



Introducing analytics to adolescents

Are you smart enough to teach O.R. to a third-grader? How business analytics can reframe simple K-8 math problems.



By Kenneth Chelst

In my previous *OR/MS Today* article, I wrote that Common Core Standards in mathematics that are being adopted widely have critical elements that are fully aligned with the field of operations research [1]. The standards include two distinct elements. One relates to specific technical skills. The second element is called Standards for Mathematical Practice and would fit well in any operations research, management science or business analytics textbook. The standards require students to:

- make sense of problems and persevere in solving them,
- reason abstractly and quantitatively,
- construct viable arguments and critique the reasoning of others,
- model with mathematics,
- use appropriate tools strategically,
- attend to precision,
- look for and make use of structure, and
- look for and express regularity in repeated reasoning.

For the past decade, my team has worked on developing and disseminating a high school math curriculum entitled, “When will we ever use this?” (Volume I: Algebraic Modeling and Volume II: Probabilistic Decision Modeling). Originally funded by NSF under the title “Project MINDSET,” we have since completed the NSF project and broadened and rebranded it as “Applied Mathematics Practices for the 21st Century” (AMP21). This was done to more explicitly align with the above Common Core standards. Everything we have developed addresses most of these standards.

This summer we offered three-day workshops in the Los Angeles area hosted by the University of Southern California and in the Chicago area hosted by Northwestern University. More than 200 teachers applied to take the workshops. However, the programs were limited to 35 to 40 teachers each.

This high school effort was my passion; I had no grandiose dreams of moving beyond an elective mathematics course in operations research designed for juniors or seniors in high school. However, in order to ensure that aspiring athletes could take the course, one high school teacher went so far as to file paperwork and receive approval from the NCAA so that the course could count toward advanced mathematics.

New Middle School Initiative

Three years ago, two of my colleagues in mathematics education at Wayne State were each on the cusp of obtaining substantial grants in different aspects of middle school mathematics teacher training. One, an NSF grant (Project MEDdeATe: Jennifer Lewis, PI), required a mathematician. I was asked to fill that role. The other, designed around engineering (Project ImPRINT – Improving Proportional Reasoning Instruction through eEngineering Tasks: S. Asli Ozgun-Koca, PI), was natural for me to participate. Thus began my education in middle school mathematics.

One set of core middle school mathematics skills involves rates, ratios, percentages and proportionality. We began a series of weekly discussions only to find out that my math education colleagues and I did not necessarily use the terms the same way. In addition, it was not clear from textbooks which concept was most appropriate in different contexts. Textbook questions, asked students willy-nilly to calculate rates, percentages, ratios and proportions in diverse word problems. We eventually coalesced around a series of definitions with examples and published our first middle school math paper entitled, “Rethinking ratios, rates and percentages” [2]. This was followed by an applied example that was classroom tested: “Exercise Away the Big Mac: Ratios, Rates and Proportions in Context” [3].



Teaching K-5 teachers how to teach O.R. was a new experience for the author.

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From these experiences, I put on my business analytics cap and began to develop a simple series of questions to be asked about every word problem in their textbooks.

1. Why should anyone care about the problem context and the answer?
2. Is there a decision to be made?
3. Would simple counting answer the question?
4. Does the question only ask about what is? Are there opportunities to explore what can be or should be?
5. Can multiple similar examples be created that are different enough to maintain student interest?
6. Is there something to discuss in the problem context that goes beyond the basic mathematics?
7. Can students embed themselves in the problem context and produce different answers?

Brenda Dietrich, vice president in the IBM Research Divisions and a former president of INFORMS, highlighted the core problem: much of math education is descriptive mathematics. Students are asked to describe what is. One common example of a ratio word problem can illustrate this point.

The ratio of boys to girls in the class is 3:2. There are 30 students in the class. How many boys are there? How many girls are there?

As the problem is stated, it fails all of the above questions. The problem asks students to calculate what is and offers no reason to care about the finding. This problem fails one additional test: Did the person who created the problem have to know the answer in order to create the problem situation?

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Whoever asked the question had to know there were 18 boys and 12 girls in order to claim that the ratio is 3:2. The same would be true for an even dumber question found in textbooks. *There are 10 more boys than girls in the class of 30. Write a pair of equations to determine the number of boys and girls in the class.*

Whoever asked the question had to know there were 20 boys and 10 girls in order to claim that there were 10 more boys. Do we really want students to see simultaneous equations as an alternative to counting or partial memory loss?

Relevant Context

In the world of business analytics there are limitless possibilities for using the knowledge of the ratio of boys to girls is 3:2. The ratio may have been determined by a survey in any number of contexts. The decisions could involve allocating shelf space in a store or allocating budgets to targeted marketing programs. We developed a relevant context around a school sports outing.

Sixty students are planning a sports outing. There are 40 boys and 20 girls in the group. They were considering three different sports activities for everyone. They wanted to keep the ratio of boys to girls the same on each team.

1. If they play full-court basketball, how many boys and girls should be on each team?
2. If they play volleyball with the standard six person teams, how many boys and girls should be on each team?
3. If they play softball, how many boys and girls should be on each team?

Question 1 is trivial, but Question 2 does not have an exact answer. It is not possible to keep the 3:2 ratio. This does not mean mathematics is useless because there is no exact answer, a radical idea in K-12 math education. Students would be encouraged to think about keeping each team's ratio close to 3:2 and

using other criterion to make the teams balanced. One bright child might suggest going with teams of five for volleyball instead of six. Question 3 poses two challenges. First, it is not possible to keep the exact ratio. Second, nine does not go evenly into 60. Again, the students could use math creatively to come up with suggestions for forming teams.

One indicator that a math problem is relevant to students is that there is something to discuss beyond the mathematical calculations. This team formation context offers the teacher an obvious opening for discussion. Is it important to keep the gender ratio constant when forming sports teams? What other criterion could be used? Would it vary by sport?

The "Exercise Away the Big Mac" example similarly addresses all of the above questions. Students use the Big Mac website to explore changes to the sandwich and determine whether or not the changes would enable the sandwich to meet specific nutritional guidelines that are expressed as percentages. They are then directed to a website that estimates the number of calories burned for different exercises. The goal is to burn off the Big Mac calories. Each student must input his or her own weight, as the calorie burn rate is dependent on this piece of information. Each student can select his or her own preferred exercise or activity.

As in the previous example, the contexts can lead to discussions about nutrition and exercise. In addition, teachers can create similar problems with other fast food websites that are very different, such as a series of questions around a Subway sandwich. Too often math texts have dozens of end-of-the-chapter problems that look all the same except for a word here or there and the specific numbers.

Multiplication in Minnesota

Then I received a call from Susan Wygant, a mathematics specialist with the Minnesota Department of Education. She has been a supporter of our efforts ever since attending one of our one-day high school O.R. programs at the INFORMS Annual Meeting in Minneapolis in 2013. In 2014, she hosted our three-day workshop. This year she asked our team to create a one-day program for more than 60 specially motivated K-12 math teachers. Half of the program was for all attendees, and the other part of the day separated the teachers into three grade groups: K-5, 6-8 and 9-12. I drew the smallest straw and ended up with the K-5 group.

I went to the Engage NY math website [4] that has a complete mathematics curriculum along with large a set of problem contexts for each topic. I focused on third grade, looking for something I could turn around with analytics. Here is what I found and did.

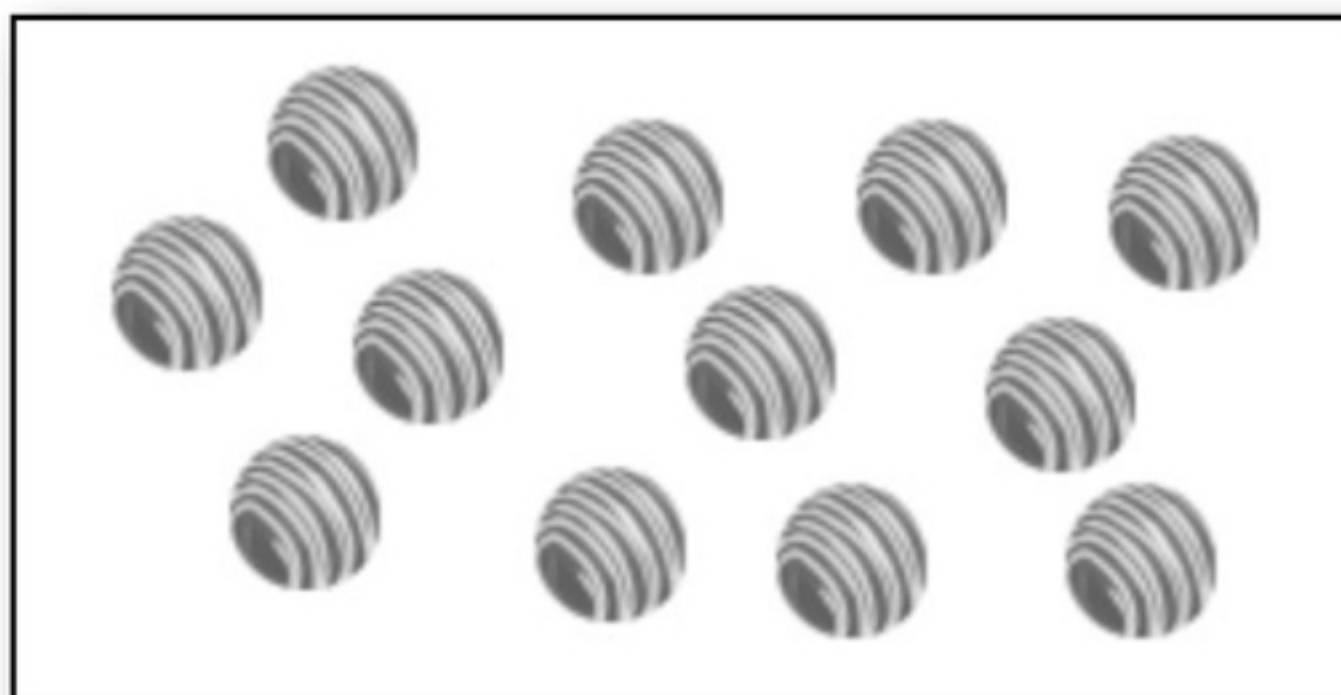


Figure 1: How to share a box of chocolates.

REFERENCES

Caroline, Brian and Marta share a box of chocolates. They each get the same amount. Circle the chocolates in Figure 1 to show three groups of four chocolates. Then write a repeated addition and multiplication sentence to represent the picture.

In reframing this example, I wanted to inject analytics by:

1. making it a decision,
2. providing a motivation for using the picture,
3. creating an example in which the numbers do not work out perfectly, and
4. providing something to discuss.

Thus, the revised problem became:

1. Caroline, Brian and Marta want to share equally a box of 12 chocolates. How many should each one receive? Double check your answer. Circle a set of chocolates each child will receive.
2. Their friend Jamal came by. They decided to share the box with him as well. How many would each child now have? Color the pieces of candy that would be given to Jamal. How many chocolates will Caroline, Brian and Marta each give to Jamal?
3. Darlene came by and joined the group. They decided to share the box with her as well. What problem do they now have in dividing the chocolates equally? Why do they have a problem? What would you suggest they do? Explain your decision.

The teachers enjoyed the example because the first two questions would build the confidence of the students and teach different factors of 12. Question 3 teaches that 5 is not a factor of 12, but you still need to use math to divide up the chocolate. The students can also discuss what would be a "fair" division in the final case. The teachers were also encouraged to ask the following questions.

4. Why would you not use fractions to answer question 3?
5. What if the candy was in the form of 12 large Hershey candy bars? What could you do then?

Challenge to Business Analytics Community

I am challenging any member of INFORMS who has a child, grandchild, niece, nephew, guardian, neighbor kid, etc. studying math in K-12. Get your hands on the child's math textbook but commit no crimes in the process. Then pick up the same grade's science textbook or history textbook or English literature book. Compare the level of sophisticated contexts in these diverse educational materials.

1. Chelst, K. and Edwards, T. G., 2012, "Innovative Education: Early O.R. Education: "Operations Research is aligned with the Common Core Revolution in K-12 Mathematics Education," *OR/MS Today*, Vol. 39, No. 4.
2. Chelst, K. R., Özgün-Koca, S. A., and Edwards, T.G., 2014, "Rethinking ratios, rates and percentages," *Mathematics Teaching (GB)*, Issue 240, 26-2.
3. Özgün-Koca, S., Edwards, T. G., and Chelst, K. R., 2013, "Exercise Away the Big Mac: Ratios, Rates, and Proportions in Context," *Mathematics Teaching in the Middle School*, Vol. 19, No. 3, pp. 184-188.
4. <https://www.engageny.org>

It is embarrassing to see that the vast majority of mathematics problems would fit well in an early 20th century math textbook with minor modification to include travel time problems involving airplanes. Next, pick out a few of the word problems and apply the principles presented here to create a business analytics question. Send your concrete examples to me kchelst@wayne.edu. I will be pleased to share your examples with math teachers by posting them on our AMP21 website. **ORMS**

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