### Stage 1 – Desired Results

**Content Standard(s):**
- Standard 7.2.3.2- Benchmark: Evaluate algebraic expressions containing rational numbers and whole number exponents at specified values of their variables.
- Standard 8.1.1.4- Benchmark: Know and apply the properties of positive and negative exponents to generate equivalent numerical expressions.

**Understanding (s)/goals**
Students will understand: When solving algebraic expressions with positive and negative exponents understanding their properties is essential to help them simplify and evaluate the expressions.

**Essential Question(s):**
- Why are numbers represented in different ways?
- How are exponential expressions used in real-life?
- Where do we see exponential expressions in our lives?

**Student objectives (outcomes):**
All students will be able to:
- Recognize an exponential expression.
- Restate the multiplication, division, negative and zero properties of exponents.
- Evaluate expressions that contain exponents.

Most students will be able to:
- Apply the properties of exponents to an exponential expression.
- Use the properties of exponents to simplify then evaluate exponential expressions.

Some students will be able to:
- Explain how the multiplication and division properties of exponents were developed.

### Stage 2 – Assessment Evidence

**Performance Task(s):**
- Research an exponential growth function, apply it to a problem or topic that interests you, evaluate accordingly.

**Other Evidence:**
- Class discussions which will act as an in-class assessment to see where the students are at
- Peer-tutoring activity with 3 different level worksheets (4-6 questions per worksheet)
- Exit/Muddy-points card

### Stage 3 – Learning Plan

**Learning Activities:**
**Materials and Resources:**
- Exponent Review SMART Notebook document
- 3 worksheets that move up in difficulty as they progress (4-6 questions per worksheet)
- Notecards (enough for 1 per student)

Prior to lesson:
Develop a SMART Notebook document for the class discussion/lecture on exponents and their properties. Topics covered will be zero and negative exponents, multiplication and division properties of exponents, and real-life applications of exponents. Additionally, make 3 worksheets labeled A, B, and C with A being the easiest worksheet and C being the hardest worksheet. The worksheets will cover the topics discussed in the lecture (zero and negative exponents, multiplication and division properties, and real-life uses of exponents) and questions will have students identify, apply, and utilize the properties.

**Lesson:**
Intro: 5 min
Ask the students where they have seen exponents; whether it is in this math class (What topics have you seen them used in? Expect to hear answers such as the chapter on exponents, quadratic equations, polynomials, scientific notation, geometric sequences, exponential growth/decay) or in a different class. Ask them if they know of any professions that use exponents to solve problems (Biologists, Physiologists, Astronomers, Chemists, Physicists, Environmental Scientists, Ecologists, Businesses-Finances, City Planners)

Transition into main topics of lesson: 1-2 min
List off other professions that use exponents and explain that the ability to use exponents and their properties is important in a wide variety of fields and life (makes big numbers easier to calculate/use) and that it is important to know these properties so we will be reviewing them today.

Real-World/Science Application: 7-10 min
Ask students “Has there ever been a time where someone told you not to touch something because it was full of germs, like a dirty table, an object that someone sneezed on, or the gum under the desk that you accidentally touched? If we went around the school, what objects do you think would have the most germs? What if you went around Duluth, what do you think would have the most germs?” Let students hypothesize on different places then ask “How can we figure out how many germs are at these places?” Bring up exponential growth models and that they are used to model how many germs would be present after a certain time period.

Application: So, we can use the function \( f(x) = 300(3^x)(2^{(x+1)}) \), where \( x \) is the number of 15 minute periods, to model how many germs there are. Ask students how we can find the initial population of germs (they should answer \( x=0 \)). So solving for \( f(0) \) we get \( 300(3^0)(2^{(0+1)})=300(1)(2)=600 \). [During this calculation ask students what they remember about zero exponents (this is a review lesson so most students should remember that a non-zero base number with a zero power equals 1)] also remind students what the base number is and what the
power is when working with exponential expressions.] Then, ask students how many germs there would be after 30 minutes and after 1 hour.
f(2) = 300(3^2)(2^{2+1}) = 300(9)(2^3) = 300(9)(8) = 21600
f(4) = 300(3^4)(2^{4+1}) = 300(81)(2^5) = 300(81)(32) = 777600
So because germs grow really fast that’s why we don’t eat the piece of candy that we find on the floor, even if we dropped it 5 minutes before.

Break: 2 min (Instruct students that they should have a pencil and paper ready after the 2 minutes because we will be going into a quick review of exponent properties when we resume the lesson. [Use break as a transition.])

Zero and Negative Exponents: 3 min
Ask the class “Does anyone remember what the property is for an exponent that has a value of zero? We used it in the problem we did before break.” (Looking for the answer to be For every nonzero number a, \(a^0 = 1\)) If students cannot recall ask them “What is any nonzero number to the power of zero?” Then ask the class if anyone remembers what the property of negative exponents is. (Looking for: For every nonzero number a and integer n, \(a^{(-n)} = \frac{1}{a^n}\) ) Then have one example problem for a negative exponent.

Multiplication Properties: 5 min
Ask students to recall the multiplication properties. Looking for:
For every nonzero number a and integers m and n, \(a^m \times a^n = a^{(m+n)}\)
For every nonzero number a and integers m and n, \((a^m)^n = a^{(m \times n)}\)
For every nonzero number a and b and integer n, \((ab)^n = (a^n)(b^n)\)
There will be one example for each property.

Division Properties: 5 min
Ask students to recall the division properties. Looking for:
For every nonzero number a and integers m and n, \((a^m)/(a^n) = a^{(m-n)}\)
For every nonzero number a and b and integer n, \((a/b)^n = (a^n)/(b^n)\)
There will be one example for each property.

Break: 2 min (Hand out sheet A to each student)

Peer-Tutoring activity: 20 min
Instruct students to work with their table partners to answer the questions on
the worksheet. When they are done with worksheet A they are to put it in the folder on the front table and grab worksheet B. When they are done with worksheet B they are to put it in the folder on the table and grab worksheet C, turning that worksheet in when they are done. When they are done with all of the worksheets instruct the students to grab a notecard on which they can write one thing they learned or one thing they still have trouble understanding.

**During the activity move around the room and make sure students are understanding the problems or help them if they need any help.**

If students finish the worksheets early they can use the time to work on any homework or late work they have.

**Stage 1:**

The design of this section is based off of the targets we want our students to reach. It starts with the standard(s) we are targeting for the specific lesson. Then, our enduring understandings are built off of the standard(s). Educational neuroscience supports the establishing of a target and big picture (enduring understanding) because as John Medina noted, our brains see patterns and remember the meaning of events better than the exact details (2008). So, we want to make sure we know what our end goal is. As Dan Glisczinski put it, if we go to the grocery store and start grabbing different ingredients with no idea of what we are going to make, we will not end up with everything we need to complete the meal. However, if we know the meal we want to make, we will then know which ingredients we need (2014). Thus, singling out the main points allows us as teachers to direct the learning towards those points. Marzano supports this by saying “a teacher who designs and organizes academic tasks well will produce better student learning than a teacher who does not.” He then goes on to point out that since the district and school curriculum is designed by way of the standards, it is only logical that a teacher’s design of academic tasks come from the standards as well (2007). So, with our target(s) placed the next question is, how do we
get our students to “want to know?” The answer to this comes from Medina (2008), Immordino-Yang & Faeth (2010), and Zull (2011) who all say that emotions (somatic markers) guide cognitive learning. Goleman also warns that we should avoid spending too much time on intellectual intelligence at the cost of emotional intelligence (2006) because Information before ECS precipitates Cs for grades (Dan, 2014). Therefore, our Essential Questions should try to trigger the ECS of our students so we can get them emotionally invested in the learning.

Our student objectives are then the culmination of the learning. Our main goal(s) should be present in the objectives of all students with the finer details being in the objectives obtained by most or some students.

**Stage 2:**

The design of the formative assessment comes from and is supported by educational neuroscience in multiple ways. The classroom discussion and peer-tutoring activities help students to meet their need to belong by making connections. This stems from Maslow’s hierarchy of needs (1943) which if they are not met, can influence a student’s emotions and ultimately influence if information will be taken in or rejected from the brain. Furthermore, the peer-tutoring activity allows for repetition which Medina (2008) shares as being a key for moving information from STM storage to LTM storage. The additional experiences with the material, by way of the peer-tutoring activity and the reflective exit card, also support student learning. This comes from Begley, who shares that brain specialization is a result of experience (2008) and Zull (2002) who said basically the same thing, that learning depends on experience. So, multiple forms of formative assessment (experience) leads to brain specialization, or neuroplasticity, which is the restricting and re-organizing of neurons that allows our
brains to become good at the things we do a lot. This is all backed up by research presented in Marzano (2007). The first point is from Black and Wiliam (1998) who reported that “formative assessment does improve learning.” Bangert-Drowns, Kulik, and Kulik (1991) also pointed to formative assessment improving learning but also found that the higher the frequency of formative assessments, the higher the gain in student achievement percentile points.

Additionally, summative assessments, if used properly, can be a key to student learning. Since summative assessments are graded and a student’s grade can evoke strong feelings, I will bring us to a finding of Zull’s. He says that in achieving a goal that has caused us anxiety or fear we can find rewards. However, we need to have appropriate levels of anxiety in order to find joy in the outcome (2011). So the design of the performance task comes mainly from this point. It takes an activity that usually causes anxiety (a graded assessment) and asks the student to relate the topic to something they like (brings in joy or positive emotions).

**Stage 3:**

This stage is about answering the question “How will I get them there?” Zull (2002) points us to David Kolb who says that “deep learning, learning for real comprehension, comes through a sequence of experience, reflection, abstraction, and active testing.” Furthermore, this “learning cycle arises naturally from the structure of the brain” (Zull, 2002).

So starting with experience we have to look at our sensory or sense-luscious information. This information is plentiful though as Zull (2002) points out “our brains are literally awash in signals both from outside and inside our bodies.” The good thing is that we can filter this information with help of the reticular activating system, which
regulates information to the brain (Willis, 2010). Additionally, novel stimuli catches our attention (Medina, 2008). These findings show that we can filter information down to the things that catch our ECS. This sense-luscious experience is happening in the hook of the lesson (intro/real-world application). The lesson plan then moves to a class discussion on the properties of exponents (reflective part of the cycle). This part of the learning cycle happens in the back integrative cortex, which helps in the formation of memories and recalling them (Zull, 2002). Medina’s work then shows us that this is a key part in the learning cycle when he notes that the more we elaborately encode information at the moment of learning, the stronger the memory (2008). So, reflective observation allows our brains to store the information that has just been brought in through our senses. Medina (2008) also went on to say that we see patterns and remember the meaning of events better than we remember the exact details. So in other words, we are making an abstract of the information, the next part of the cycle!

In this lesson, our goal, target, big idea is that students know and can apply the properties of exponents and then evaluate, so the discussion of the properties was put into the lesson after the experience part of the cycle. This also allows the students to reflect and pull out the ideas (the properties) that are needed to solve the problem in the experience part of the cycle (real-world application). Design wise, I put the discussion of the properties where they are in the lesson so that the brains of my students will make the connection that the properties were needed during the “experience.” The last part of the cycle is active testing, which uses the motor cortex to “carry out the plans and ideas originating from the front integrative cortex” (Zull, 2002). In other words, this is the part of the cycle where the main ideas pulled out during abstraction are put out into the world to be seen or heard. So, this is the applying of
the properties in actual problems or in the design of this lesson, it is the using of the properties to complete the worksheets in the peer-tutoring activity.

The last note where educational neuroscience reveals the human learning process is the building in of breaks during the lesson. Medina (2008) and Zull (2002) both note that people can handle about 10 minutes of stimulus before they “check out.” Zull also shares that this allows us to consolidate the information just taken in.