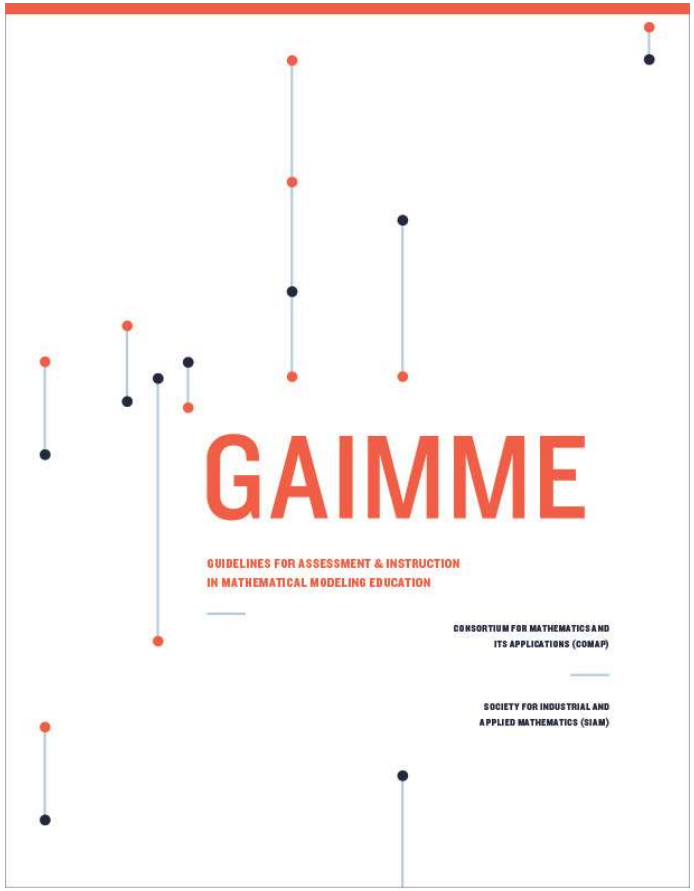


Guidelines for Assessment and Instruction In Mathematical Modeling Education

Laura Pahler

7th and 8th Grade Math Teacher
Cortez K-8 Math and Science Magnet School
Pomona Unified School District, CA

Lead teacher for the IMMERSION program (K-8)

Email: laura.pahler@pusd.org

GAIMME@siam.org

http://www.comap.com/Free/GAIMME/index.html
http://www.siam.org/reports/gaimme.php

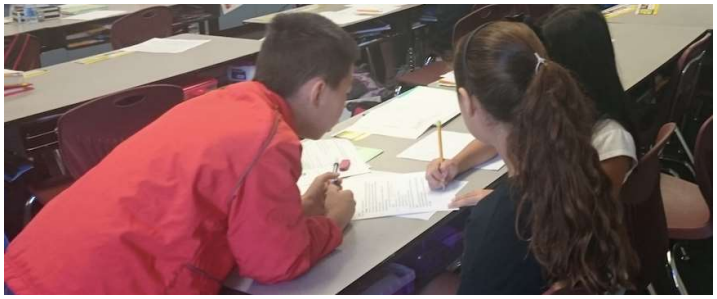
My teaching and mathematical modeling experience

15 years teaching experience (3rd, 5th, 7th, and 8th grades)

Planned and implemented mathematical modeling with 6th-8th graders

Attended Modeling across the Curriculum (MaC) Workshop II in 2014

Prepared professional development for elementary teachers in mathematical modeling
Facilitated a study group of 4th grade teachers who designed, implemented, and revised a math modeling lesson (IMMERSION)



A talk-workshop in four parts

GAIMME: Who , What, Where

What is Mathematical Modeling?

Facilitating Math Modeling in Middle Grades

Assessment

A talk-workshop in four parts

GAIMME: Who , What, Where

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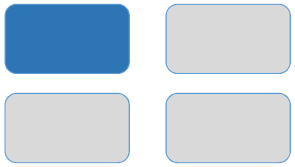
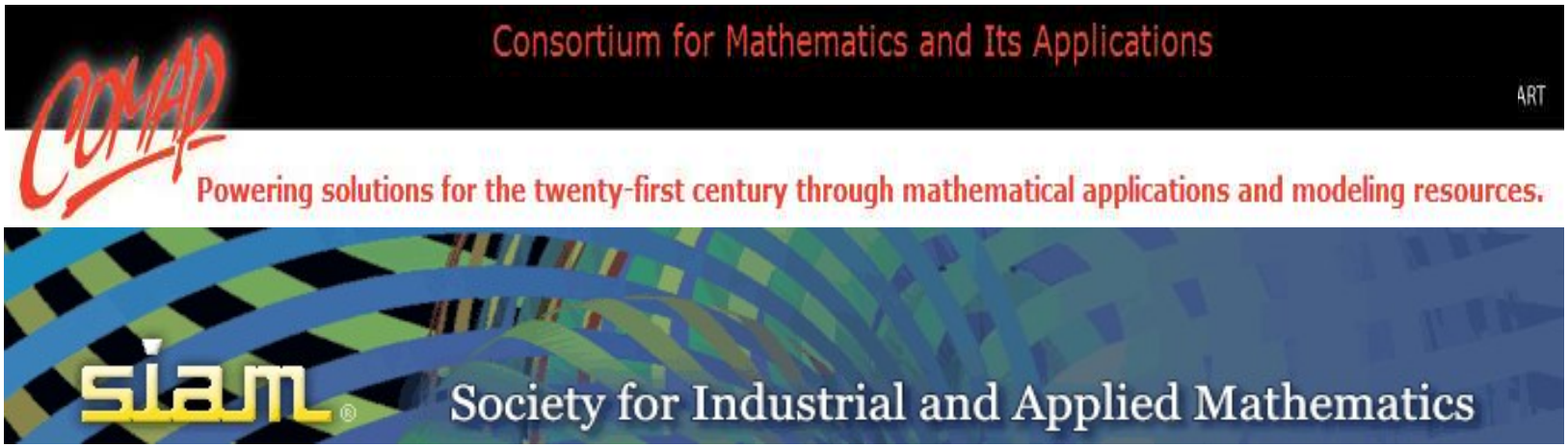
GAIMME: who , what, where?



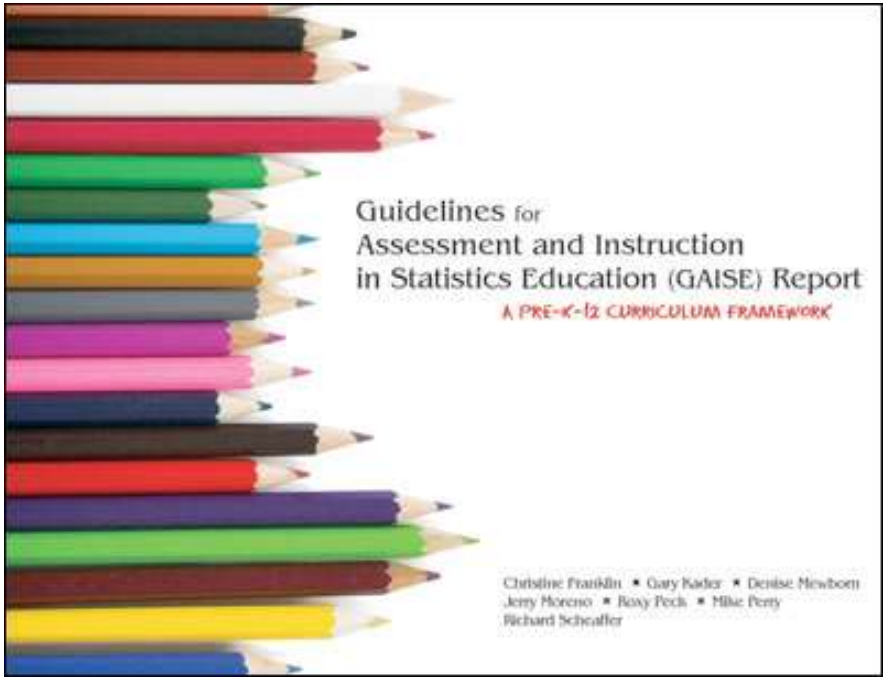
Sponsors: COMAP and SIAM



in cooperation with

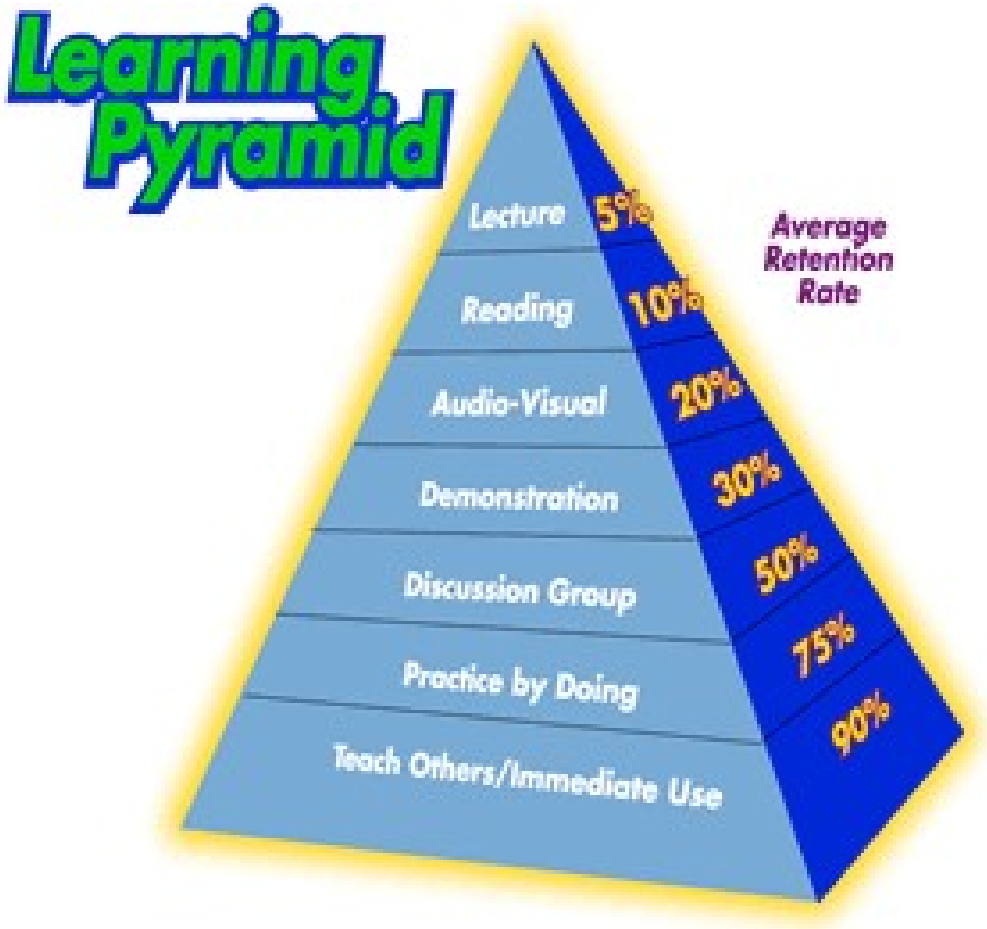
NCTM | NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

Inspiration – the GAISE Report



Context


Office of Instructional Technology
Engaging • Student Centered • Engaging • Student Centered • Engaging • Student Centered • Engaging • Student Centered •
Critical Thinking
Problem Solving
Communication
21st Century Learning
Collaboration
Creativity
Innovation
intranet.bcps.org/offices/oit/



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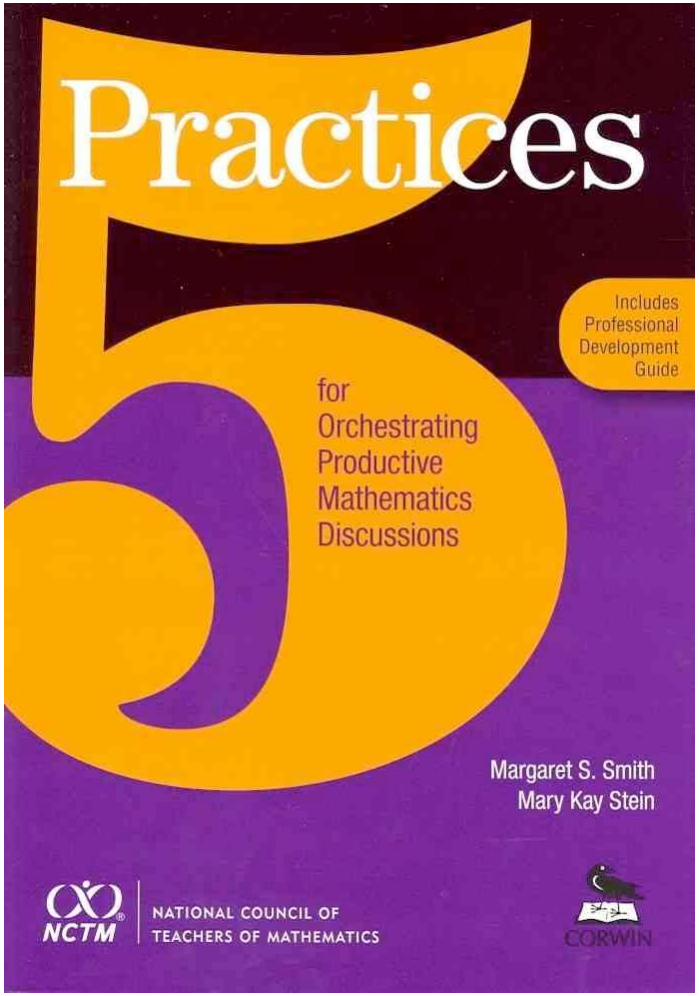


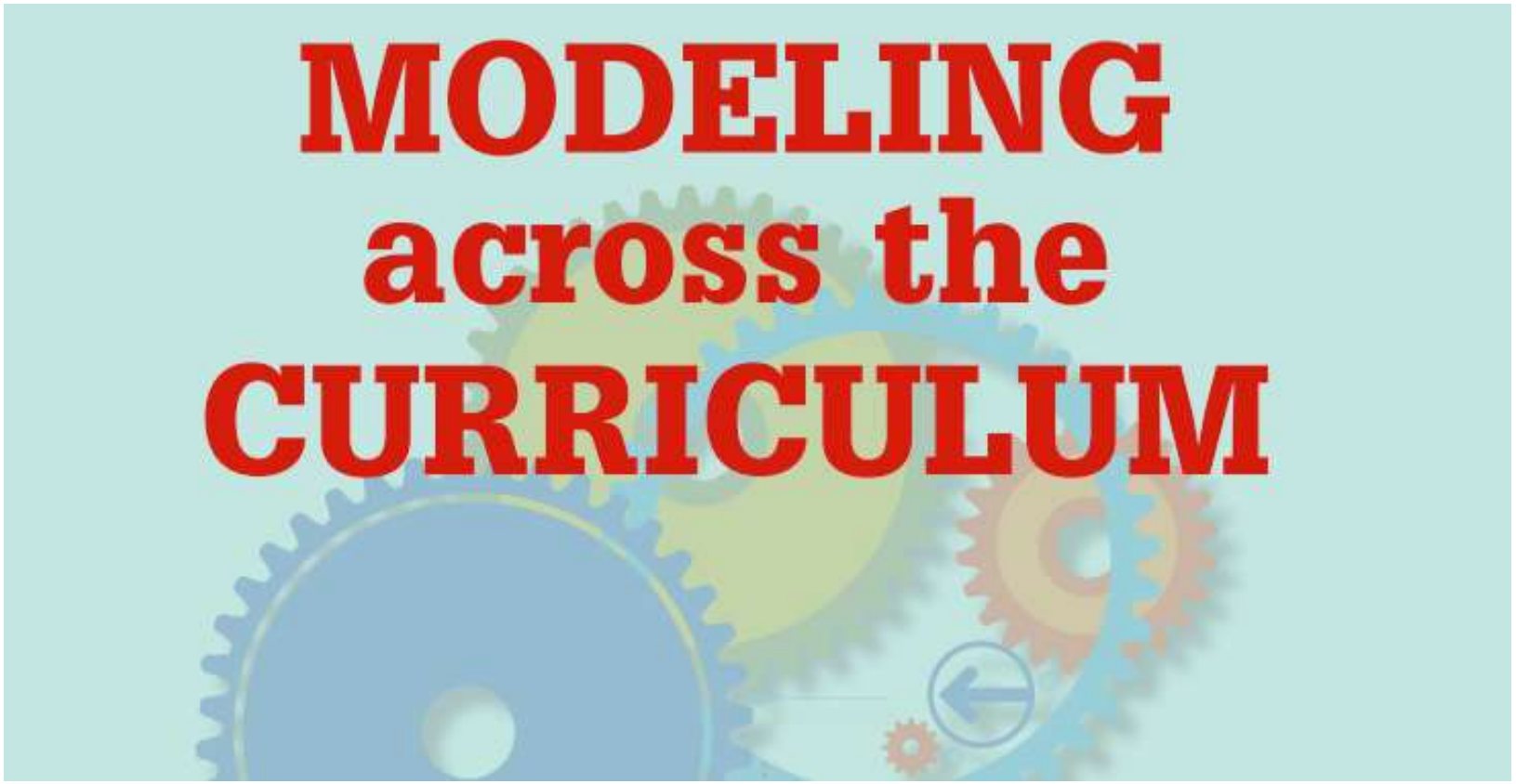
Anticipating what students will do--what strategies they will use--in solving a problem
Monitoring their work as they approach the problem in class
Selecting students whose strategies are worth discussing in class
Sequencing those students' presentations to maximize their potential to increase students' learning
Connecting the strategies and ideas in a way that helps students understand the mathematics learned

CCSS.MATH.PRACTICE.MP4 **Model with mathematics.**

Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

Standards of Mathematical Practice:
Model with Mathematics

High School Modeling Challenges


MODELING
across the
CURRICULUM

writing team

writing team

What is Mathematical Modeling?
Karen Bliss*, Jessica Libertini

Early and middle grades
Rachel Levy*, Rose Mary Zbiek, Ben Galluzzo, Mike Long

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*lead writers

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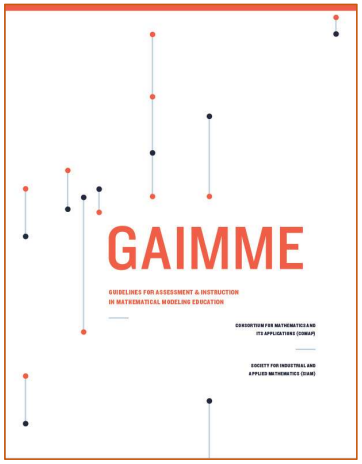
CONTENTS



GAIMME is a living document

www.buckleytree.com/images/consultation.png

GAIMME is a living document

Future:
Workshops
Webinars
Repository
Revision

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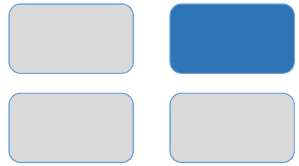
What is mathematical modeling?



Activity: Many meanings of modeling

In the context of mathematics teaching and learning, how have you heard/seen/used the term modeling?

2 min: think individually, make notes
3 min: discuss in groups of 2-4

Raise your hand if your group mentioned

- Demonstration
- Manipulatives
- Symbolic representation
- Strategies (e.g. tape diagrams)
- Word problems
- 3-Act Task
- Real world problems

These are ALL appropriate uses of the term “modeling”

- Demonstration
- Manipulatives
- Symbolic representation (e.g. box for variable)
- Strategies (e.g. tape diagrams)
- Word problems
- 3-Act Task

These are ALL appropriate uses
of the term “modeling” but GAIMME focuses on

Real world problems

Mathematical modeling, both in the workplace and in school,

uses mathematics to answer big, messy, reality-based questions.

Mathematical Modeling is a *process* that uses mathematics to represent, analyze, make predictions, or otherwise provide insight into real-world phenomena.

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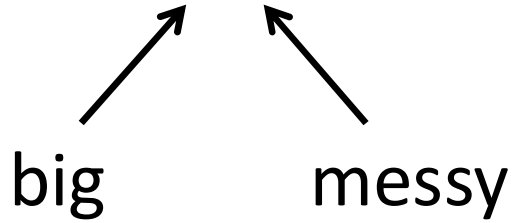

My problem

Credit: http://www.united-states-map.com/topo/ustopo11.gif

Activity: What is your problem?

Think of a problem you have encountered recently.

How can mathematics help you

- understand something
- make a decision
- optimize something (best, fastest, cheapest, most fair)

about your problem?

What makes a good modeling problem?

- Context is relevant and important to students
- Openness
  - Beginning: multiple entry points, how you define the question
  - Middle: multiple mathematical approaches
  - End: multiple solutions
- Inspires questions right away to focus problem through assumptions
- Information needed to inform and test solutions
- Someone cares about solutions; solutions are useful

Math problem ➡ Word problem ➡ Modeling problem

Computation problem: 6 + 3 = ?

Word Problem: Jim has 6 pretzels and Suzy has 3 pretzels. How many pretzels do Suzy and Jim have in all?

Why is this word problem not a modeling problem?

"First, it does not have intrinsic value or meaning for students. Other than answering this problem for homework, why would students care about how many pretzels Jim and Suzy have? The word problem is closed at the beginning and the end. While students may use a few different approaches to reach the answer, such as drawing a picture and counting or writing and evaluating an arithmetic expression, all of the necessary data is clearly provided, and there is only one correct solution." --GAIMME p.10

Activity: what might your students ask?

"In order to have students *engage with the context* more, you could ask the students to imagine that they are helping pack a picnic lunch, and they have to determine how many pretzels they need to pack. Students will need to take many factors into consideration."

Possible Considerations/Variables

- How many people will be attending the picnic?
- How many pretzels is each person likely to eat?
- Does anyone have dietary restrictions that should be considered?
- How much other food will be available at the picnic?

Making assumptions

Students must make *assumptions*
which will affect the outcome (solution)
while still engaging in mathematical skills or standards
such as adding whole numbers.

How many pizzas should we order for our upcoming class party?

What assumptions would you make in order to solve this problem?

How many pizzas should we order for an upcoming class party?

- How many people will attend?
- Number of slices each person eats
- Where we would order the pizza from (affects size of slices and desirability of pizza)
- Number of slices in a pizza
- Cost of the pizzas – if we order more expensive pizzas, we might have to limit or reduce the number of slices each person gets

Are My Students Modeling?

Did they start with a big, **messy**, real-world problem?

Did the students make genuine **choices** and **assumptions**?

Are students using **mathematical tools** to solve the problem?

Are students **testing** and **revising** their model?

Did they **ask questions** to **clarify** or focus the problem?

Who cares about or is **invested in the solution**?

Can students explain **if/when** their model makes sense?

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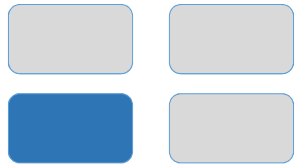
Facilitating Modeling in the Middle Grades



Middle school modeling advantages

Mathematical Development

- Creates a positive disposition toward mathematics, potential for fluency
- Motivates mathematical processes and tools
- Lays groundwork for more sophisticated modeling
- Develops teamwork skills
- Allows for differentiation

Assessment

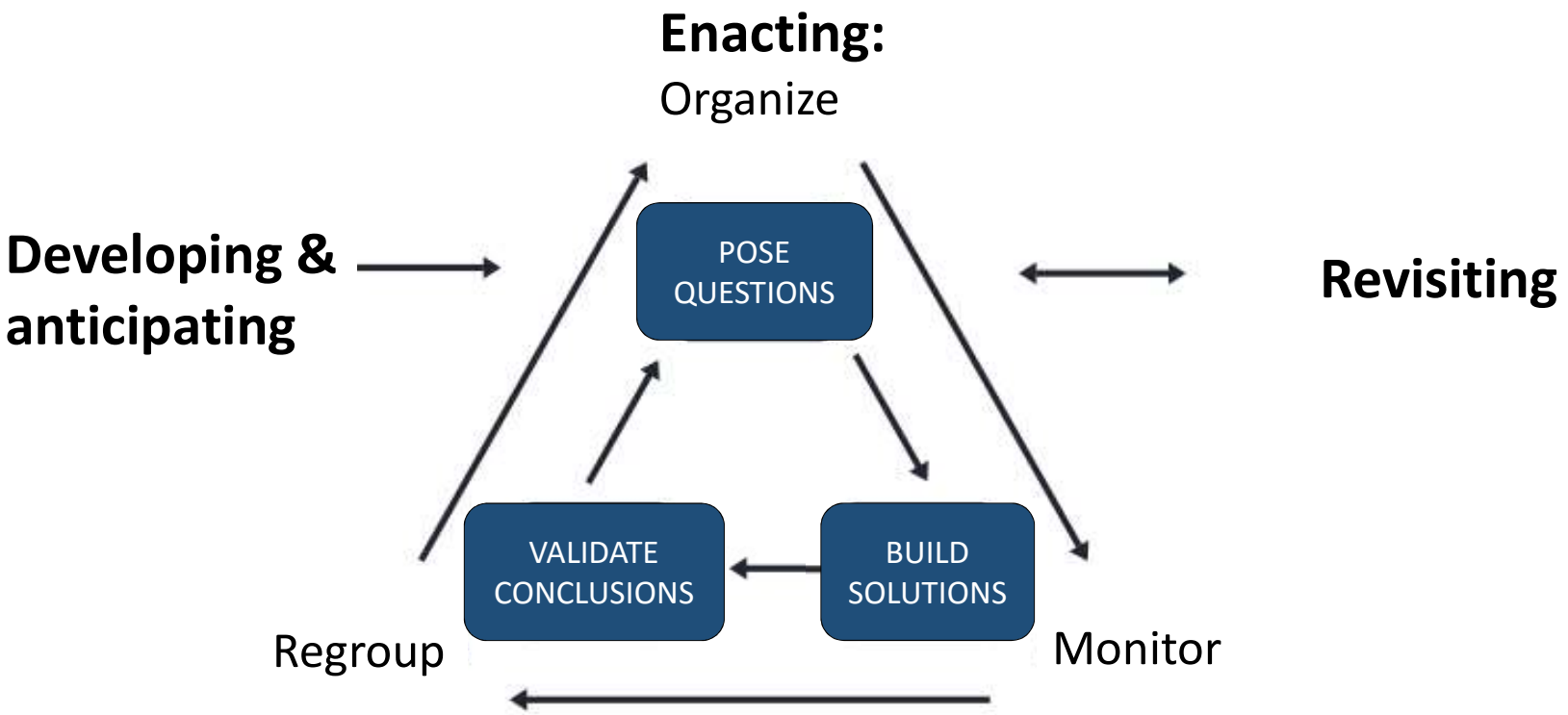
- Provides communication opportunities
- Helps teachers identify misconceptions

Integrating **M**athematical **M**odeling, **E**xperiential learning and **R**esearch through a **S**ustainable **I**nfrastructure and an **O**nline **N**etwork for teachers in the elementary grades (K-6)

- Informed the GAIMME report
- 3-year NSF grant to work with K-8 teachers
- Sites in urban, rural and suburban areas (VA, MT, and CA) and in Common core and non-common core states
- Ongoing, in the process of building a repository of modeling lessons for each grade level

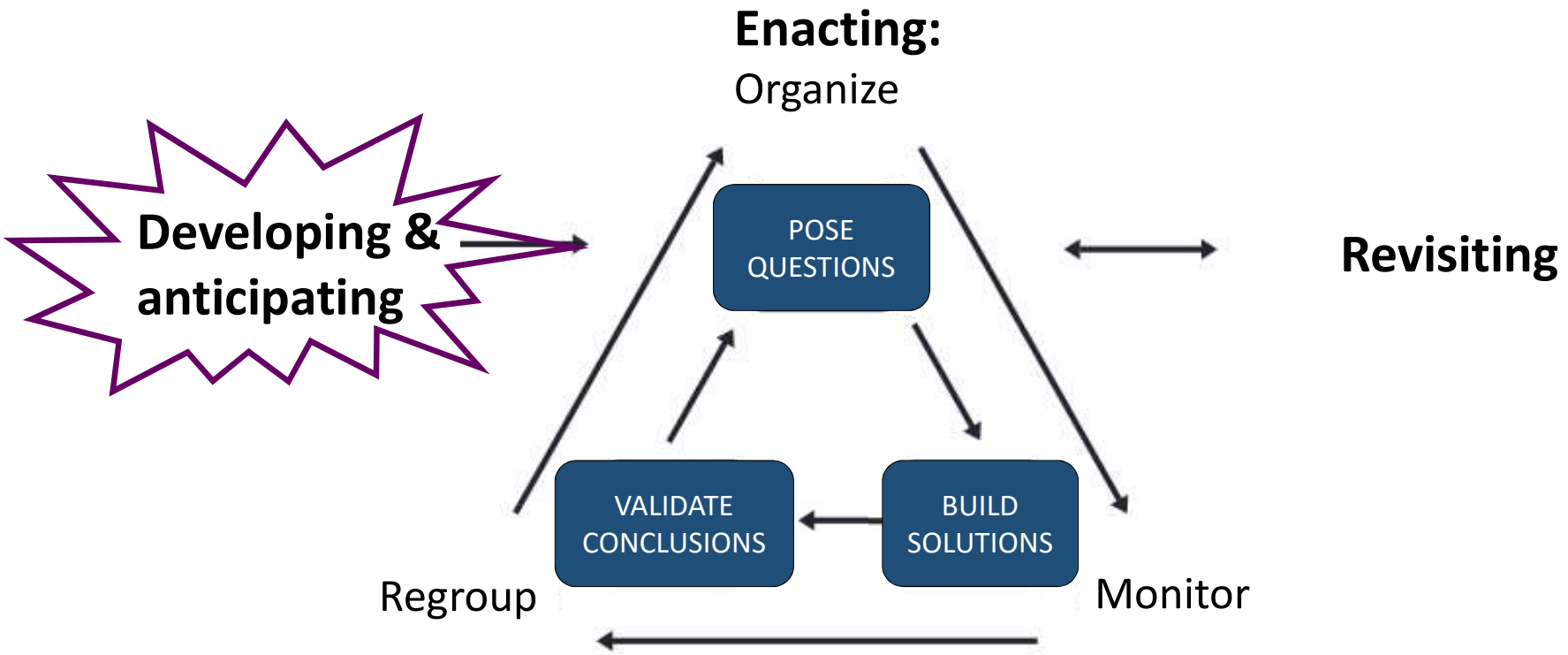
http://nsfimmersion.gmu.edu/

The Teacher/Student Modeling Cycle



Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

STUDENT ACTIONS



Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

STUDENT ACTIONS

Activity: developing and anticipating

How might your students use mathematics to approach the problem?

What tools, techniques, visualizations, strategies might they use?

Your parents want you to plan your lunches for the week. What should you take into consideration? What would you include? What is a reasonable amount to spend?

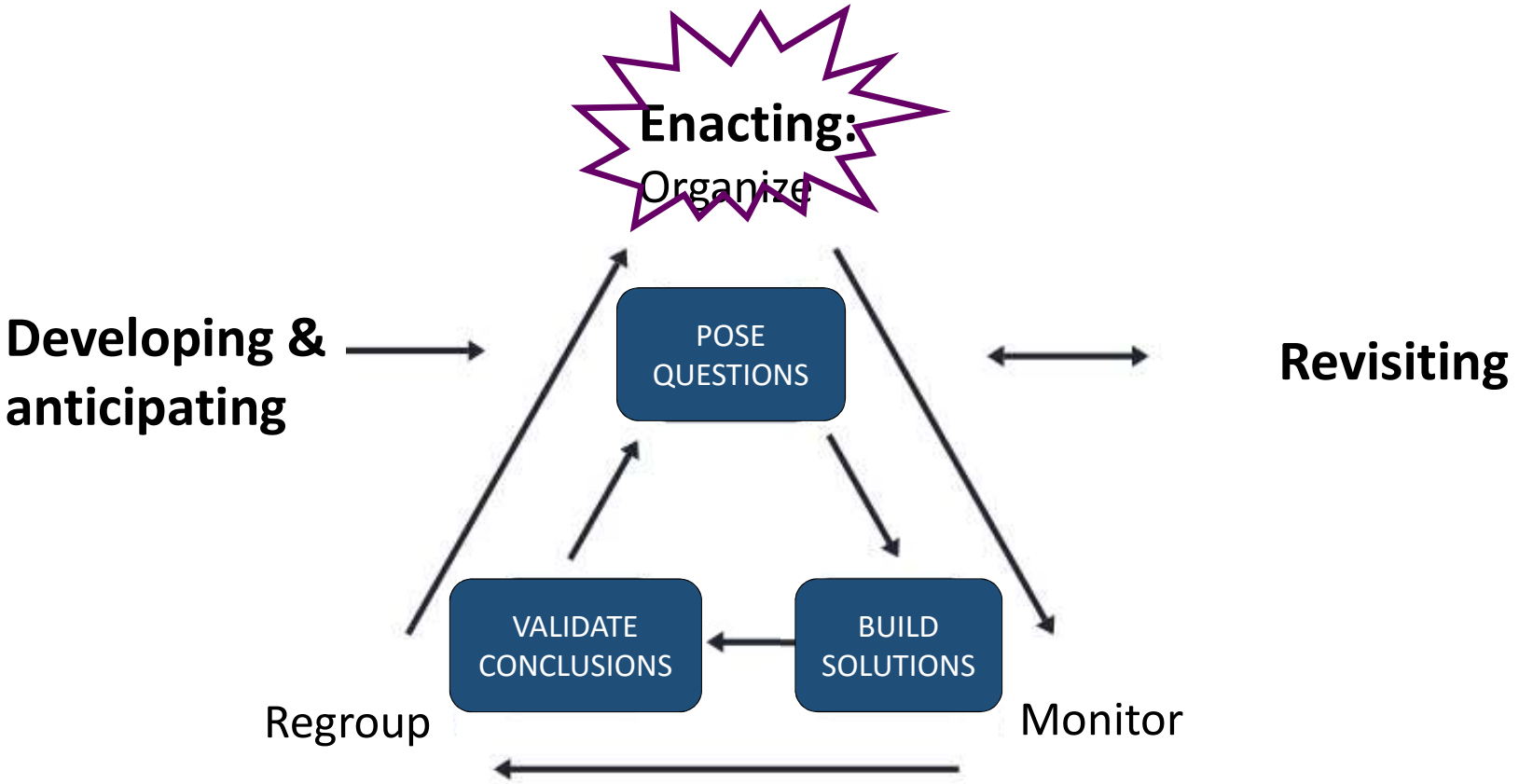
Middle Grades – Typical Approaches

Grade-level appropriate tasks:

- Ratios and proportions
- Linear relationships
- Collecting data and finding an average

Typical student approaches:

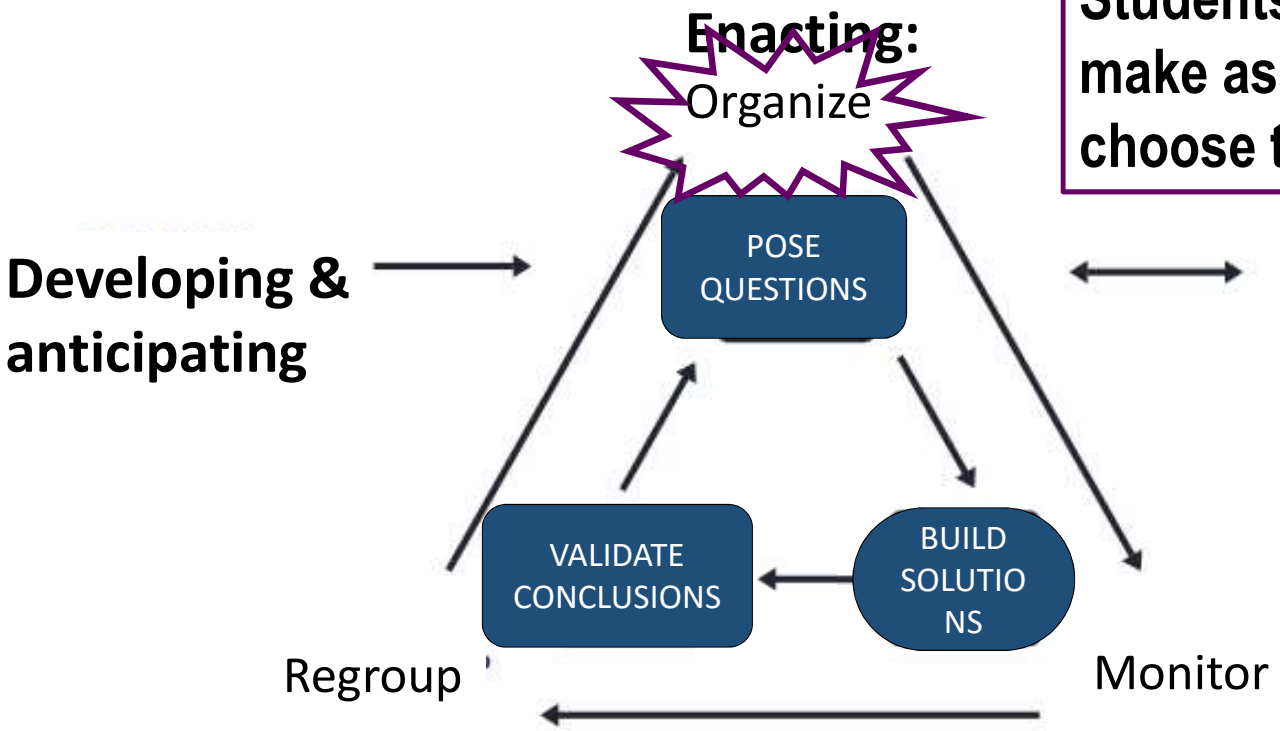
- Multiplication and division
- Creating a table
- Making a list



Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

STUDENT ACTIONS

You launch task. Students refine problem, make assumptions, choose their approach.



Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

STUDENT ACTIONS

Gas Station Problem

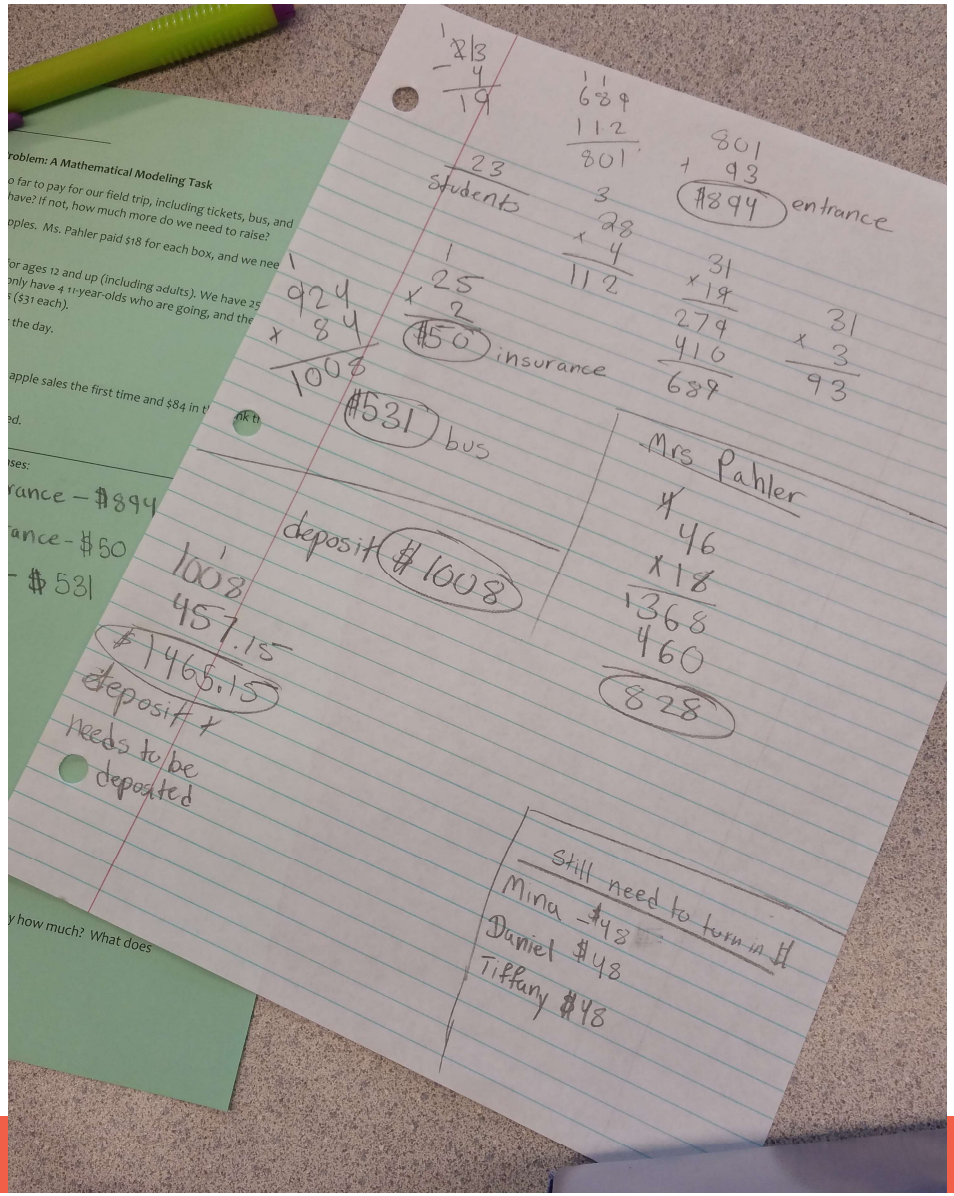
Is it worth it to drive a little farther to a gas station that has cheaper gas? What would make it worth it?

Students' thinking might initially look messy

Students may consider:

How much would it cost to drive to the farther station?
How many gallons of gas are we using to drive there and back?
How many miles farther away is the cheaper gas station?
How many miles per gallon (mpg) do we get?

Students at this age group might use many separate calculations that involve the above considerations but may not necessarily be combined into one equation.


Problem: A Mathematical Modeling Task
23 students
25 x 2 $50 insurance
924 x 8 1008
$531 bus
deposit $1008
1008 457.15 $1465.15
deposit + needs to be deposited
689 112 801
801 + 93 $894 entrance
3 28 x 4 112
31 x 19 279 416 687
31 x 3 93
Mrs Pahler
46 x 18 368 460 828
Still need to turn in $
Mina $48
Daniel $48
Tiffany $48

Stuck? Solve a simpler case

FIGURE C.16: DIAGRAM ILLUSTRATING THE SIMPLE PROBLEM

Gas Station Problem – Model #1

Cost of extra gas = $Miles\ between\ stations * \frac{gallons}{mile} * \frac{dollars}{gallon}$

Money saved $= Difference\ in\ price\ * number\ of\ gallons\ bought$

Conclusion: If the cost of the extra gas is less than the amount of money you save, then it is worth it to drive farther to go to the cheaper station.

Different considerations

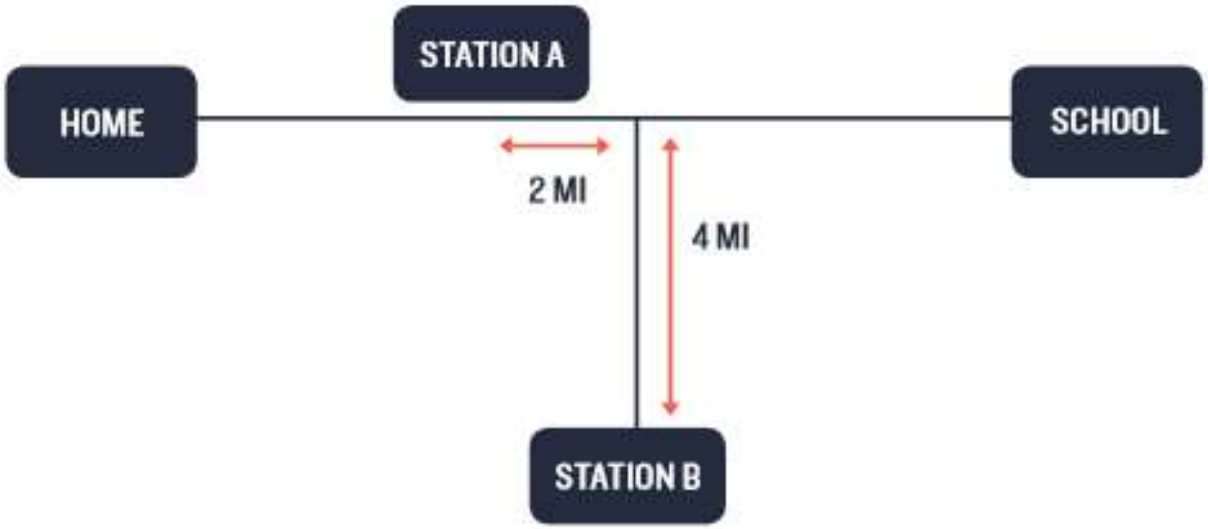


FIGURE I.3: WHY TEAM A'S INITIAL ASSUMPTION ABOUT ADDED DISTANCE SHOULD BE REVISITED

Gas Station Problem – Model #2

Only count the additional distance you have to travel outside of your normal route, not the distance between gas stations

Cost of extra gas = $Miles$ $\boldsymbol{outside\ of\ normal\ route} * \frac{gallons}{mile} * \frac{dollars}{gallon}$

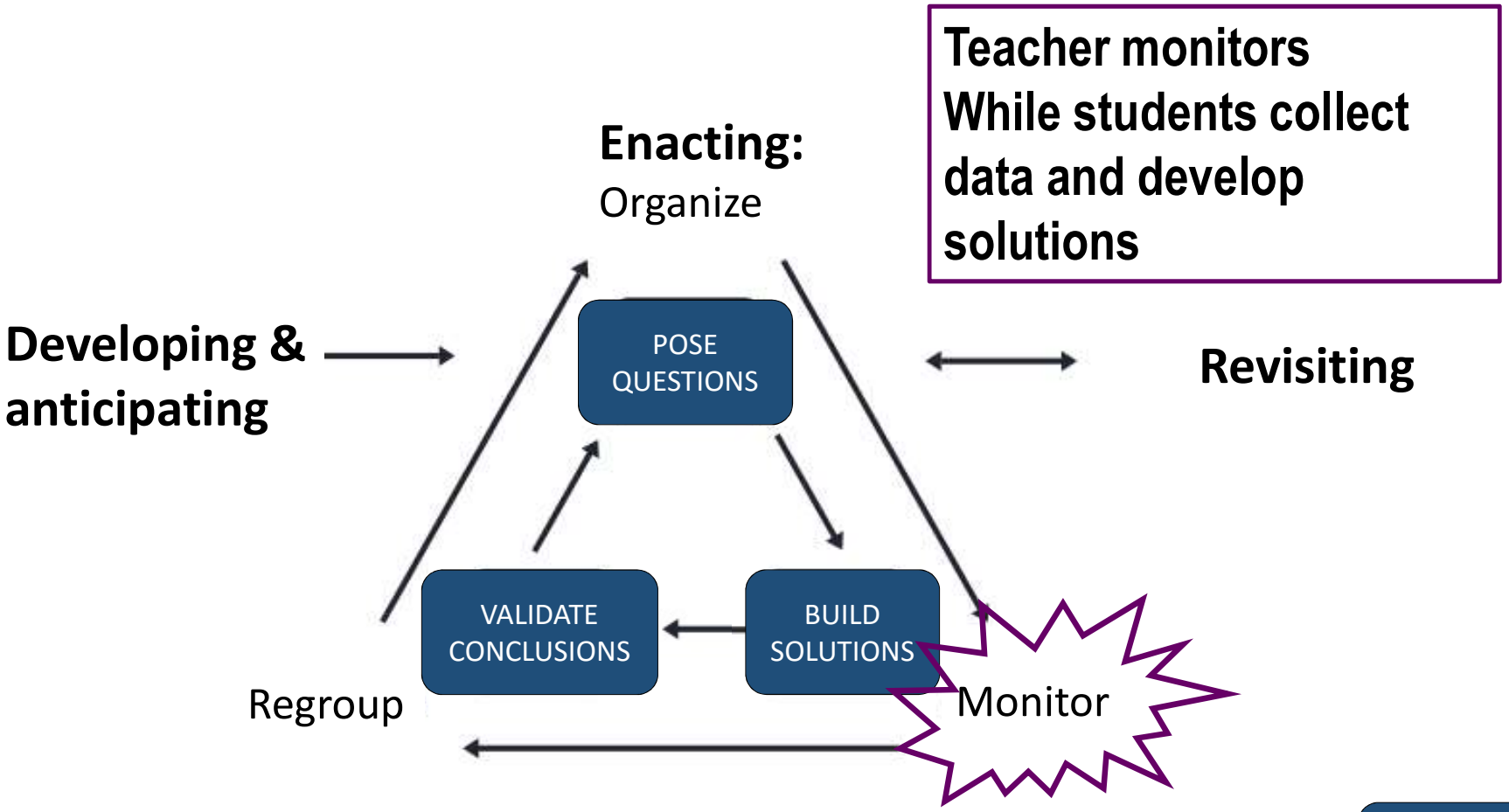
Money saved $= Difference\ in\ price\ * number\ of\ gallons\ bought$

Conclusion: If the cost of the extra gas is less than the amount of money you save, then it is worth it to drive to the farther station.

Gas Station Problem – Model #3

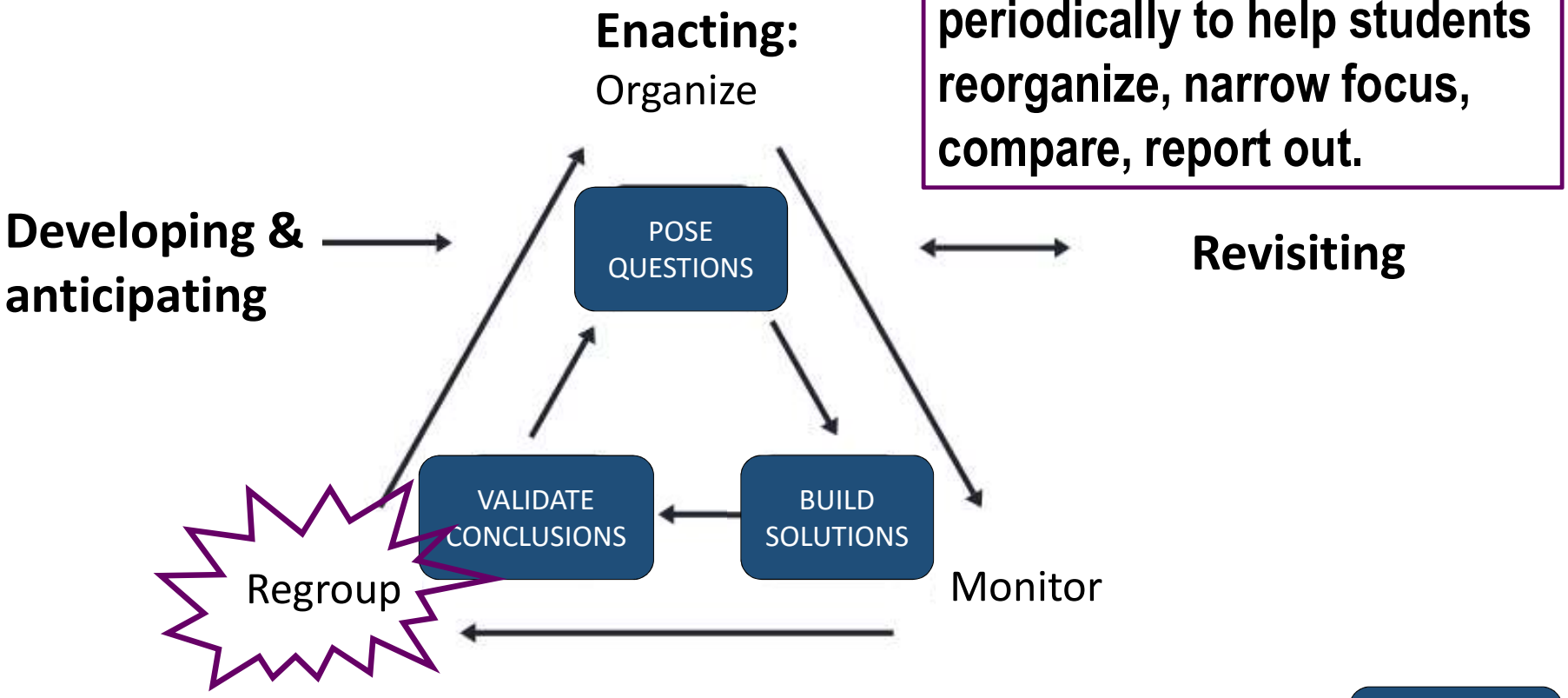
Takes into account:

- Cost of gas to drive extra distance
- Value of the person's time
- Environmental concerns (carbon emissions)



Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

Teacher regroups the class periodically to help students reorganize, narrow focus, compare, report out.

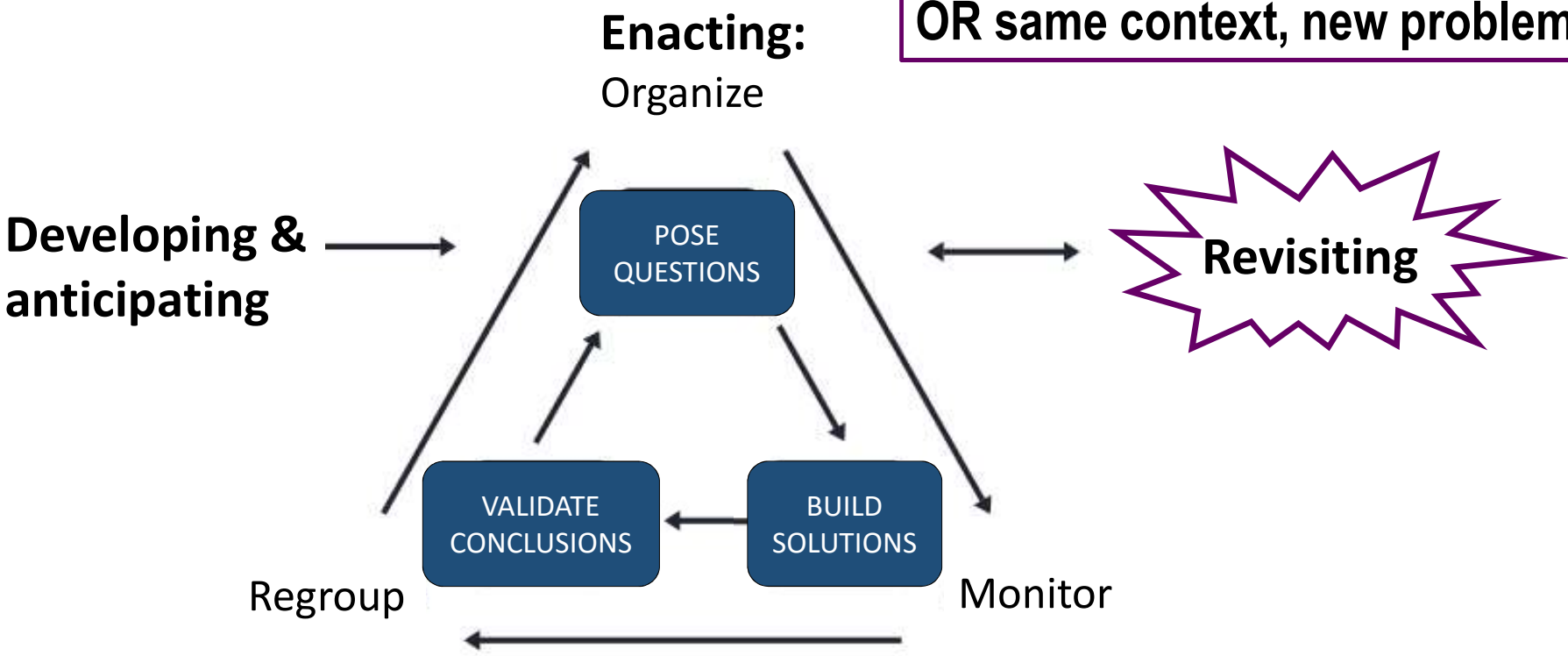


Framework for teachers' roles in facilitating modeling, Carlson et. al. (2016).

Regroup:

- Mini-lesson
- Introduce a new tool (e.g., table, chart) or a new application of a previously learned tool
- Focus/ organize work
- Have students share solutions in-progress

Same problem, new tool
OR same context, new problem.



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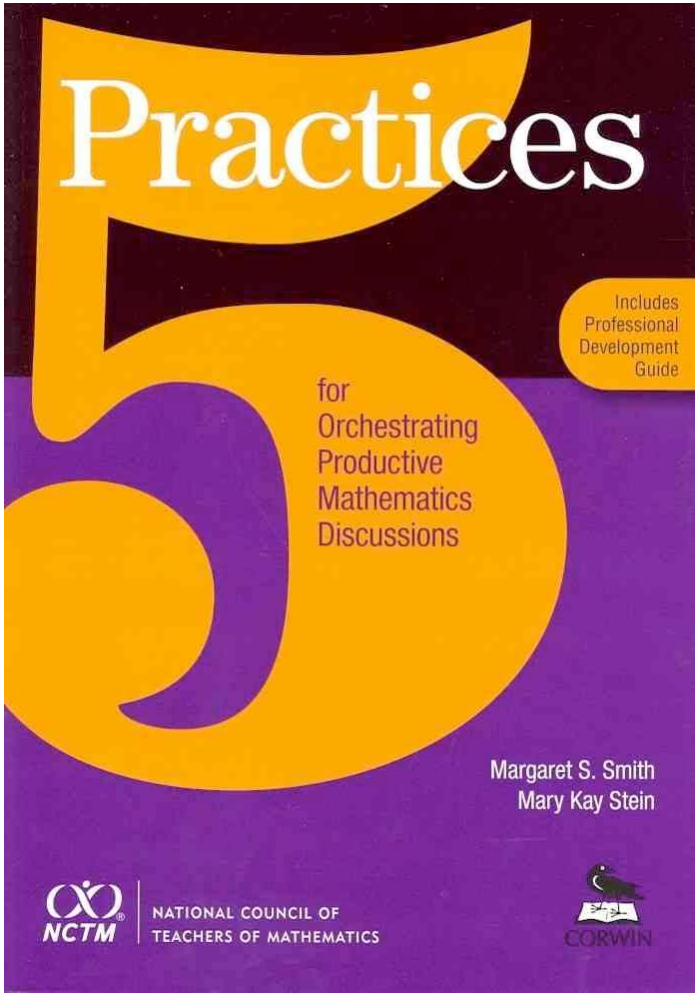
STUDENT ACTIONS

Revisiting

- Combine solutions of groups
- Eliminate or add variables
- Change weights of variables
- Think about the problem in a new way
- Which method was most efficient?
- Which method was communicated clearly so another reader could understand?



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Monitoring their work as they approach the problem in class
Selecting students whose strategies are worth discussing in class
Sequencing those students' presentations to maximize their potential to increase students' learning
Connecting the strategies and ideas in a way that helps students understand the mathematics learned

Revisiting: using the distributive property

P_1 = first gas station's price
P_2 = second gas station's price
g = the number of gallons purchased

Two ways to find the difference in price:

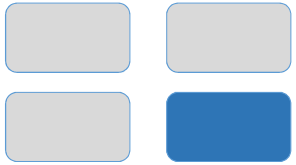
- We could calculate the difference in the amount spent at both gas stations: $P_1 * g - P_2 * g$

- Or we could first find the difference in price per gallon, then multiply that by the number of gallons: $(P_1 - P_2) * g$

Adapting the problem for middle-schoolers

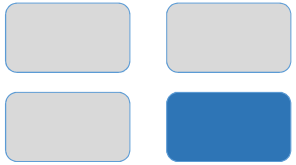
What kind of sale on Hot Cheetos would make it worth going to a 7-Eleven in a different neighborhood instead of the closest 7-Eleven? How many bags of Hot Cheetos would you have to buy to make it worth it for you? Does it matter if you are walking versus getting a ride?

Assessment and resources



Many options to be adapted to your problem and students.

Appendix A – Resources



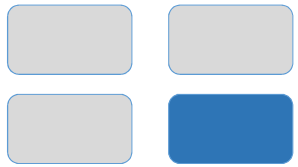
Modeling in State, National, International Standardized Assessments

Modeling Competitions (high school)

- Moody's Mega Math Challenge (M3 Challenge)
- High School Mathematical Contest in Modeling (HiMCM)
- Mathematical Contest in Modeling (MCM)
- Interdisciplinary Contest in Modeling (ICM)

Modeling handbook from M3 Challenge and COMAP mathmodels.org

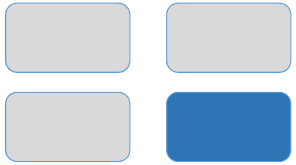
Appendix B – modeling examples for elementary and middle grades



Big Idea: to explain for a variety of problems what it looks like "over the shoulder" of a teacher facilitating modeling and responding to student work.

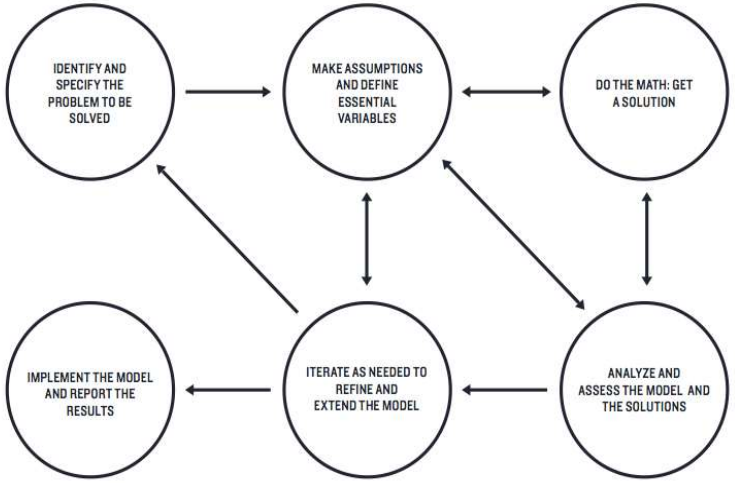
You will find even more examples in the upcoming repository with videos and lessons.

Appendix D – Assessment



Many options to be adapted to your problem and students.

Assessment Tool: Set of questions for students for each stage of the modeling process



STAGE: DEFINING THE PROBLEM

- Describe the problem that your team has been asked to solve. What information do you need in order to solve this problem?
- What does a solution to your problem "look like"? Is it possible that your solution will have more than one reasonable answer? Why?
- What is the specific problem your model is going to solve? How can you complete this sentence "Our model will tell you _____"

Assessment questions

paired with vocabulary for each stage of the modeling process

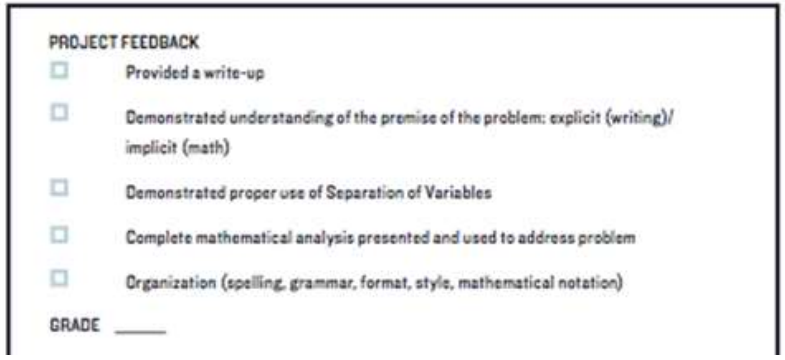
MODELING COMPONENT	QUESTIONS ABOUT YOUR MODEL AND HOW YOU MADE IT	MODELING-RELATED VOCABULARY TO BUILD
DEFINING THE PROBLEM	What is the big problem that you have been asked to solve? It might have more than one possible answer.	open-ended problem, constraints
DEFINING THE PROBLEM	What is the specific problem your model is going to solve? (My model will tell you...)	specific, focus
MAKING ASSUMPTIONS	What ideas did you think about that you decided not to try?	eliminate, prioritize
MAKING ASSUMPTIONS	What have you assumed in order to solve the problem? Why did you make these choices?	assumption/assumed
DEFINING VARIABLES	What quantities are important? Which ones change and which ones stay the same?	variable
DEFINING VARIABLES	Where did you find the numbers that you used in your model?	resources, citations

Assessment: Revisiting the pizza problem

- What is the problem you have been asked to solve?
- What ideas did you think about that you decided not to try?
- What assumptions have you made in order to simplify the problem?
- Which quantities are important?
- Which quantities change and which ones stay the same?

Project checklist for middle grades

- □ Demonstrates understanding of the premise of the problem
- □ Explains use of variables
- □ Equations clearly written, include units
- □ Complete mathematical analysis presented and used to address problem
- □ Mechanics (spelling, grammar, format, style, mathematical notation)



PROJECT FEEDBACK

- ☐ Provided a write-up
- ☐ Demonstrated understanding of the premise of the problem: explicit (writing)/ implicit (math)
- ☐ Demonstrated proper use of Separation of Variables
- ☐ Complete mathematical analysis presented and used to address problem
- ☐ Organization (spelling, grammar, format, style, mathematical notation)

GRADE _____

Rubric

For each stage of the modeling process defines:

- ideal (3 points)
- satisfactory (2 points)
- needs improvement (1 point)
- incomplete (0 points)

DEFINE THE MODELING PROBLEM (3 POINTS TOTAL)			
IDEAL	**SATISFACTORY**	**NEEDS IMPROVEMENT**	**INCOMPLETE**
(3 points) Concise problem statement that indicates exactly what the output of the model will be and, if appropriate, identifies the audience and/or perspective of the modeler. Statement is presented early in the paper.	(2 points) Problem statement is easily identifiable but not precise or consistent with other statements in paper.	(1 point) Problem statement is difficult to understand or is buried in the text.	(0 points) No problem statement is given.

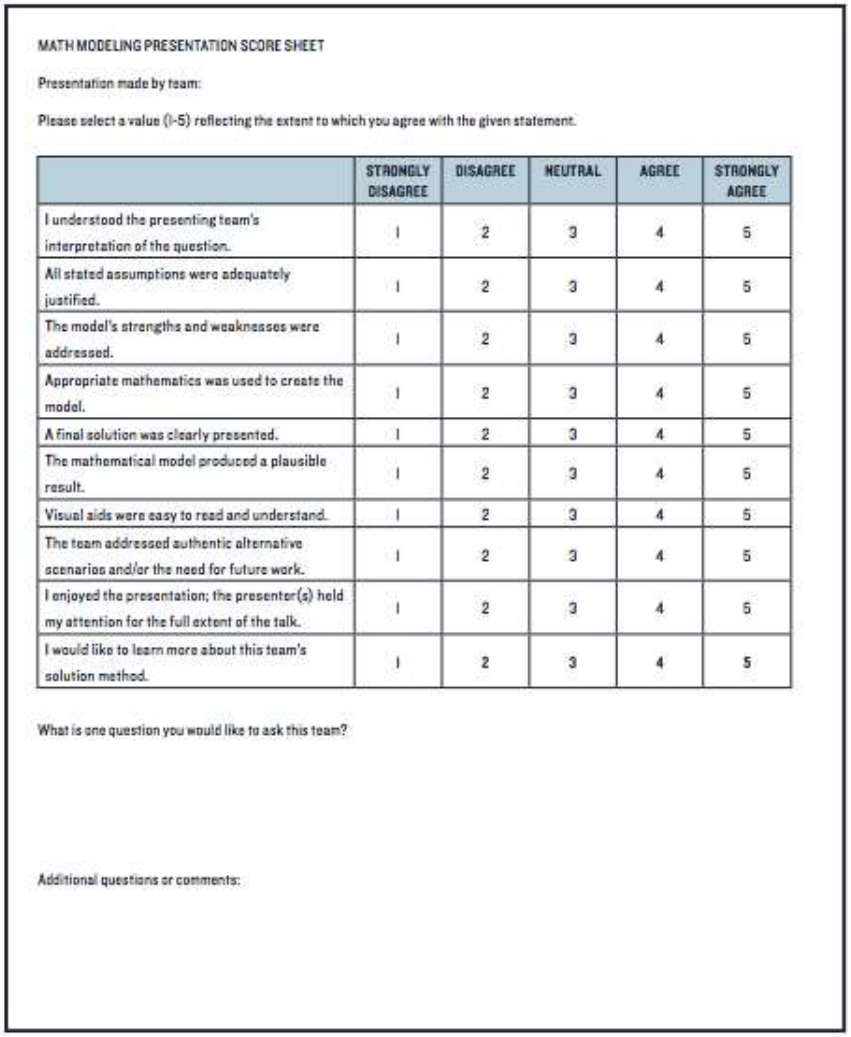
BUILDING THE MODEL: MAKE ASSUMPTIONS AND ACKNOWLEDGE LIMITATIONS (3 POINTS TOTAL)			
IDEAL	**SATISFACTORY**	**NEEDS IMPROVEMENT**	**INCOMPLETE**
(3 points) Primary assumptions used to develop the model are clearly identified, easy-to-read and well justified. Limitations due to simplification are stated when appropriate.	(2 points) Primary assumptions are noted; justification or readability is lacking.	(1 point) Assumptions and justification exist, but are difficult to identify in the text.	(0 points) No assumptions –or justification for lack of assumptions is provided.

BUILDING THE MODEL: DEFINE VARIABLES AND IDENTIFY PARAMETER (3 POINTS TOTAL)			
IDEAL	**SATISFACTORY**	**NEEDS IMPROVEMENT**	**INCOMPLETE**
(3 points) Notes and rationalizes the need for the primary factors that influence the phenomena being modeled in a readable format; proper units are specified.	(2 points) Important parameters and variables are listed properly but without sufficient explanation.	(1 point) Variables/parameters are wither barely mentioned or hard for the reader to identify in the text.	(0 points) No variables or parameters are identified.

Presentation Rubric

Students fill out the rubric

- Likert scale (agree-disagree)
- 2 short-answer questions



MATH MODELING PRESENTATION SCORE SHEET

Presentation made by team:

Please select a value (1-5) reflecting the extent to which you agree with the given statement.

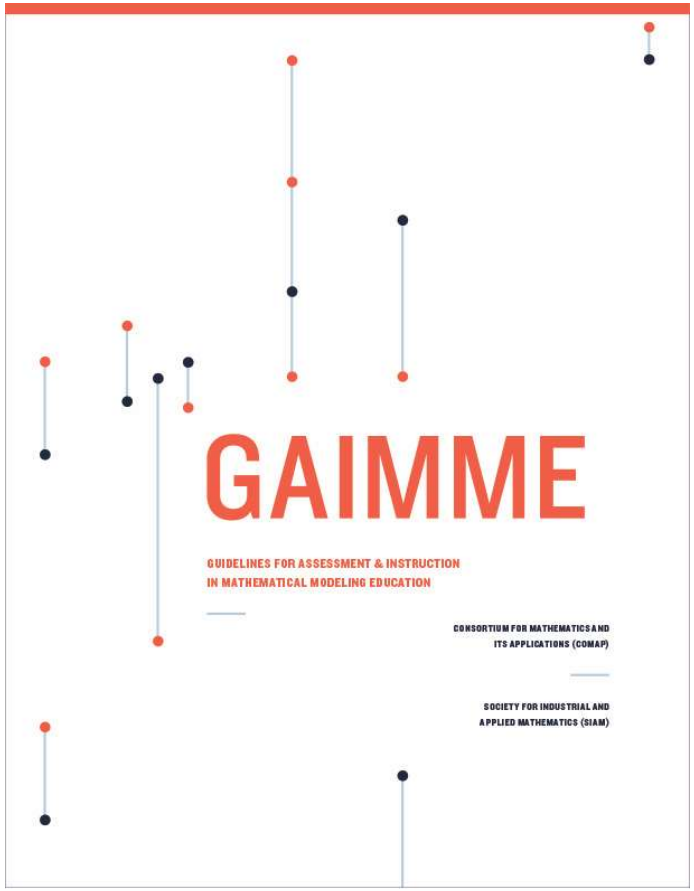
	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
I understood the presenting team's interpretation of the question.	1	2	3	4	5
All stated assumptions were adequately justified.	1	2	3	4	5
The model's strengths and weaknesses were addressed.	1	2	3	4	5
Appropriate mathematics was used to create the model.	1	2	3	4	5
A final solution was clearly presented.	1	2	3	4	5
The mathematical model produced a plausible result.	1	2	3	4	5
Visual aids were easy to read and understand.	1	2	3	4	5
The team addressed authentic alternative scenarios and/or the need for future work.	1	2	3	4	5
I enjoyed the presentation; the presenter(s) held my attention for the full extent of the talk.	1	2	3	4	5
I would like to learn more about this team's solution method.	1	2	3	4	5

What is one question you would like to ask this team?

Additional questions or comments:

Modeling Principles

1. *Modeling (like real life) is open-ended and messy.*
2. *When students are modeling, they must be making genuine choices.*
3. *Assessment should focus on the process, not the product.*
4. *Modeling does not happen in isolation.*
5. *Start big, start small, just start.*



Guidelines for Assessment and Instruction In Mathematical Modeling Education

Laura Pahler

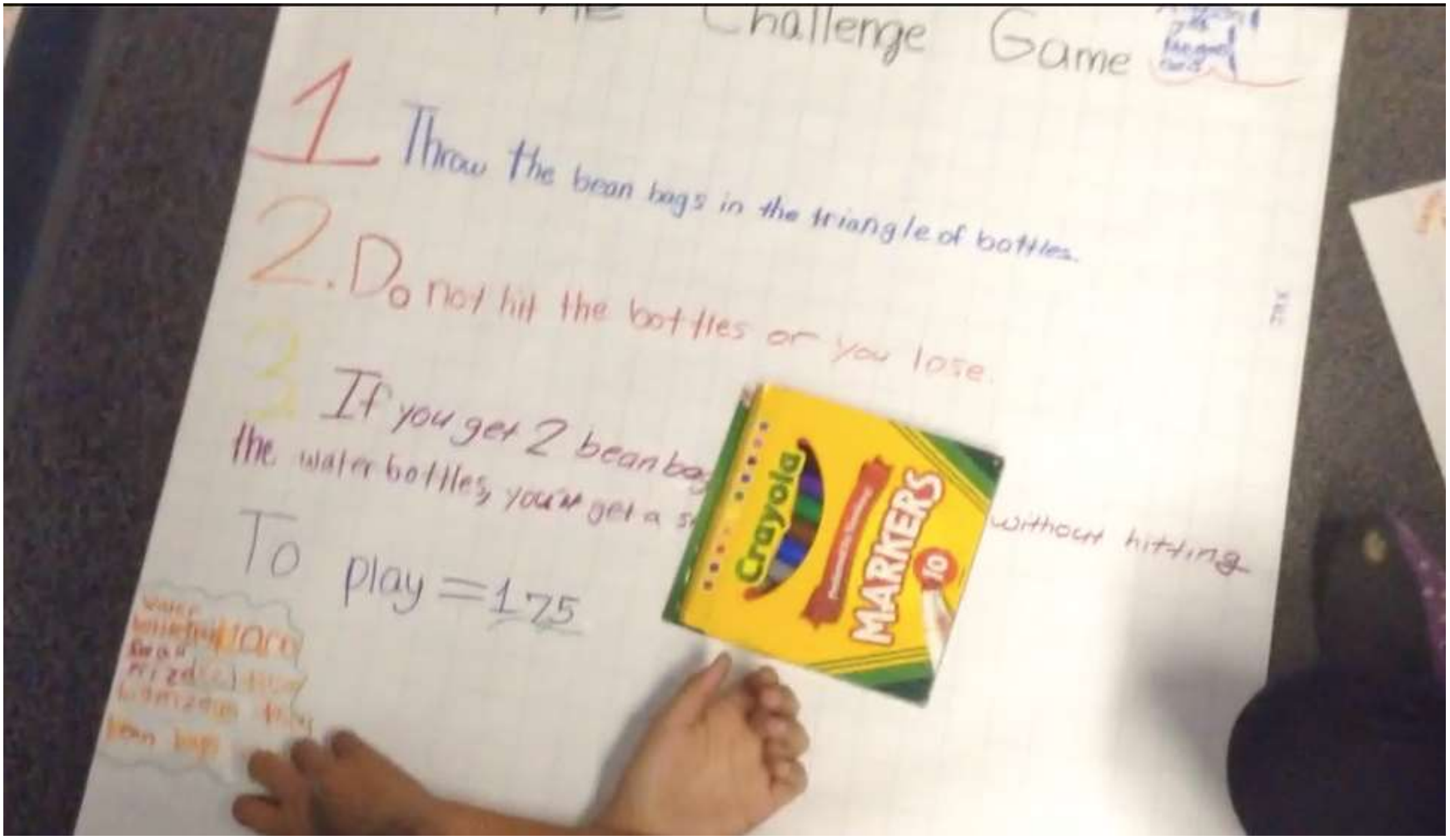
7th and 8th Grade Math Teacher
Cortez K-8 Math and Science Magnet School
Pomona Unified School District, CA

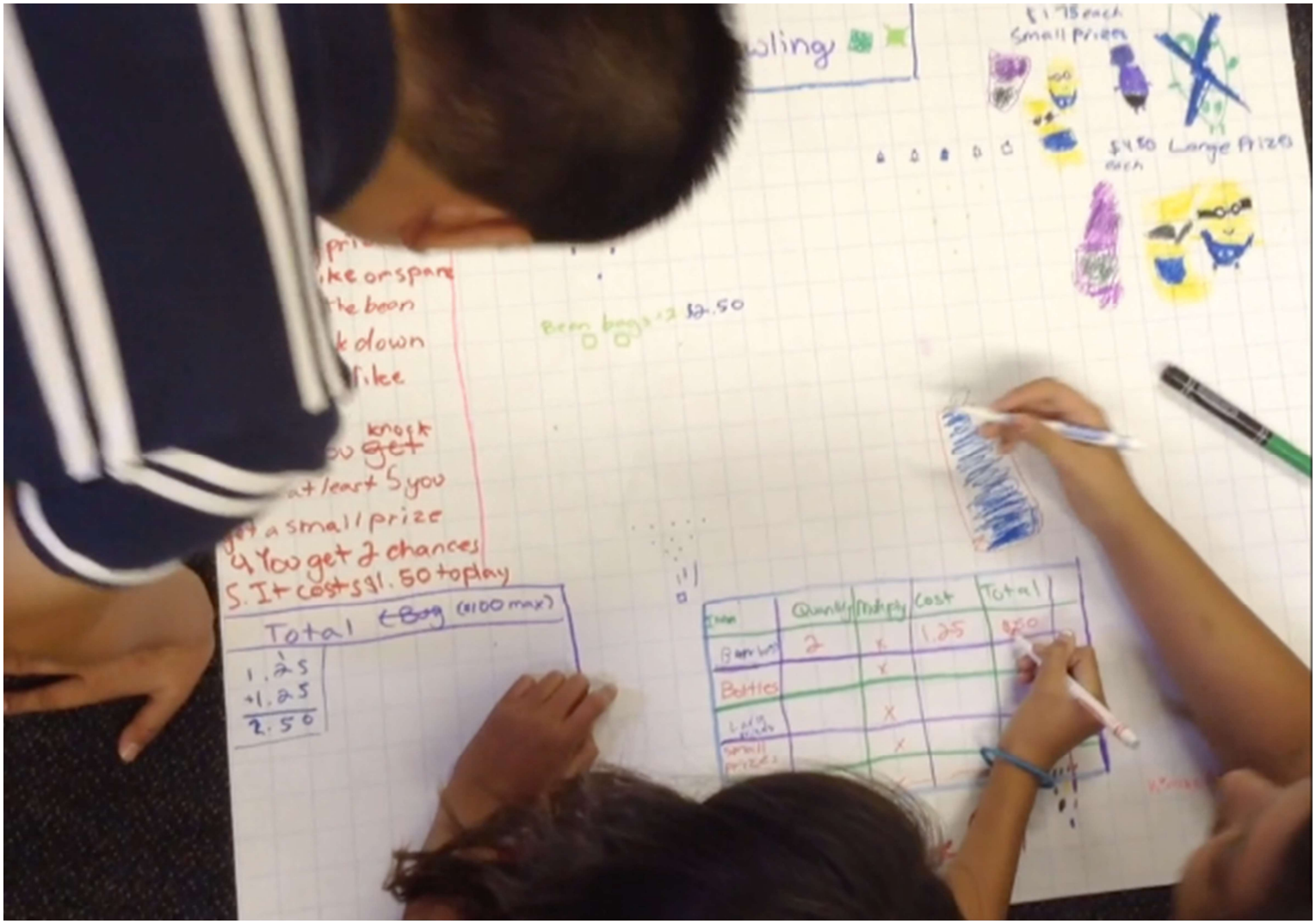
Lead teacher for the IMMERSION program (K-8)

Email: laura.pahler@pusd.org

GAIMME@siam.org

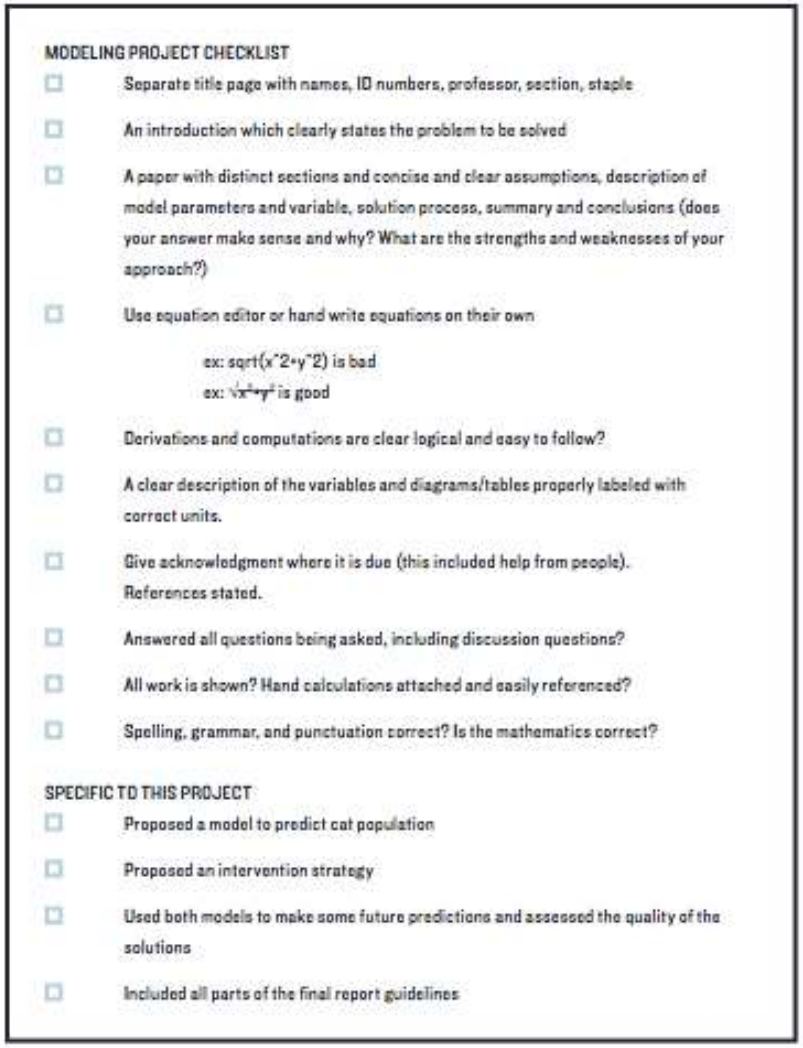
http://www.comap.com/Free/GAIMME/index.html
http://www.siam.org/reports/gaimme.php


Challenge Game
1. Throw the bean bags in the triangle of bottles.
2. Do not hit the bottles or you lose.
3. If you get 2 bean bag
the water bottles, you'll get a
without hitting
To play = 1.75
Crayola
MARKERS
10


Small Prizes
Large Prizes
Bean bags
Total
1.25
+1.25
2.50
Quantity
Cost
Total
Bottles
1. You get 2 chances
2. It costs $1.50 to play
3. You get
4. at least 5 you
5. get a small prize

Project checklist 2

Many item checklist
Based on “feral cat” problem



MODELING PROJECT CHECKLIST

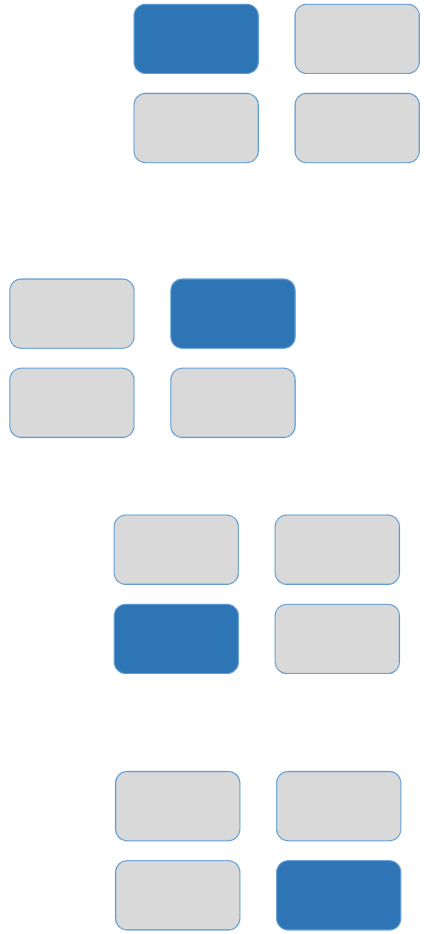
- ☐ Separate title page with names, ID numbers, professor, section, staple
- ☐ An introduction which clearly states the problem to be solved
- ☐ A paper with distinct sections and concise and clear assumptions, description of model parameters and variable, solution process, summary and conclusions (does your answer make sense and why? What are the strengths and weaknesses of your approach?)
- ☐ Use equation editor or hand write equations on their own

  ex: sqrt(x^2+y^2) is bad
  ex: $\sqrt{x^2+y^2}$ is good

- ☐ Derivations and computations are clear logical and easy to follow?
- ☐ A clear description of the variables and diagrams/tables properly labeled with correct units.
- ☐ Give acknowledgment where it is due (this included help from people). References stated.
- ☐ Answered all questions being asked, including discussion questions?
- ☐ All work is shown? Hand calculations attached and easily referenced?
- ☐ Spelling, grammar, and punctuation correct? Is the mathematics correct?

SPECIFIC TO THIS PROJECT

- ☐ Proposed a model to predict cat population
- ☐ Proposed an intervention strategy
- ☐ Used both models to make some future predictions and assessed the quality of the solutions
- ☐ Included all parts of the final report guidelines



Popcorn model example 1

Cups of popcorn needed

= (# people) * (2 cups per person) + (1/3) * (# people) * (2 cups per person)

= (1 + 1/3) * (# of people) * (2 cups per person)

= (4/3) * (# of people) * (2 cups per person)

Popcorn model example 2

Cups of popcorn needed

= (# people) * (2 cups per person) + 15 cups extra

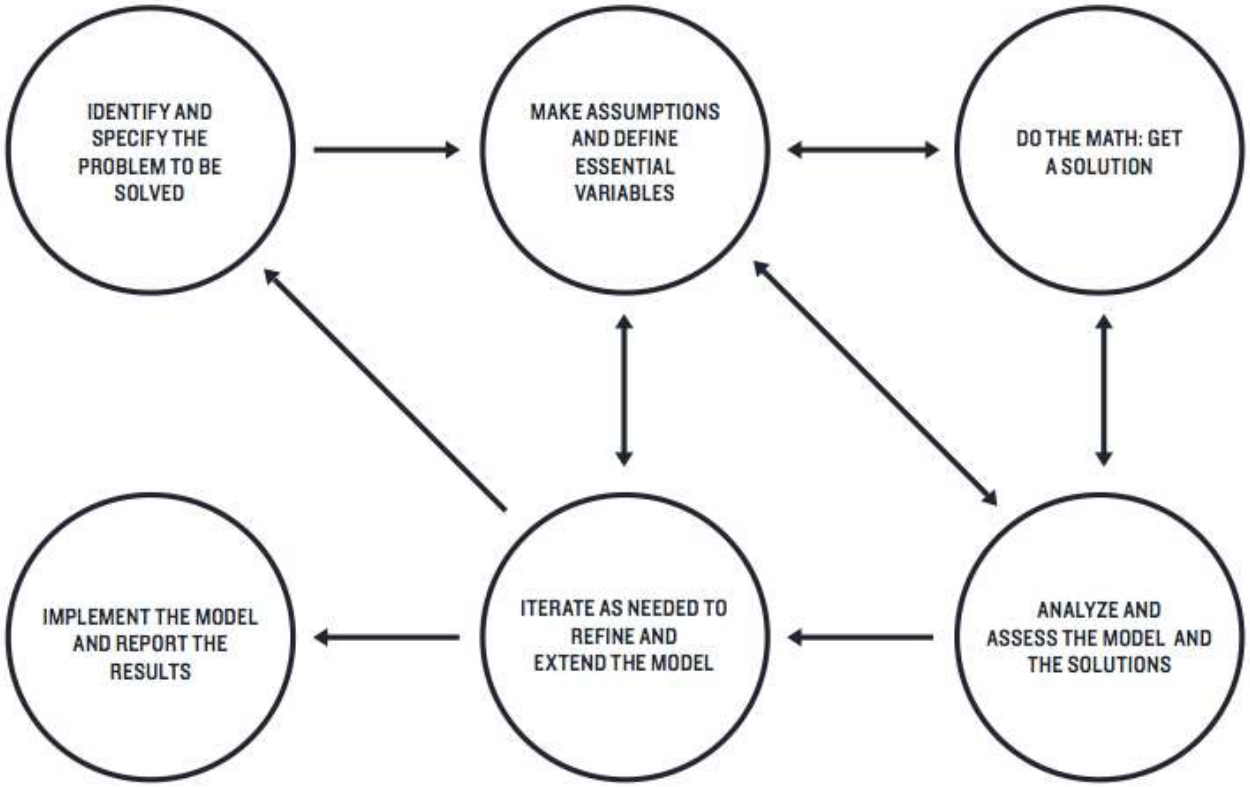
Popcorn model example 3

Cups of popcorn needed

= (# adults) * (2 cups per adult) + (# kids) * (1 cup per kid)

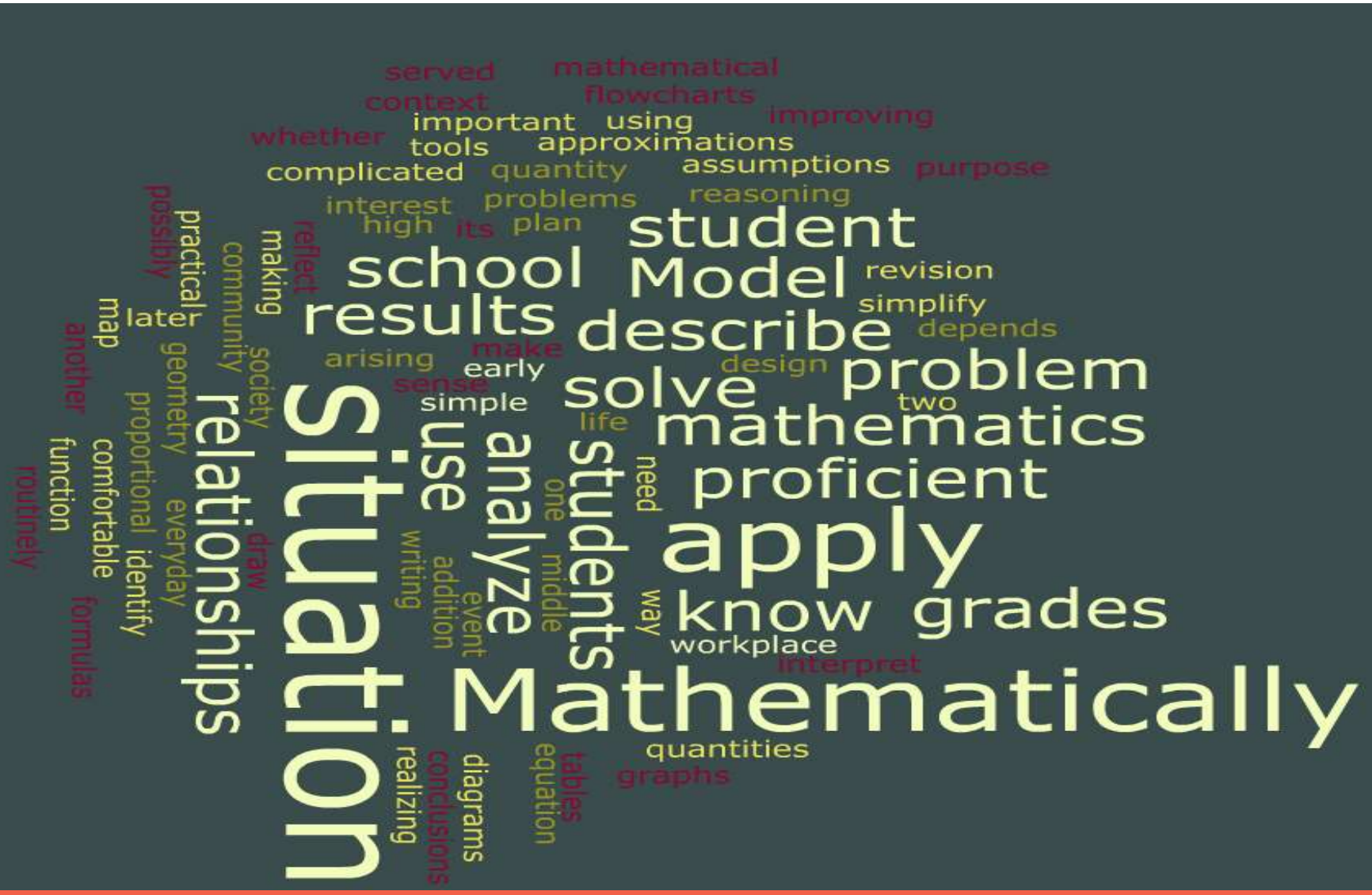
Other ideas PK - 8?

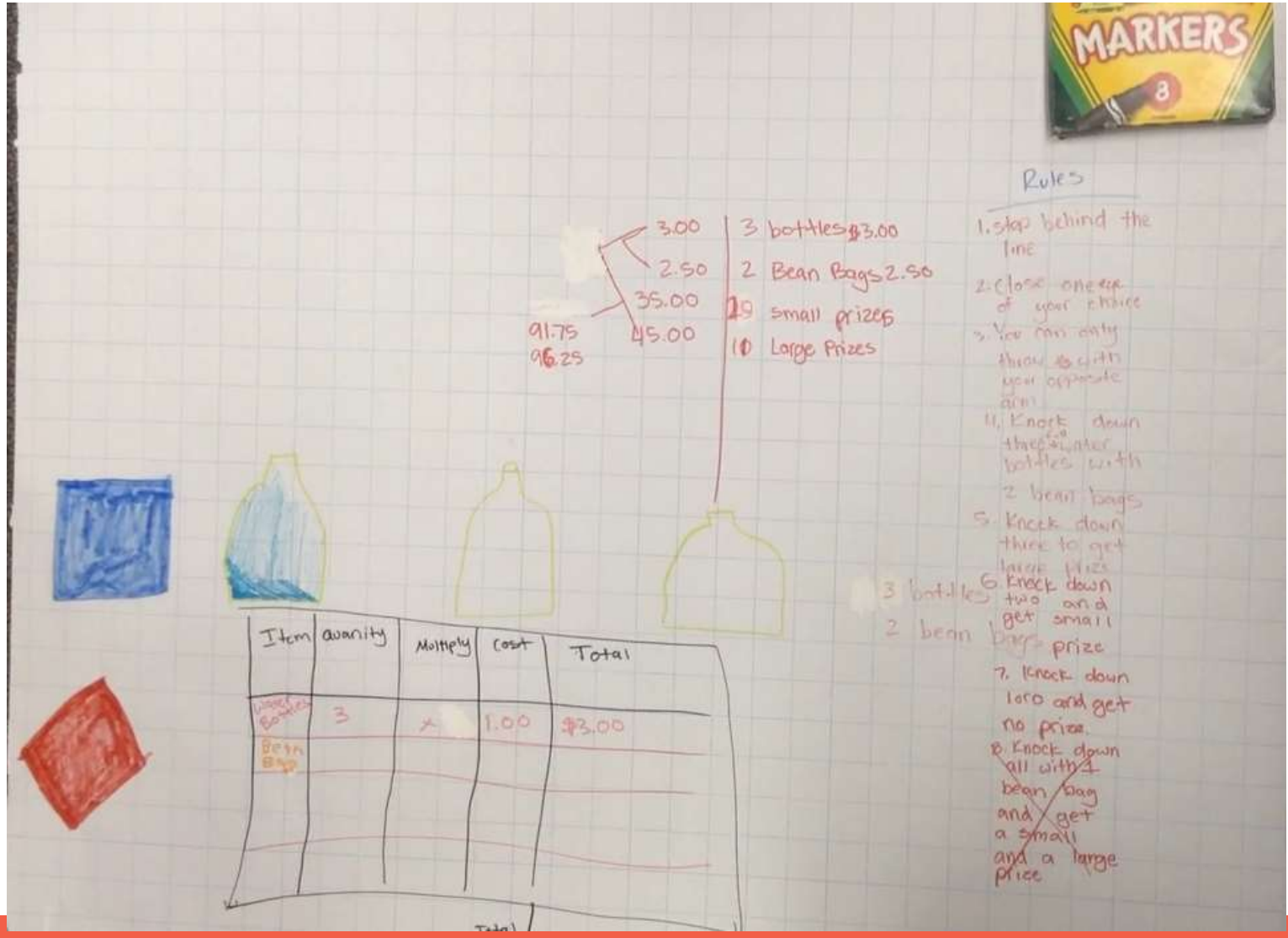
Math modeling process – see report

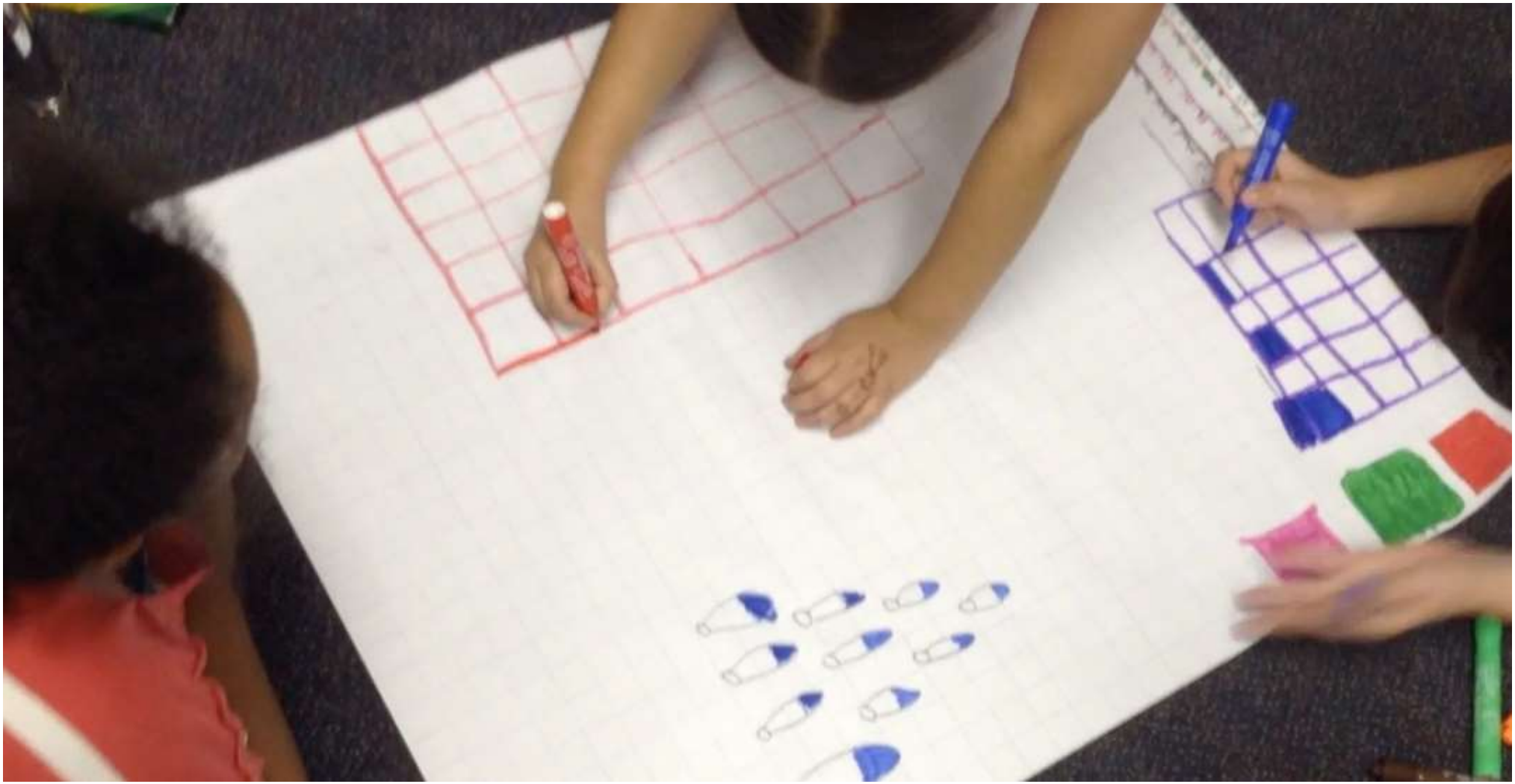


Grades PK-2

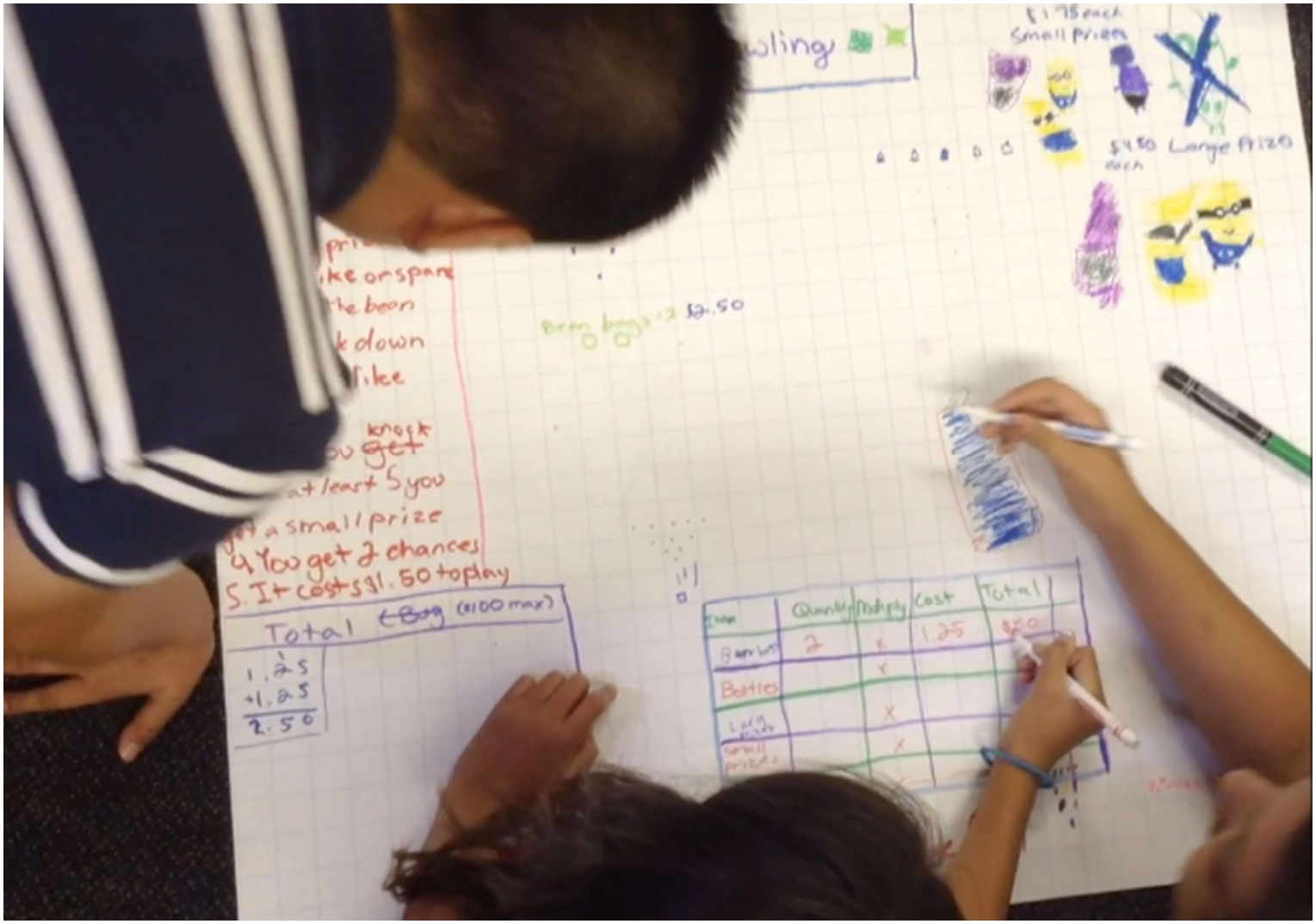
- Take one portion, count how many pieces you took
- Compare to others
  - Pairs: Who has more/fewer?
  - Pairs: How many more pieces does one person have than the other?
  - Whole class: Who has the most? Least?
- Histogram of portion sizes
- Should we assume portion size is the biggest one?
- What if we make too much? Too little?


Mathematically
situation.
apply
proficient
mathematics
problem
solve
describe
Model
student
school
results
relationships
use
analyze
students
know
grades
workplace
quantities
graphs
tables
diagrams
equation
conclusions
realizing
interpret
way
middle
addition
event
writing
one
need
two
life
simple
sense
arising
early
make
design
depends
simplify
revision
reasoning
problems
interest
high
its
plan
purpose
assumptions
quantity
complicated
approximations
tools
whether
important
using
improving
flowcharts
context
served
mathematical
reflect
making
community
society
practical
possibly
later
map
another
geometry
proportional
comfortable
everyday
identify
draw
function
formulas
routinely


MARKERS
8
Rules
1. Stay behind the line
2. Close one eye of your choice
3. You can only throw with your opposite arm
4. Knock down three water bottles with 2 bean bags
5. Knock down three to get large prize
6. Knock down two and get small prize
7. Knock down 1 or 0 and get no prize.
8. Knock down all with 1 bean bag and get a small and a large prize
3.00
2.50
35.00
45.00
91.75
96.25
3 bottles $3.00
2 Bean Bags 2.50
9 small prizes
10 Large Prizes
3 bottles
2 bean bags
Item
Quantity
Multiply
Cost
Total
3
1.00
$3.00



GAIMME


Small Prizes
Large Prizes
Bean bags
Total
1.25
+1.25
2.50
Quantity
Cost
Total
Bottles
1. You get 2 chances
2. It costs $1.50 to play
3. You get
4. at least 5 you
5. get a small prize

$$P_1 * g - P_2 * g \quad or \quad (P_1 - P_2) * g$$

Activity: How are these words related to each other?

BIT
BEG
BIG
BAT
BAG
FAT
BAT

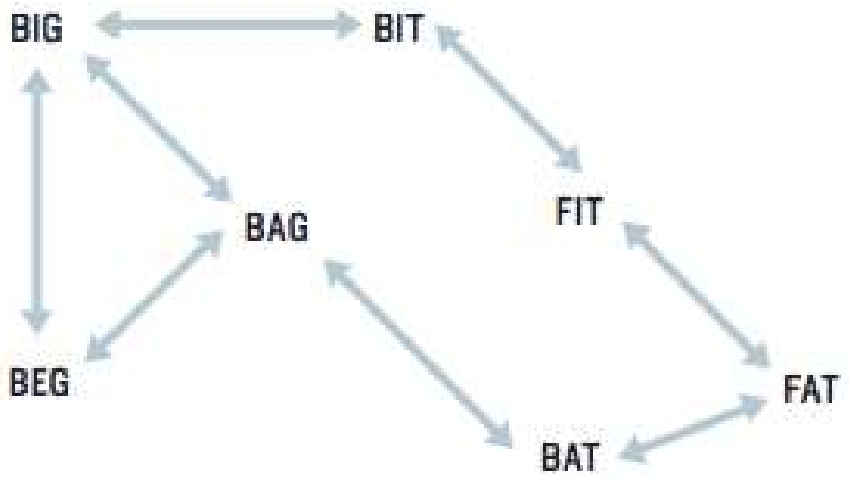


FIGURE 2.1: A NETWORK WITH A SELECTION OF THREE-LETTER WORDS AS NODES AND LINKS BETWEEN WORDS THAT DIFFER BY ONE LETTER

Mathematical Modeling is a superpower

Grades 3-5 – more independent, student-driven

- Histogram of portion sizes
- Should we assume portion size is the biggest one? Average one?
- For a given portion, plot number of people at party versus portions.
- How can we estimate how many people to expect at the party?
- What if we make too much? Too little?
- What size and how many containers will we need based on our portion sizes and total amounts?

PK-2: typical approaches

- Best way to do something
- Simple visualization of data or trends
- Voting and ranking
- Comparisons or ordering