Curriculum Units by Fellows of the National Initiative
2018 Volume IV: Big Numbers, Small Numbers

What Makes a Superhero Super? Putting Scientific Notation in Context

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Introduction

Calculating numbers with a decimal point or a lot of zeros can be a daunting task for some of my students. Although many of them can compute three to five digit whole numbers with ease, most have difficulties conceptualizing the magnitude of very large and very small values; this makes the connection between values written in scientific notation to the real world even more of a challenge. One student told me that when she sees a scientific notation expression, she thinks, "Oh no, there are three different kinds of math problems in one: decimals, multiplication, and exponents." Considering this, I am confident that my students will greatly benefit from a curricular unit that teaches them a more advanced way in which to think about whole numbers, and provide them with opportunities to practice writing very big and very small numbers in standard notation in the context of a superhero character they create. Even though the current math curriculum explicitly addresses computations in scientific notation, my students can become familiar with writing the form and engage in activities that strengthen their number sense. They can experience firsthand how very big and very small numbers exist in everyday life and use what they learn about scientific notation to enhance their writing skills. Understanding how to compare big and small numbers, and how and when to represent them is a foundational part of mathematical literacy.

Demographics

George Shirakawa Sr. School is one of twenty-one schools in the Franklin McKinley School District, a Title 1 district, located in the east side of San Jose, California. Our school is a (kindergarten to eight grade) campus with a rich multi-ethnic population of 800-900 that consists of Hispanic (46%), Asian (44%), Caucasian (5%), African American (2%) Filipino (2%), and mixed race (1%) students, and of these students, 40% are categorized as English Language Learners (ELL). About 77% of our students qualify for free or reduced lunch, and their families also qualify for free breakfast and monthly food distribution sponsored by the county. The surrounding neighborhood is comprised of lower-income families where English is not the native language nor is it spoken at home. Grandparents or other guardians are raising students, some students have gang affiliations and some families live in homeless encampments. Considering these obstacles, I always try to make mathematics lessons culturally relevant, and to maintain a positive learning environment that allows students to feel safe, comfortable, and excited about school.

In 2014, our district adopted the Common Core State Standards for mathematics and language arts. The transition to common core instruction has been difficult for those of my students that prefer a more teacher-led approach. When planning lessons, I often rewrite word problems to make them more culturally relatable to all my students, and I often include supplementary practice problems from online resources and other textbooks.

The lesson on scientific notation in the district-adopted textbook is one of the most challenging for my students. The lesson is divide into two sections:

1. Rewriting numbers and expressions involving measuring the length of skin cells and finding the distance between planets.
2. Performing operations with numbers and expressions involving exponents (i.e., scientific notation).

My students find these problems far too abstract, which makes problems with extremely large and small numbers seem unmanageable. This unit helps my students gain perspective through relatable and personalized examples so they can better understand each component of scientific notation: the product of the first term (the coefficient) that tells us about accuracy and the second term (a power of ten) that tells us about magnitude.

Content Objective

This cross-curricular unit combines foundational mathematical concepts with narrative writing to deepen my students' learning. It is designed to help solidify my eight-grade students' conceptual understanding of the base ten principles and scientific notation by locating multiples of powers of ten on a number line. For example, locating multiples of 100, and then multiples of 10 on a number line declared to have length 1000, or locating multiples of 100,000 and 10,000 of a number line declared to have length one million, etc. Students will also engage with narrative writing techniques, such as character description, reflection, and pacing to create and develop an entertaining narrative. The unit addresses key concepts that help students to know when and how to write numbers in standard notation (long form), practical uses for scientific notation, comparing quantities written in scientific notation, and how to write a coherent and effective narrative.

The unit meets several objectives for formative and summative student assessment including:

1. Describe the patterns in the placement of the decimal point when a number is multiplied by a power of 10.
2. Locate and compare very large and very small values on a number line.
3. Write and compare quantities in scientific notation.
4. Use narrative techniques to develop a character.

Unit Content

This unit is subdivided into three sections:

1. A Foundational Understanding Approach to Place Value and Base Ten.
2. How I Use a Number Line to Help My Students.
3. Writing Expressions Using Scientific Notation and Comparing Quantities Using Scientific Notation.

Place Value and Base Ten

One of the most important conceptual understandings my students need is knowing how the system of place value and the base ten works. My students begin to learn about these essential mathematical concepts in the primary grades, but afterwards, they are no longer mentioned in our curriculum. Place value is generally understood as the way in which to determine the value of a number by the position of its digits: for the number 2,794, the 2 is in the thousands place, the 7 is in the hundreds place, the 9 is in the tens place, and the 4 is in the ones place. Although this way of describing place value is conventional, this is only the beginning. Students were taught to see numbers as one whole number: 2,794 comes after 2,793 and before 2,795. This unit can positively impact my students' number sense by helping them to acquire a foundational understanding of the power of place value. This thought process begins by viewing the number 2,794 not as one number, but as representing a sum composed of special parts within the base ten place value system. Thus,

2,794 = 2,000 + 700 + 90 + 4

The parts, 2000, 700, 90 and 4, are called "place value pieces"[1] . We will also use this terminology in this unit. In article 2, the authors identify five sequential stages in interpreting a base ten number, and demonstrate a way of unpacking the numbers. The authors also describe a way to think about the number's actual composition. Each stage presents a more advanced representation of the relationship between each digit and the value it represents in base ten notation. As a visual of processing a number in standard form, consider the number 2,794 written in standard notation:

Stage 1. The number is represented in standard form. Each number represents a specific positional value.

2,794

Stage 2. The number is written in expanded form. Numbers are broken apart with each piece identified by its place value, and assigned to the appropriate place value notation making a unique base ten piece meaning there is only one 2,000 piece, only one 700 piece, and so on. Base ten pieces are arranged in decreasing order, and then added together, resulting in the original standard form number.

2,794 = 2,000 + 700 + 90 + 4

Stage 3. The next step expands the number a second time by the multiplicative structure of each place value piece, to show that each individual digit is multiplied by a specific base ten unit (i.e., 1, 10, 100, 1000, etc.).

$2 \times 1000 + 7 \times 100 + 9 \times 10 + 4 \times 1$

Stage 4. The next step expands the number a third time by expressing each base ten unit as a product of certain number of factors of ten. This prepares my students for the concept of ten to the power of a (whole) number.

$2 \times (10 \times 10 \times 10) + 7 \times (10 \times 10) + 9 \times 10 + 4 \times 1$

Stage 5. The final step uses exponential notation to put the expression in the form of a polynomial. This simplified way of representing powers of ten is a great steppingstone for writing in scientific notation, which comes later on in this unit, but is worth mentioning now. The stage five expression shows that whole numbers can be expressed as a sum of terms, each of which is a digit multiplied by a power of 10.

$2 \times 10^3 + 7 \times 10^2 + 9 \times 10^1 + 4 \times 10^0$

After practicing several problems using all five stages, I will assess student understanding by posting whole numbers written in standard form and asking them to write the five stages on their whiteboards. Students will have processing time to write their responses, which will then be used as part of a whole class discussion. Students will then be ready for more small group or individual practice with base ten and place value problems using manipulatives including base-ten blocks and a number line. Practice problems will also provide students the opportunity to brainstorm real-life situations and items that represent base ten to show place value. A number line with movable parts will be used as a visual to demonstrate how each place gets bigger or smaller using base ten and give students a more practical sense of what a million looks like. As an extension of this lesson, my students will learn how to interpret decimal fractions on a number line going from 0 to 1 and 0 to 10.

Teaching my students about the importance of each of these five stages will take more time than is usually allowed for this topic. Nevertheless, completely decomposing numbers written in standard form is necessary for them to grasp the power of the base ten place value structure. This may be the first opportunity students have to fully understand what each digit represents. This process will extend and refine the place value and base ten concept for them. It will build algebraic knowledge and prepare my students for future mathematical learning.

How Can Number Lines Help My Students?

A number line is a tool used to represent numbers and their relationship to each other, and can be instrumental in fostering numeracy and operational proficiency. A number line can be used as part of a strategy that helps us teach conceptual content in a concrete way. In this case a number line will be used to show how moving the decimal just one place affects a number’s size. It is important for students to be familiar with number lines prior to the eighth grade. In primary grades my students used number lines for counting, adding, and subtracting whole numbers. Number lines can be used to show positive integers increasing to the right, negative integers decreasing to the left, and showing the placement of fractions and decimals between whole numbers. Number lines are also helpful when learning how to interpret data on graphs. In the upper grades, number lines are typically used to display numerical data in plots, including dot plots, histograms, and box plots. Later on, number lines are used to teach scale, represent inequalities, make coordinate graphs, and help demystify irrational numbers when students are able to locate and graph them. Number lines play an important role in a variety of mathematical stages of learning, as they model a major way we naturally think about all numerical relationships and operations. In this unit, I use the number line to help students visualize place value and base ten.

My students have been overly reliant on symbolic procedures when comparing number size or numbers that contain decimals, which leads to self-doubt and misunderstandings. A common challenge for students when working with decimals is to know when and how to line up the decimals, add or subtract them, or count them. I want students to have some intuitive tool that will help them understand the number by looking at its important features first, rather than being concerned with the placement of decimals. In this case, I want them to visualize where each number belongs on the number line once the decimal is moved either to right. (The number get bigger or smaller? How much does it get bigger?) I notice that my students have several misconceptions about decimals that lead to erroneous thinking. One common misconception is the thought that a longer decimal is a bigger number than a shorter decimal. For instance, some students may think 2.4567 is bigger because it has five numbers, and 4.1 is smaller because it has two numbers. Another misconception, occurs when the decimal point is viewed as separating two distinct whole numbers. For example, 5.9 is seen as a 5 and a 9 instead of 5.9. I want my students to visualize on a number line to understand that 5.9 is 5, and 9 tenths more, between 5 and 6, but closer to 6. A number line is accessible to all students and offers them a way to intuitively know how to arrive at the correct answer. This unit uses the number line to help students develop place value and base ten proficiency by thinking in scale (finding where a certain a number lies on the number line).

I will begin discussing the number line by posting textbook problems and asking students to sketch the number lines in their notebooks. Figure 1 is an example of how I will have my students practice with the number line inside the classroom. Note that there are three number lines, one from 0 to 10, then one from 0 to 100, and a third from 0 to 1,000. I will begin by discussing the number lines, what the ten equal subintervals mean on each line, and what ten equal subdivisions of one of these intervals mean, on each line. I will then ask my students to study the first number line, and then the second one, and then asking guiding questions:

Can someone state where 7.68 lies on the first number line?

What do you notice about the numbers when you compare the two lines?

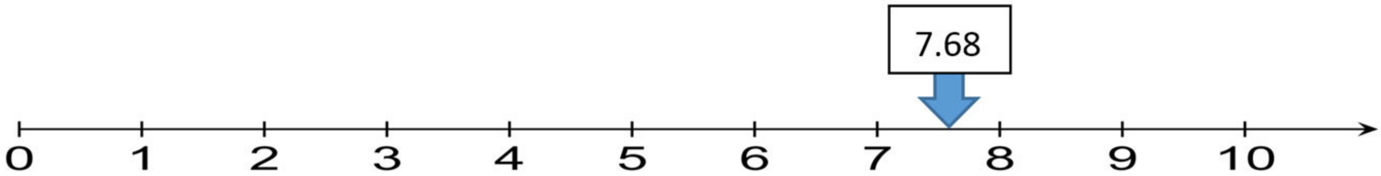
What do you notice about the intervals?

How do you say each number?

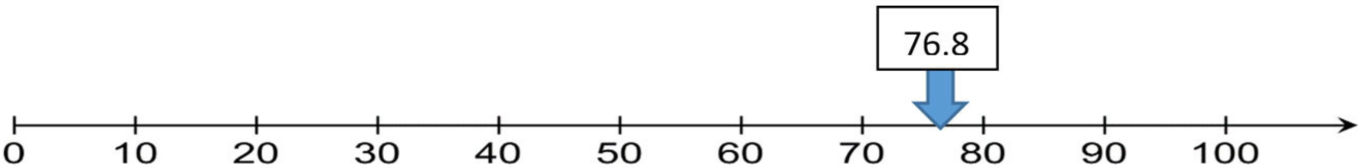
What would the next line look like?

As students move along the number line, they are able to share their thinking with their classmates. The number lines illustrate what is happening to the number when the decimal moves to the right (the number gets larger; precisely, ten times larger). Each number line begins at zero and is segmented by hatch marks evenly spaced apart, then ending at a specific point (i.e., 10, 100, and 1000). I use several differently spaced number lines (0 to 10, 0 to 100, and 0 to 1000) to illustrate the different sized numbers. The goal is for my students to see that a number changes in a big way when the decimal point is moved right: it gets multiplied by 10. For example, I ask my students to notice how multiplying by 10 moves the decimal point to the right, therefore increasing the original number as in Figure 1.

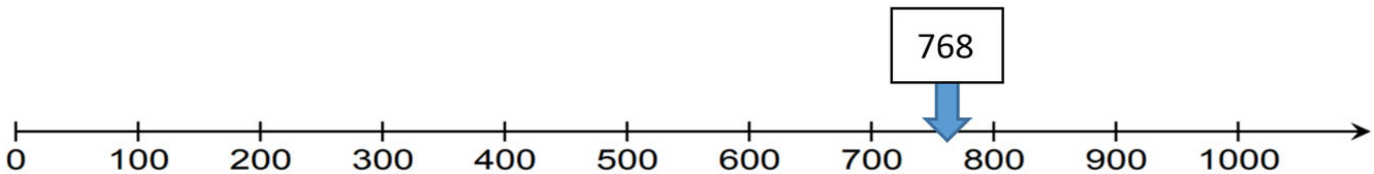
Figure 1.



$$7.68 \times 10 = 76.8$$



$$76.8 \times 10 = 768$$



I will design number lines to fit my students' needs. For example, students use number lines when working with scaling and proportional relationships. Teacher-generated number lines become a tool I use to assess specific skills as a whole class or individual basis. Asking my students to draw number lines provides a good way to assess students' comprehension as they demonstrate their thought processes. I include a "human number line," a hands-on activity, in the Classroom Activities section below as way to help my students visualize and understand the relative size of numbers and to reinforce what is practiced inside the classroom. In addition to writing numbers on the number line, my students also learn to locate and stand in the appropriate position on the number line to demonstrate how numbers get bigger or smaller.

How Can I Make Scientific Notation Relevant to My Students?

The guiding questions for the lesson on scientific notation may also serve as a review, or help introduce some students to the concept for the first time:

What is scientific notation and why do we use it?

What are the components of an expression written in scientific notation?

What do they tell you about the number?

Throughout this lesson, I will pose these guiding questions to students as a means of formative assessment to determine if students are ready to move forward with their learning or if there needs to be some re-teaching prior to moving forward.

Scientific notation is more than just a convenient way of expressing very large or very small numbers. Textbooks typically show this expression for representing scientific notation:

$a \times 10^n$

Numbers written in scientific notation reveal a great deal about a number: writing a number in scientific notation highlights its size and how accurately the value is represented. Numbers expressed in scientific notation are presented as a decimal fraction *a* with non-zero single-digit whole number part, multiplied by some power of 10. The digits in *a* to the right of the decimal point tell how accurately the number is known.

Numbers greater than 1 are considered large numbers, and are written with a positive power of ten (e.g., 10^3). Numbers less than 1 are considered small numbers and are written with a negative power of ten (e.g., $10^{-4)}$. The specific power of 10 indicates just how big or how small the number is. We will only work with positive powers in this unit. We deal with negative powers later in the year.

I want to make sure that my students understand the components of an expression written in scientific notation. Taking the number 2.3×10^2 as an example, the decimal term 2.3 is the called the *coefficienta*. The absolute value of *a* is restricted: it should be at least 1, but less than 10.

$1 \le |2.3| < 10$

The second term is a power of 10 (which is 10^2 in this example). I find it helpful to look at the exponential term first because it tells me just how big or small the number is. The exponent indicates how many times to multiply ten by itself. In this case, it tells me that the number will be in the hundreds, and less than 1,000.

The main purpose of the exponent is to tell us the order of magnitude, which is a big deal! The order of magnitude is a way of describing the size of quantities in terms of powers of base ten. For example, an American ant can lift its body thousands of time over, which means it can lift anywhere from 1 to 10 thousand, in units of its weight.

Explanation: 10^n = a product of *n* 10s.

$10^4 = 10 \times 10 \times 10 \times 10$ = 4 tens

$10^3 = 10 \times 10 \times 10$ = 3 tens

$10^2 = 10 \times 10$ = 2 tens

$10^1 = 10 \times 1$ = 1 ten

$10^0 = 1$

Although the thousands value is correct, we need more information to be precise. We need the coefficient to bring us even closer. For the expression 2.3×10^2 , I know that I should multiply 10 times 10, which is 100. The coefficient tells me how many hundreds I have, 2.3 times one hundred, which is 2 hundreds and 30. Here are some more examples:

$8 \times 10^0 = 8 \times 1 = 8$

$3 \times 10^1 = 3 \times 10 = 30$

$5.1 \times 10^2 = 5.1 \times 10 \times 10 = 5.1 \times 100 = 510$

$1.9 \times 10^3 = 1.9 \times 10 \times 10 \times 10 = 1.9 \times 1000 = 1{,}900$

$2.6 \times 10^4 = 2.6 \times 10 \times 10 \times 10\ 10 = 2.6 \times 10000 = 26{,}000$

My students should understand the reasoning in these examples, from our discussion, described above, that moving the decimal point right multiplies a number by 10, and vice versa.

My students need to know automatically that there is implicitly a decimal point just to the right of the ones digit in whole numbers written in standard form. When a number is whole, it has no other parts: 39 is 39 wholes. On the other hand, a decimal fraction such as 39.5 is 39 wholes and 5 tenths.

Here is a practical procedure for converting numbers written in standard form to scientific notation.

1. Insert a decimal point just to the right of the ones place, then move it so that it is just to the right of the first non-zero digit.

Thus, for example, 123,000,000,000 = 123,000,000,000. -> 1.23,000,000,000.

2. Remove the trailing zeroes (if there are any).

Continuing, 1.23~~,000,000,000~~ -> 1.23.

3. Count how many places you moved the decimal point in step 1, and make that number the exponent for your base 10. In this, case we moved the decimal 11 places to the left.

So, 1.23 -> 1.23×10^{11} .

4. Now write the coefficient 1.23 times 10 to the eleventh power.

Thus, we have found that $123{,}000{,}000{,}000 = 1.23 \times 10^{11}$.

Examples:

$678 = 6.78 \times 10^2$ $1043 = 1.043 \times 10^3$.

These are some of my students' common errors in performing this process:

- The final answer is not written in correct form because the coefficient is not between 1 and 10.

They write: 34×10^1

Instead of: 3.4×10^2 .

- When comparing numbers, they think the larger coefficient signifies the larger number, because it has more digits. They are thinking of standard form for whole numbers, and ignore the power of ten.

Thus, they might claim that $1.2876 \times 10^3 > 1.2 \times 10^5$.

Note that the example on the left side of this inequality is not a whole number. I want my students to understand that, for any two numbers written in scientific notation, if one has a larger exponent, it is larger (whatever the coefficients may be).

- They leave out the decimal or place it in the wrong position.

For example, 678×10^6 for 6.78×10^6, or $105. \times 10^2$ for 1.05×10^2 .

How Can I Help My Students Compare Expressions Written in Scientific Notation?

Once my students fully understand exponential notation and have practiced using exponents to denote powers of ten, they begin to evaluate and compare exponential expressions.

The guiding questions for writing numbers in standard notation form are meant to promote conversation about background knowledge and serve as a review for students:

What does it mean to write numbers in standard form?

What kind of terms do numbers in standard form and numbers in expanded form contain? When is it best to write numbers in standard form?

As previously mentioned, textbook problems usually refer to the field of science as a focus for lessons on scientific notation, but I want my students to know that scientific notation can also serve practical purposes for everyday life. At this point in the unit, I will have my students start to build upon their foundation with scientific notation while making conjectures about the relative size of numbers. For example, several of my students have video game competitions. We will write those numbers in scientific notation to compare scores on a number line to find out who has the highest score. My students might also compare city populations, movie blockbuster revenues, and the total annual cost of health care in the US, how much that is per person.

Comparing Magnitude

To compare the size and magnitude of numbers written in scientific notion, we first look at the exponents.

Which is larger, a) 2×10^3 or b) 2×10^5 ?

The answer is *b* because $10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100{,}000$

$10^3 = 10 \times 10 \times 10 = 1{,}000$.

Thus, $2 \times 10^5 > 2 \times 10^3$.

We will also compare numbers with different coefficients. For example,

$1 \times 10^6 > 9 \times 10^5$, etc.

I will make sure that my students understand that, if two numbers written in scientific notation use different exponents, the one with the larger exponent is larger, no matter what the coefficients are. Only when the exponents are the same, do we look at the coefficients to compare. This may require students to process the number further, since students will have already practiced writing numbers in standard notation and can use this to determine which value is larger. Ultimately students should be able to recognize that when the exponents are the same, the number with the larger coefficient is larger, and also, able to compare coefficients efficiently.

Example 1:

a) 37 $\times 10^6$ or b) 1.34 $\times 10^6$

The answer is *a* because 1.37 is larger than 1.34.

Thus, 1.37 $\times 10^6 > 1.34 \times 10^6$.

Example 2:

a) 326 $\times 10^3$ or b) 5.9 $\times 10^3$

The answer is *b* because 5.9 is larger than 5.326.

Thus, 5.326 $\times 10^3 < 5.9 \times 10^3$.

These examples illustrate for my students the rule: to compare two base ten numbers between 1 and 10, compare their digits one place at a time, starting at the ones place, and moving right. The one with the larger digit in the first (leftmost) place where they differ, is the larger number.

We will use the problems below to help us visualize what happens to a number when we multiply it by different powers of 10. We make a conjecture and then simplify each expression and discuss how the numbers change. Our process:

1. Notice the exponents.
    1. 97 $\times 10$
    2. 97 $\times 10^2$
    3. 6.97 $\times 10^3$
    4. 6.97 $\times 10^4$
2. Write each number in standard notation form.
    1. 97 $\times 10$ = 69.7
    2. 97 $\times 10^2$ = 697
    3. 6.97 $\times 10^3$ = 6,970
    4. 6.97 $\times 10^4$ = 69,700
3. Discuss what you notice with a partner and share with the class.
4. Why would you want to write a number in scientific notation?
5. What is your process for ordering numbers written in scientific notation?
6. How do you convert a number in standard form to a number in scientific notation?

When the class is able to respond competently to these and similar questions, we will follow up with number talks helps to enrich our mathematical understanding and academic vocabulary.

Teaching Strategies

Collaborative Grouping

Our current mathematics curriculum, College Preparatory Mathematics Core Connection 3 (CPM), is designed to enhance student learning through real-world activities and collaborative learning. Students work in heterogeneous teams of four, each team member having a specific role: resource managers get supplies; recorder/reporters share the team's work with the class; facilitators get things started by asking someone to read; and task managers keep the team focused. My role is to be a facilitator of student learning as they become active participants in their collaborative teams. This may include providing support and guidance, facilitating discussions, and promoting the use of higher-order thinking skills. CPM's student-centered and problem-based curriculum consists primarily of word problems in the form of scenarios with few examples of how to solve problems. Each requires varying degrees of language translation before the mathematics can be addressed.

Think Ink Pair Share

I ask my students to engage in topic discussions to assess their conceptual understanding. I start by asking a question and allowing them time to think (wait time). I ask them to write down their response before discussing it with their partner, and then with the whole class. I find my middle school students more likely to share with the entire class after discussing with a partner first. After a few students have shared, I follow up to make clarifications and correct errors. The class returns to their writing to make necessary modifications. Students share one final time with their team to make sure that everyone understands the concept. I will select a one or two teams with an accurate explanation to share with the whole class. This activity fosters student accountability and presents opportunities to address content misconceptions.

Practice and Review Time

Students are assigned homework practice after each lesson and core homework problems are used to review concepts from the prior lesson. For example, at the start of lesson I provide students with 30 seconds to review a problem I have written on the board and write as much information and details they can recall about the problem. Using a stopwatch, I walk around to make sure each student utilizes their 30 seconds. If I notice any students who cannot think of anything to write about the problem, I provide them with an entry point by focusing on a specific piece of the problem and ask probing questions. If students are still unable to recall information, they are instructed to listen to the responses of their classmates and be prepared to repeat what they have heard their classmates share.

A few times per week, I save time for teams of students engage with more practice problems through textbook problems, worksheets, or student generated problems. In general, I give students time to practice and review skills individually and within small groups. Students have processing time with problems on their individual whiteboards and then are asked to share their thinking and learning with a partner or within a small group. I try to provide students with a few examples of problems and then ask teams to discuss any patterns they find within their observations or calculations, form a conjecture, and work to justify their conjecture.

Gallery Walks

I use Gallery Walks as a strategy for students to visually share ideas with a poster, project, or presentation. I place each team at a station around the room to set up their work. Students walk around the room with their team to quietly evaluate other team's work and provide written feedback. Teams write three positive comments and one "next time try" comment. After the Gallery Walk, teams read and discuss the comments they received from their classmates, then select and share one plus and one delta they feel is most useful feedback for their team.

Number Talks

I use Number Talks as a 10 to 15 minute review, to summarize, or as a way to assess overall understanding. Number Talks are basically a mental math activity where we think, ink and share (think consists of mental math, but some students need to write out their thoughts, thus ink means to write). After several minutes, students share with the class the strategies they used to find their answer, which I record on the board. I find that this whole class processing time helps to encourage collaboration, student discourse, and mathematical discussion. My students seem to focus more on content when they hear it from peers. They become engaged and are encouraged to explain their thinking, justify their reasoning, and make sense of each other's problem-solving strategies, following the standards for mathematical practice. Number Talks are ideal for formative assessment and checking for understanding. Sometimes, I use number talks as a way to gauge whether or not certain students require additional support. Conversely, if students answer the questions with ease, I feel comfortable with giving a quiz or moving on to the next topic.

Journal Entry Using Sentence Frames

At the end of each lesson, students write in their math journals. I ask my students to write about something they learned or reviewed and give an example. I provide sentence frames for extra support, to help guide thinking, and as a method of scaffolding for my English language learners and students who struggle with writing. I write a sentence and leave a blank line for students to fill in the blank with a word, sentence or illustration.

For example:

A. Exponential notationis a shorter way of writing ________(repeated factors), for example:

$10 \times 10 = 10^2 = 100$.

B. Exponential notation has two parts. One part of the notation is called the The base is the number that is being multiplied by itself. The other part of the notation is the exponent, or power. This is the small number written up high to the right of the base. The _____ (exponent), or power, tells how many times to use the ____ (base) as a factor in the multiplication.

Classroom Activities

Human Number Line: Comparing Decimals and Numbers in Scientific Notation Activity

My students enjoy the human number line outdoor activity. To prepare, I make two identical sets of numbers on large index cards ranging from 0 to 10, 0 to 100, or 0 to 1000 including decimals and numbers written in scientific notation. I place two ropes on the ground that are 25 to 50 feet in length and a few feet apart parallel to each other. I use tape to make a starting line on the ground several feet away form the number line. Students are divided into teams of 10 each holding a set of numbered cards and team members line up behind the starting line. I blow a whistle and students race to stand on the line holding the numbered card in the appropriate position. When the first team positions all cards correctly, I blow the whistle to end that round. Finally, in order for the team to win, each student on the team must say the number correctly on the card they are holding. For example, “fifty-six and nine tenths” (56.9) or “4 times ten to the fourth power” (4×10^4). I change the set of cards, rearrange teams and start another round.

Superhero Cross-Curricular Classroom Activity

My goal for this culminating activity is to help my students put numbers written in scientific notation into context, and to improve their writing skills. In teams of four, students will design a comic book about a superhero they create that has special powers and abilities. Students will be graded on their narrative essay, oral presentation, and comic book. I provide a rubric (see in Materials section below) to help guide students through each of the three components and as a form of assessment.

Part 1: Research

In teams of four, students will use the internet to collect data to use as benchmarks to make comparisons between humans, animals, and the superhero. My students will research multiple human and animal capacities including weight, speed, strength, reach, jumping distance, etc. by responding to (and are not limited to) prompts such as the ones below:

Benchmark Data Prompts

I use the following benchmark data prompts only as a starting point for discussion and data collection. I inform my students of the many capacities that a superhero might have that are not so obvious. I anticipate that each prompt will invite more whole-class conversations and brainstorming ideas. I post one prompt at a time in order to have the whole class working together. I provide students with a chart to record their responses and data. Because of the engaging discussions that come from the research, responding to the prompts can take several days.

Prompt Examples

What is the speed of the fastest person in the world? This information can be used to design a superhero with super speed.

How much weight can the strongest person bench-press? What is a benchmark for a human’s grip strength? This information could be use when designing a superhero like Spiderman because he swings around on cables and hangs from windowsills.

What is the average age of a person? This information could be used when a superhero travels light years to reach earth.

What non-human creature can lift the most weight in pounds? Possible class discussions can include but are not limited to the kind of weight, kind of lift, and height of lift. How much weight can it lift? How does it lift things?

More example benchmark data prompts:

What is the maximum height a human can jump?

How long can a human hold their breath?

What is the highest and lowest temperature a human can tolerate wearing normal clothing?

Who is a great humanitarian and what kind acts did they perform?

What is the fastest non-human creature on land, in the sea and in the sky? What size is it? How does it move? How much does it weigh?

What creature can see the farthest or clearest? What is its vision…how is it measured?

Once the data has been recorded, I proceed to part 2. Students are encouraged to generate additional prompts.

Example of a data chart:

When students fill in the charts they will record their data in standard form and in scientific notation, ideally, finding scientific notation to be more efficient. The project will allow students to see actual differences in the way we represent certain values.

Chart 1: Average Human Male and Female Chart Example (Search the internet to fill in chart.):

Name	Average Body Weight	Weight Can Lift (deadweight)	Average Running Speed
Human Male[4]	1.9×10^2 Pounds		
Human Female[4]	1.7×10^2 pounds		

Charts 2: Average Animal Weight and Strength Chart Example:

Name	Average Body Weight	Weight Can Lift	Average Speed
Gorilla[3]	4×10^2 pound		
Elephant			
Cheetah			
Panther			

Part 2: Reponses

Students will use the information they gather to respond to prompts. Here is an example of the response discussion process:

Teacher: Let’s answer the first question together: How long will it take someone to run from our school to San Francisco? What information do we need to know to answer this question?

Possible student responses: We need to know the distance from our school to a landmark in San Francisco. We need to know how long it takes the person to run a certain distance. We need to know if the person will be stopping to rest.

Once the class has generated a list, they will research the information with their team. They must record all responses on the chart.

Examples of Prompts for Part 2:

How many puppies can the world's strongest person lift?

How far could a person swim in a straight line while holding their breath?

How long could a person skateboard wearing shorts in Alaska in the wintertime?

What is the maximum distance that an eagle can fly without stopping? How long would it take an eagle to fly from California to New York, considering stopping time if necessary (please provide an explanation on stopping time)?

Who can travel farther in a day, a man walking, or a horse and rider? How far?

How many baby penguins can an elephant lift?

Part 3: Creating the Superhero

The guiding questions for the superhero activity will be the following:

How can an imaginary superheroes' strength and abilities be described and compared to a regular human's?

What makes your superhero super?

Here is how I will get my students started.

Steps:

I. Watch a movie that contains a superhero.
II. Make a list of your favorite superheroes and explain why you like them.
III. Discuss what makes your favorite superhero super. (Are they strong; can they see through steel; do they perform humanitarian acts?)
IV. Have a Think-Ink-Pair-share about a superhero you would create: origin, personality, super powers, code name, what they stand for, their regular human form (Clark Kent is really Superman), their nemesis, etc.
V. Students will use the data from the response prompts to inform their superhero creation. Parts 1 and 2 will give students perspective on what is considered as normal weight, speed, and strength in humans and animals. Using the data chart, students will gradually put together their superhero's physical, mental, emotional, and personality traits. For example, I found that an average man runs 100 meters at a speed of 9 miles per hour. Therefore, I want my superhero to run fifty times that speed. Student will extend their charts to fit the requirements of their superhero. Students will refer to a rubric like the one below as a guide for the superhero project. The rubric will list specific information about criteria, expectations, and scoring. The rubric will be used to help students synthesize their final project and as a form of teacher assessment. Each of the four teammates will develop one or more characteristics before contributing to the team within a timeframe. Teams will combine the attributes from each member to

design their unique superhero. As a starting point or to give my students more ideas to brainstorm, I will provide discussion prompts. For example, I will say, “It would be interesting to know how much strength it would take your superhero to rip a tree out of the ground.” We would then discuss different kinds of trees in our state, and then compare the masses and root strengths of a small fruit tree with a mature oak, and again with a mature redwood or sequoia.

VI. Students will write a one- to two-page essay about their superhero. They will write about the superhero’s physical characteristics (before and after superhero transformation), origin, strengths, powers, personality, and nemesis (optional). Student will use a rubric as a guide and form of assessment.

VII. Students will introduce the character to the class by using a presentation platform. I will use Prezi[5] as an example. Students will make a one-page presentation with their superhero’s name, an illustration, and one fact and present it to the class. I will grade students’ oral presentation performance.

VIII. Students will design a digital or hard copy comic book for the final portion of this project. For the digital comic books, my students will use a program such as Google Slides. They can use any paper they choose for the hardcopy version.

IX. Students will present their comic books to the class

Materials

Essay Expectations and Assessment Rubric:

Essay Expectations Rubric	Advanced—5	Proficient—4	Needs Improvement—3	Rewrite—2
Organization	Essay is excellently organized and easy to follow.	Essay is organized with a few confusing areas.	Essay is not well organized and at times is hard to follow.	Essay lacks organization making it difficult to read.
Word choice	Essay contains rich and sophisticated word choice. Excellent use of synonyms.	Essay contains good word choice. Good use of synonyms.	Essay contains simplistic word choice. Some descriptive words are repeated.	Essay contains too simplistic word choice and descriptive words are far too repetitive.
Sensory details	Essay is rich in sensory details and creates a vivid picture of the character.	Essay has some strong sensory details and creates a somewhat clear picture of the character.	Essay has too few sensory details and does not create a clear picture of the character.	Essay is lacking in sensory details and character focus.
Mathematics content	All expressions are relevant and written correctly. There is an appropriate amount of mathematical references included to explain to superheroes abilities.	Some expressions are relevant and written correctly. There is a fair amount of mathematical references included to explain to superheroes abilities.	Few expressions are relevant and written correctly. There are few mathematical references included to explain to superheroes abilities.	Expressions are not relevant and written incorrectly. There are no mathematical references included to explain to superheroes abilities.

Conventions	Excellent use of punctuation, capitalization, grammar, and spelling. Uses transitions to connect ideas and paragraphs well.	Correct use of punctuation, capitalization, grammar, and spelling with a minimal amount of errors. Uses some transitions to connect ideas and paragraphs.	Contains errors in one or more punctuation, capitalization, grammar, and spelling. Uses some transitions to connect ideas and paragraphs.	Contains many errors in punctuation, capitalizations, grammar, and spelling. Uses no transitions to connect ideas and paragraphs.
Format	Essay has a proper heading and centered title, typed in Times New Roman at 12 point font, double spaced with proper margins.	Essay has most of the proper formatting but wrong font, or spacing, etc.	Essay is lacking most aspects of formatting but not all.	Essay does not use correct formatting.

Comic Book and Oral Presentation Rubric and Self-Assessment:

Comic Book and Oral Presentation Self-Assessment Rubric	4	3	2	1
Superhero Character Development	I included all of the necessary components: background/origin, physical makeup, strengths, powers, personality, and nemesis (optional).	I included all components, but my character needs more work.	I included most of the components and my character is almost fully developed.	I included few components and my character in not fully developed. I need to keep working on it.
Research	I used at least 7 reputable resources including a novel, website, comic book, and an interview.	I used 5 to 7 reputable resources including a novel, website, comic book, and an interview.	I used 3 to 4 reputable resources including a novel, website, comic book, or an interview.	I used only 1 to 2 reputable resources including a novel, website, comic book, or an interview.
Questions	I answered the guiding questions completely providing excellent details and examples.	I answered the guiding questions providing many details and examples.	I answered some of the guiding questions providing some details and examples.	I answered very few of the guiding questions providing no details and examples.
Math Content	I wrote all expressions correctly, showed and checked my work.	I wrote some expressions correctly, showed and checked some of my work.	I wrote few expressions correctly, and barely showed or checked my work.	I wrote no expressions correctly, and did not show or check my work.
Writing Content	I followed the essay rubric, wrote 3 drafts, and asked a peer to edit my work.	I somewhat followed the essay rubric, wrote 2 drafts, and asked a peer to edit my work.	I barely followed the essay rubric, wrote 1 draft, and asked a peer to edit my work.	I did not follow the essay rubric, wrote 1 draft, and did not ask a peer to edit my work.

Organization and Connection	My project was well organized and easy to follow. My superhero character and narrative showed a clear connection to the concept of scientific notation.	My project was somewhat organized, but easy to follow. My superhero character and narrative showed some connection to the concept of scientific notation.	My project was somewhat organized and difficult to follow. My superhero character and narrative showed very little connection to the concept of scientific notation.	My project was disorganized and hard to follow. My superhero character did not connect to the concept of scientific notation.
Neatness	My project was exceptional. It could not have been better.	My project was good. It had just one or two areas that needed improvement.	My project was just okay. It had a few areas that needed improvement.	My project was not acceptable. I'd like to redo it.
Prezi/Google Slides/PowerPoint Presentation	Our superhero was vivid and exceptionally designed. The fact was represented in an amazing and accurate way.	Our superhero was colorful and well designed and vivid. The fact was represented in an interesting and accurate way.	Our superhero lacked color and was not well designed. The fact was not interesting or entirely accurate.	Our superhero had no color and poorly designed. We did not include a fact about it.
Oral Presentation	I represented my team well. I spoke clearly about our superhero and provided details and examples.	I represented my team somewhat well. I spoke about our superhero and provided few details and examples.	My presentation needed improvement. I did not speak clearly about our superhero and provided only one detail and/or example.	I did not present well; I read entirely from my notes. I did not speak clearly about our superhero and did not provide any details or examples.

Resources

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Dietiker, Leslie. *Core Connections 3*. Sacramento, CA: CPM Educational Program, 2015.

Fryholm, Ph.D., Jeff. “Learning to Think Mathematically with the Number Line.”

https://www.mathlearningcenter.org/sites/default/files/pdfs/LTM_Numberline.pdf (accessed July 20, 2018) “George Shirakawa Sr. Elementary School.” Great Schools. http://www.greatschools.org/california/san-jose/11151-Shirakawa-George-Sr.-Elementary-School/details (assessed July 2017).

Howe, Roger, and Susanna S. Epp. “Taking Place Value Seriously: Arithmetic, Estimation, and Algebra.”

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Howe, Roger. “Whole Number Arithmetic for the 21st Century” (accessed July 18, 2018).

“Shirakawa (George, Sr.) Elementary”. https://www.ed-data.org/school/Santa-Clara/Franklin--McKinley-Elementary/Shirakawa-(George,-Sr.)-Elementary (assessed July 18, 2018).

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Tes Global Ltd. “My lessons (Tes Teach).” https://www.tes.com/my-resources/lessons (accessed July 23, 2018).

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1. Howe, Roger. *The Most Important Thing for Your Child to Learn about Arithmetic*. http://math2.uncc.edu/~hbreiter/CTI2015/MostImportantrev2.pdf (accessed July 10, 2018).
2. Howe, Roger and Harold Reiter. *The Five Stages of Place Value*. Teachers of India. http://www.teachersofindia.org/en/article/five-stages-place-value (accessed July 11, 2018).
3. The Telegraph. “The strongest living land creatures on Earth, measured by their power to weight ratio.” https://www.telegraph.co.uk/news/earth/earthpicturegalleries/7521275/The-strongest-living-land-creatures-on-Earth-measured-by-their-power-to-weight-ratio.html?image=3 (accessed July 30, 2018).
4. Wikipedia. https://en.wikipedia.org/wiki/Human_body_weight (accessed July 29, 2018).
5. Prezi: https://prezi.com/ (accessed July 21, 2018).

Appendix

My cross curricular lesson involves several subject areas: Mathematics, Language Arts, Life Science, and Technology. This unit aligns with California Common Core Standards for mathematics, English language development, Language Arts, and Mathematical Practices Standards.

CCSS.ELA-LITERACY.W.8.3.B: Use narrative techniques, such as dialogue, pacing, description, and reflection, to develop experiences, events, and/or characters.

CCSS.MATH.CONTENT.8.EE.A.3: Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. For example, estimate the population of the United States as 3 times 108 and the population of the world as 7 times 109, and determine that the world population is more than 20 times larger.

CCSS.MATH.CONTENT.8.EE.A.4: Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology.

CCSS.ELA-LITERACY.W.8.6: Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas efficiently as well as to interact and collaborate with others.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6 Attend to precision.

California Department of Education, English Language Development Standards for 8th Grade: SL.8.1, 6; L.8.3, 6.1. Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics.

California Department of Education, English Language Development Standards for 8th Grade: SL.8.4-6; L.8.1, 3. 9. Expressing information and ideas in formal oral presentations on academic topics.