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Grow Beasts and the New Washington State Standards in K-8 Mathematics -

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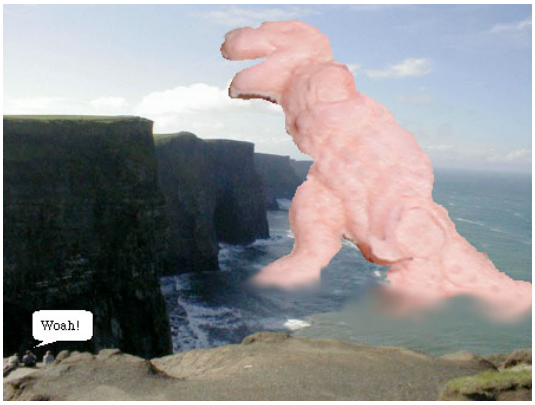

Introduction

Late in 2006 the National Council of Teachers of Mathematics (NCTM) published the *Curriculum Focal Points* (NCTM, 2006). This document sought to define the most important learning targets in K-8 mathematics. Perhaps the two most important features of this influential document and those that distinguish it from the NCTM's "*Principles and Standards for School Mathematics," (2000)* are its sharp focus on a small number of concepts and procedures at each grade level and its attention to the balance between the development of conceptual understanding and procedural fluency.

We are fortunate here in Washington State to have had a dedicated group of experts representing a broad range of interests working to produce a new set of K-8 standards that follow the example set by the NCTM Focal Points. With the recent arrival of these standards teachers have a clear set of guidelines with regard to what is most important in mathematics education. At each grade level there are now three or four "Core Content" areas and a few elements of "Additional Key Content." At all grade levels attention is to be given to the "Core Processes" of reasoning, problem solving, and communication. This represents a radical sharpening of the curricular focus. Teachers can breathe a sigh of relief as they say goodbye to the past when curriculum was often characterized as "a mile wide and an inch deep." They can now afford, indeed they are called, to pay more attention to the development of conceptual understanding that will be the foundation of procedural fluency. What is needed now are ways to get students invested in the content and processes that have been specified. The Grow Beast investigation provides an example focused on the concept of slope, the process of mathematical reasoning and the use of inquiry and data at the middle school level.

Introducing the Grow Beast investigation At the center of this investigation is the Grow Beast, a small, inexpensive toy that absorbs water and thus "grows" over the course of two to four days when placed in water and then gradually shrinks to more or less its original size when removed from the water. The Grow Beast comes in various forms and sizes, such as a dinosaur, a bug, or a sea creature. The fact that it absorbs liquid slowly and "grows" enables students to make repeated measurements. At the outset students wonder how big the Grow Beast will grow. Their interest in the question leads them to take measurements, compile data, plot points and crunch the numbers in order to develop linear projections. Students may see, for example, that over three hours the Grow Beast goes from 4.5 to 5.1 centimeters in length. They subtract the two measurements, divide by three, and conclude that the beast is growing at the rate of .2 cm per hour. This leads to the reasonable assumption that in forty-eight hours it will be 9.6 cm longer – a total of 14.7 cm (nearly 6 inches) long!

Students continue to take measurements, plot new points and eventually discover that this rate of growth is not sustained. This leads them to make new projections, perhaps tempering their enthusiasm with more reasonable assumptions about the shape of the growth curve. Each time they make a new forecast of the creature's eventual stature, subtracting subsequent measurements, plotting points on a growth chart, deriving a rate of growth and projecting forward in time, they are developing their conceptual understanding of the notions of slope and linear rates of change. This builds a firm foundation for the development of the procedural fluency that will be necessary in algebra.

Overview of Washington State's 7th grade standards Reflecting the broad structure of the Focal Points, the Washington State K-8 Mathematics Standards feature proportional reasoning and the beginnings of algebra in the middle school years. Specifically, in the seventh grade the core content areas are: (7.1) Rational numbers and linear equations, (7.2) Proportionality and similarity, (7.3) Surface area and volume, and (7.4) Probability and data. Additional Key Content areas are (7.5) graphing skills, plotting points, and prime factorizations. As in all grades the Core Processes are (7.6) Reasoning, problem solving, and communication. The Grow Beast investigation presents a useful opportunity for students to address several of these targets.

The Investigation

Introduction The Grow Beast investigation will be presented following the curriculum design principles proposed by Grant Wiggins and Jay McTighe in their influential book, "Understanding by Design" (2005). In this scheme learning targets come first; teachers must be able to state clearly what it is that students should know, understand, be able to do, etc. Next, teachers must be able to say what it would look like if students reached these goals (This is the *evidence*.) *and* they must know how they are going to give students a reasonable chance to demonstrate their achievement (This is the *assessment*.). Having clearly defined the learning targets, the evidence of achievement, and the mechanism of assessment, it is time to design the instructional activity that will help students reach the desired destination.

Learning Targets In this case the Washington State K-8 learning targets to be addressed are associated with the 7th grade Core Content areas (7.2) Proportionality and Similarity, (7.5) graphing skills and plotting points, and Core Processes, (7.6) Reasoning, problem solving and communication. Specifically targeted are the student's abilities to:

(7.2.F) "Determine the slope of a line corresponding to the graph of a proportional relationship and relate slope to similar triangles,"

(7.2.G) "Determine the unit rate in a proportional relationship and relate it to the slope of the associated line,"

(7.5.A) "Graph ordered pairs of rational numbers and determine the coordinates of a given point in the coordinate plane," and

(7.6.H) "Make and test conjectures based on data collected from explorations and experimentation."

(It should be noted that the relationships encountered in the Grow Beast investigation do not meet the definition of a proportional relationship as presented in the standards document ["…linear relationships whose graphs pass through the origin and can be written in the form y = kx"]. Nevertheless, the required reasoning and skills are extensions of those needed to deal with strictly proportional relationships.)

Evidence Students demonstrate success with respect to learning target 7.5.A when they are able to plot data points (e.g., Grow Beast length vs. elapsed time) correctly and interpret the meaning of the data points plotted by others. Success with regard to targets 7.2.F and 7.2.G will be indicated by the student's ability to go back and forth between the rate of change in their Grow Beast's measured variable (e.g., length) and the slope of the line connecting the data points. Students should be able to start with either one of these and calculate the other. Finally, students who are successful with regard to target 7.6.H will be able to do two things. First, they will be able to make a quantitatively specific conjecture regarding the rate and eventual extent of the growth of their Grow Beast. Second, they will be able to collect, organize, and analyze data that can be used to address their conjectures.

Assessment Assessment data may be gathered in an informal, formative sense, perhaps with a checklist focused on the evidence and employed in observations of small groups, or in conjunction with interviews with scripted questions addressed to individuals or teams. Summative assessment might take the form of a simulated episode of Grow Beast growth in which students are asked to plot specific points, interpret the meaning of plotted points and sets of points, determine slope and use slope to forecast growth. They might also be required to define and defend their reasoning in these processes. Another possibility would be to situate and assess these same skills in another context (e.g., the accumulation of money in a checking account with variable rates of deposit and withdrawal) in order to check for transfer of understanding.

Instructional Activity - Getting ready The activity begins with an introduction to the Grow Beast and to the central question: "*How big will our Grow Beast grow in three days?*" The teacher must decide whether there will be one beast for the whole class or whether small groups will each be given their own beast. There are advantages either way; with one Grow Beast everyone is dealing with the same data and the process of data analysis is simplified. With multiple Grow Beasts in small groups there is likely to be greater commitment to the process as students inevitably root for their beast to be the biggest. In addition there will be multiple sets of data enabling the use of simple descriptive statistics to compare and contrast one beast with another. In any case the teacher gives a rough outline of the growth process, emphasizing the fact that no one knows how large the Grow Beasts will grow. The teacher can prompt students' thinking about growth with a quick look at a stature vs. age chart (available on the Web at http://www.cdc.gov/growthcharts) perhaps familiar to some students through their experiences at the pediatrician's office. It is, of course, possible to measure other variables such as mass or width but length works well. A little bit of negotiation with the students as to the exact procedure for tracking the beast's growth – who will measure, how often and

how will the measurements be recorded - will generate more student investment in the process.

Not everything should be nailed down at this time. For example, while the teacher could provide the students with a worksheet that specifies the steps to compute a forecast of eventual growth, ("Subtract the measurements of length at time B from those at time A. Divide by the number of hours between times A and B. Multiply the quotient by the number of hours in your forecast. Write the result on the line provided. Don't forget units!") this is probably not helpful if the long term targets include the development of number sense and conceptual understanding. The investigation provides an opportunity for students to encounter rates of change reflected in a graph of their data points, to discover the utility of comparing rise and run and thus to discover the meaning of slope.

Plop Once the general procedures for collecting data have been established and the initial measurement has been made it is time for everyone to make and record their initial prediction for the size of the Grow Beast after 72 hours. The Grow Beast is then plopped into the water. Growth is relatively rapid at first; discernable change appears within an hour. If the metric system of measurement is used computation is simplified and fractions are avoided. (If your learning targets emphasize computing with fractions then by all means, use our customary system!) A typical Grow Beast in the shape of a dinosaur may have an initial length of 4.5 cm and will grow within the first hour to perhaps 4.7 cm. Following the example provided by the pediatrician's growth charts, growth should be plotted with time on the horizontal axis and length on the vertical axis. Plotting these first two points and extending the growth linearly leads students to forecast a 72-hour total of 4.5 cm + (72 hours x .2 cm per hour) = 18.9 cm. This is more than quadruple the original length!

The first day's growth will follow a similar trajectory but variations in the growth rate will appear. These variations provide students with a reason to use mathematics to get more realistic estimates of the eventual size of the beast. They will see over time that the rate of growth, represented in the slope of the line that emerges in their growth chart, slows down and begins to level off. Students should continue to revise their projections of the 72-hour total using these new data and the teacher should provide focused opportunities for discussion regarding the methods used and the reasons why they work. If it is desired, competition to see who can come up with the most accurate prediction can be encouraged and facilitated.

Shrinkage After 72 hours the Grow Beast is generally getting close to its maximum size. It may continue to grow slowly for another day or so and if there is time this will allow students to see the graph reach a real plateau and the slope approach zero. When the Grow Beast is removed from the water evaporation commences and a new phase of the investigation begins. The teacher can tell the students that while the Grow Beast may never return to its exact original size and shape, it will come close. The question then becomes "How long?" As the shrinkage begins, new sets of measurements are compiled, the growth chart is extended and a negative slope is observed. At first the slope is shallow. Consequently students' estimates of the time needed for the beast to return to something

like its original dimensions may be long. Savvy students, though, will anticipate from the shape of the "uphill" portion of the curve that the rate of shrinkage will increase as time goes on. They may *not* anticipate the long "tail" that is often seen as the rate of evaporation slows down near the end of the process. Students should use their data to compute new estimates of the time needed to reach some agreed upon size. By this time their understanding of the growth process and the way it is represented by the plotted data points should be more sophisticated and their estimates should take into account more than just the last two data points.

Extending the activity For many teachers and many classes this will be enough. Some will want to go farther. Teachers (or students) may pose questions: "How might we change the conditions of growth so that the Grow Beast gets as large as possible? What if we kept the water cold, or warm? What if we used milk instead of water? Tap water is close to neutral on the pH scale; does the acidity of the liquid make a difference?" Students will generate no end of variations to the experiments that may be performed. The author has seen Grow Beasts grown in coffee, vinegar, salt water, seasoning salt water and the refrigerator, to name a few. One student devised a 6th grade science fair project starring no less than thirty Grow Beasts, growing ten each in water, root beer and lemonade. Students may work in small groups or as individuals to plan and implement new experiments in an effort to produce the largest Grow Beast, the greatest percent change, the most spectacular growth rate regardless of eventual size, and so forth. The connections to scientific inquiry are obvious.

Conclusion

The arrival of new standards in K-8 mathematics focusing on just a few content areas and processes each year gives teachers and students a chance to devote more attention to the conceptual development that will lead to procedural fluency. Investigations such as this have the potential to enable students to build a thorough conceptual grounding in the selected topics. This grounding enables students to make the connections between math and other areas of real life. Instead of functioning as a filter or a difficult rite of passage, mathematics can become what it should always be, a tool that can be used to make sense of the world.

References

National Council of Teacher of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (2006). *Curriculum focal points for prekindergarten through grade 8 mathematics: A quest for coherence*. Reston, VA: Author.

Wiggins, G., & McTighe, J. (2005). *Understanding by design*. (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Note: Grow Beasts may be ordered from a number of on-line distributors. Among them: Oriental Trading Company…. http://www.orientaltrading.com/