risk Index of interest (I am using the default, "All Natural Hazards" but there are options to have specific natural hazards such as Avalanche, Coastal Flooding, etc.)	
Step 2: Select a location of interest (here, we have input Towson University's zip code 21252)	
Step 3: On the right hand side of the County report, bottom corner, there is an option to Create Report. You can download the data as a PDF.	

Appendix B: Algebra extension

"Just in Case": An Application of Linear Equations to Natural Disaster Preparation

The Center for Disease Control recommends that families prepare emergency kits that are easily accessible and ready to use in case of natural disasters. Suppose you would like to build your own kit, but also help four additional families in your neighborhood prepare their kits. Research the list of items that are suggested for inclusion in the kits.

https://www.cdc.gov/childrenindisasters/checklists/kids-and-families.html

· On Slide 1: Identify two items that are listed on the checklist.

· Research how much each item would cost, and provide your sources.

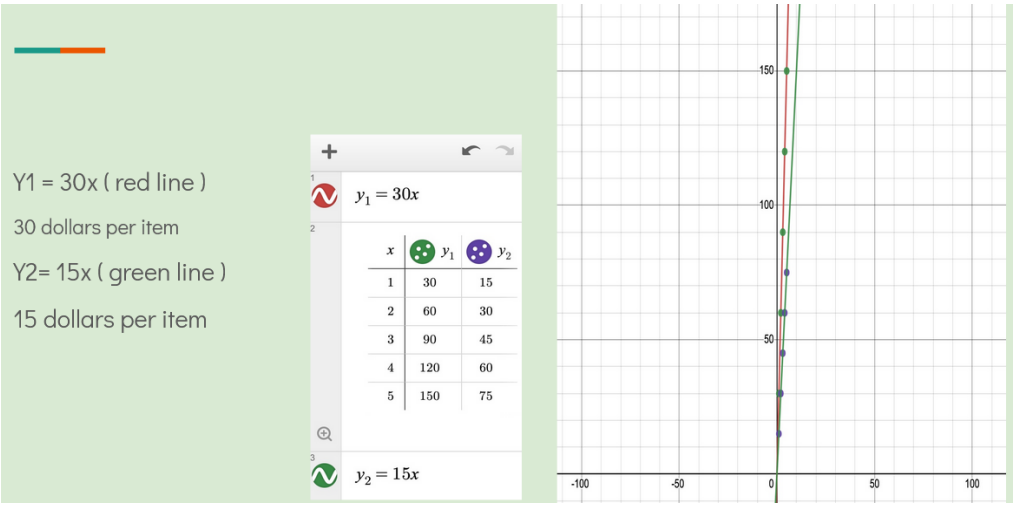
· On Slide 2: Write an equation corresponding to how much it would cost if you bought multiple copies of the items. The cost for your first item can be listed as variable y_1 and the cost of the second item can be listed as variable y_2.

· Graph the cost for increasing quantities of the items. You may use a technological tool such as a graphing calculator or https://www.desmos.com/calculator

· How much would a quantity of 5 of each of these items cost? Create a table of values to show the costs.

Sample student work:

"One identified item I chose was a toy to calm my child. The toy I picked was Legos because you can rebuild these as much as you want. Legos are $30. Another item I chose was canned goods ($15)."



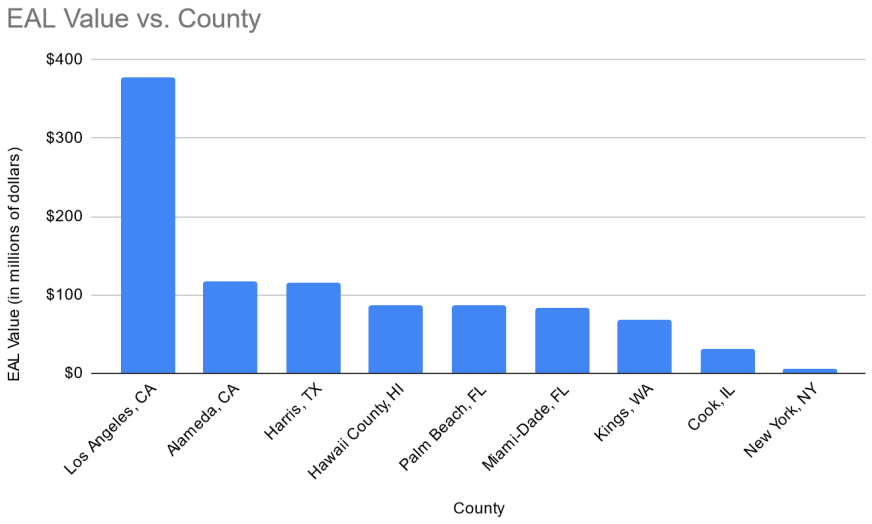
Appendix C: High school level mathematical explorations

High school level mathematics extension: Develop a key question that can be addressed using online research and explain what you have learned from examining the data.

Sample student work:

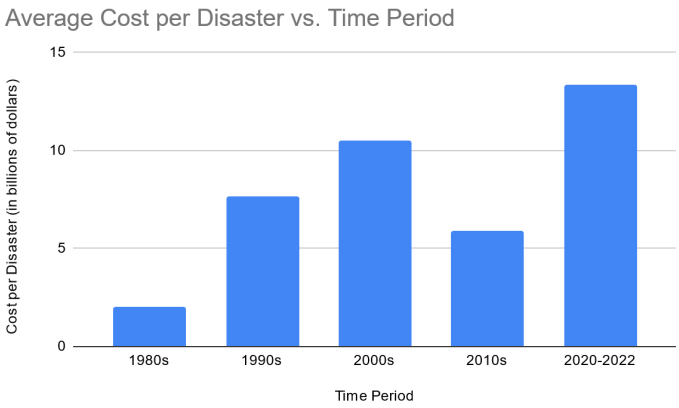
A sample research question could be a comparison across geographic locations to determine the natural disaster that caused the highest recovery costs. On the below sample work, with data reported as of July 2023, several different states' counties' natural hazards and their recovery costs were reported:
https://docs.google.com/spreadsheets/d/1_ZqSgqbgbvJ3ac4aLqpTGl77ZZeZuNm5HyJSaF8i9U8/edit?usp=sharing

Bryce compared the recovery costs from hurricanes in Florida, Hawaii, and New York; wildfires in California; tornadoes in Illinois and Texas; and earthquakes in Washington state. This led into another question about how much money the states need to budget each year in anticipation of the possible natural disasters. Below is Byrce's summary of the Expected Annual Loss from the natural disaster costing each county the most for recovery.



An extension of this investigation could be about costs' changing over time, including examining historical data. Since the FEMA website only reported current costs, and did not include costs over time, another reference (see the NOAA website below) was needed. The data that Bryce assembled is shown here:
https://docs.google.com/spreadsheets/d/113V_F5lsxHBZhT7omfHxgSu9jeRSaeLqEGhFpr_WG_E/edit#gid=224978939

A sample graph showing the average cost per natural disaster from the state of Florida is shown below (note, the NOAA website only reports costs by state and country, but not by counties). In the above link, total costs per time period for each state examined are also shown.



A future investigation could include projecting how much money each state should budget for recovery.

Reference:

NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73