# Prologue

Hello,

If you are reading this then you are about to embark on a wonderful exploration into space sciences with your cub scout den, patrol, or pack. I have put together this document to outline what you can cover, who you can reach out to, and how to make it fun. I hope your experience is a success and that the youth come out of this with a newfound love for science and the tools we use to explain the world we live in and beyond.

If you are new to the STEM/NOVA program with BSA, let me just cover some of the basics. STEM stands for Science, Technology, Engineering, and Mathematics. They are the core components in logic and deductive reasoning in our world today, a skill that has been lost by most. For generations the US was the leader in many of these fields, but we have begun to stray from this path and it only hurts us as a nation. Children, myself included, were raised to believe that science and math were hard and that they weren’t important and nothing could be further from the truth. The BSA has always incorporated STEM components in their merit badges and advancement criteria, and the NOVA awards utilize those existing awards as well as some additional steps. **1-2-3-Go!** focuses on mathematics and some cryptography. All NOVA awards follow these basic requirements:

1. Research for an hour. It doesn’t matter how (reading, video, movie etc), but it should be specific to the subject.
2. Earn one of the related rank’s elective Adventure loops or pin, or do a group activity supplied. Adventure Loops earned for another award should not count.
3. Engage in a learning activity. This may have one or more facets, but is designed to involve the youth in research, critical reasoning, and presentation of their discoveries.
4. Visit somewhere where the subject in question is being used or performed.
5. Follow up with the NOVA counselor on what was learned.

I have incorporated a slideshow presentation and handouts for the youth that will cover every requirement of every question. For **1-2-3-Go!**, you will perform all of steps 1 and 2, 4, and 5, and 2 of the 3 requirements in step 3. The following pages will help you to talk about the different subjects, provide questions that you can ask to get the youth thinking, and help to answer questions that may be asked.

NOVA awards, on average, should be accomplished in about a month’s timeframe. This gives the youth a chance to do their research, create their presentations, and discuss what they are learning along the way. Engage the youth in whatever activities you would like to in an environment that works for them, but they will learn best by doing. Follow the Leading EDGE and Teaching EDGE philosophies. I wish you the best of luck in your adventure.

Corey Peoples

Pack 455, NSC, C250-17-1

# Slide 1 - Beginning

Introduce yourself and the excitement with the youth. Why did you choose to lead this award? What’s your passion for mathematics?

# Slide 2 - Agenda

Read verbatim or paraphrase:

The goal of this STEM course is to teach us how mathematics can be used. We will start off by selecting a book from the library, or watch a movie [akela, you decide]. Then there is an adventure loop that we will earn later for your rank. For number 3, we will choose 2 of the 3 requirements to do a little math worksheet. Then finally, we are going to learn about secret codes and learn to write and read messages with the Pigpen cipher. Throughout it all, let’s keep discussing what you are learning.

# Slide 3 – Learn for an Hour

Read verbatim or paraphrase:

Our first requirement is going to be to learn for an hour. I would like everyone to [Join me in watching a TV show or movie | Select a book from the library | select from some mathematics Youtube videos]. During this learning process, I want you to tell me about what math you see and how it benefits the people using it.

# Slide 4 – Group Activity – Rank Adventure

If you are doing a rank adventure, use this slide. If the rank adventure does not work for your group because it was already earned for another award or your group is of mixed ages, move on to slides 5 or 6.

Read verbatim or paraphrase:

We are also going to earn an adventure loop. There are a few to choose from, but the adventure loop we selected is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ for you. That will be done (now, later, on another day, at home, etc). While we work on this adventure loop, I want you to keep in mind what mathematics is used in it.

# Slide 5 – Group Activity – Statistics

Read verbatim or paraphrase:

A type of mathematics we hear and see a lot is called Statistics. This is the study of how numbers compare, and they are used all of the time. On the news you hear things like 49% of the population voted for so and so, or only 20% of people prefer cheese pizza. The weather gives us a 60% chance of rain some days. Or, 1 out of 10 people drink too much Mountain Dew. For us, we are going to create a survey where we ask several people a question or two, and then we will compare the results and graph them. Let’s think of a survey question we can ask. How about “What is your favorite pizza” or “What make of car do you drive?” Once we ask this question to a group of people, at least 10, and we write down their answers, then we can start to create graphs to compare the results.

Also, let’s do a coin flip. I have here a prized quarter. This quarter is perfectly balanced and when we toss it up in the air spinning, there is no way to know whether it will land heads up or tails up. Let’s try. Looks like it was heads, so I will mark that down. Let’s try again. And again. And again. Let’s do it 24 times and see what happens each time? Ok, now looking at the results, I can see I have more heads than tails. If I flip it for the 25th time, do you think it will be heads or do you think it will be tails? Heads does seem more likely, right? Ok, let’s try it. Aww, tails!

What does this tell us about randomness? Is there any way to know for sure what the next random result will be? No, of course not. This device only has 2 sides, so I have only 2 answers to choose from, or a 50% guess. For a 6 sided dice, I can only guess 1 out of 6 answers, or about 17%. A 20 sided dice gives me a 5% chance. The more options you have, the harder it will be to guess the right answer because our guess does not change where the coin or dice will land.

Akela, this will take more time, so follow up at the next den or stem meeting. This will require graph paper, or a steady hand and a large piece of paper. Do the following:

Let’s draw a graph showing the results of our survey now. First, I will create a graph by creating an up/down line on the left, and a side to side line on the bottom. On the bottom, we put down our possible answers, or what we call “variables.” On the up/down line, we put down quantities or how many of the answers were chosen. The first answer we have is \_\_\_\_\_\_\_\_. I’ll put that on my X axis at the bottom. Each time someone uses this answer, I can add another row to this column. Eventually, once we have gone through all of the results, we will have a way of seeing the differences with our eyes. This is a quantitative result, meaning we can see the numbers. This differs from qualitative, where it is more about the quality of the results and open to opinion. Had we included the question “Why was this the model of car you chose?” then we wouldn’t get an answer we could graph.

# Slide 6 – Group Activity – Measurements

Read verbatim or paraphrase:

Measurements are used all of the time because they give us the ability to compare things and understand their scope. We can measure how far away the grocery store is, which helps us to guess how long it will take to get there, yet another measurement but this uses time instead of distance. We can measure how much electricity we use, or how much rain we got from the storms. We can measure how happy we are or how much pain we are in by making a scale and picking a point on that scale. Measurements help the world to understand how things relate to each other, so how is that mathy?

Let’s ask some adults. Parents, why don’t you come over here and tell us what you measure at work or at home? … That’s an odd thing to measure? How do you do that, and why? What does that help you to do in your job?

Now, scouts, let’s measure each other. We can usually see with our eyes whether someone is taller than another as long as they are standing together, but in this instance we are going to break off into groups of 2 scouts, measure the height in centimeters and inches, and we are going to play a fun game of who is taller. Now, let’s split up and go and measure each other’s height. (scouts will go off and measure the inche and centimeter values). Ok scouts, let’s group back together. What we are going to do now is have everyone line up but we can’t stand. Everyone’s got to be sitting on their butts and scooching to their spot in the line. You will be able to tell where you can go by talking to people and sharing their height in inches or in centimeters. I want the shortest person over here, and the tallest person over here. Ready, go!

Ok, scouts. Now that we have everyone lined up, let’s stand and see how accurate we are. Looks great! Now, how many people only said what their height was in Inches? How many used inches and centimeters? Did you notice any big difference? Centimeters was a more accurate number, wasn’t it? Because the size of the centimeter is smaller than that of an inch, it gives us a more accurate reading. That’s one of the main reasons why scientists use the metric system for measurements. A strong argument can be made for why the metric system is not great for measuring temperature (Fahrenheit is a smaller increment than Celsius), but no one can ever argue that the metric system is not accurate for measuring distances and weights.

# Slide 7 – Learning Adventure Overview

Read verbatim or paraphrase:

Now it is time to cover our learning adventure. For this section, we are going to choose 2 of the 3 options listed here. I have selected \_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_ for us to cover.

# Slide 8 – Your Weight on Another World

Read verbatim or paraphrase:

If you’ve ever watched videos of the astronauts on the moon, you’ve seen them jumping around like they’re on a trampoline. Can anyone guess why that is? (The moon’s made of cheese and cheese is bouncy, right?) It’s because the moon has less gravity than the Earth does, so it is easier to jump really high. We are going to learn the differences between weight and mass and how gravity affects weight. We will then learn how to figure out our weight on another world using a type of math called Algebra.

# Slide 9 – Your Weight on Another World

Read verbatim or paraphrase:

When scientists are talking about the weight of objects, they often use a term called mass. Mass is not the same as weight. They use it to describe the amount of stuff in an object, and weight they use to describe how much force is being applied from the object. Let’s look at an example.

# Slide 10 – Your Weight on Another World

Read verbatim or paraphrase (maybe adjust your numbers if you aren’t close to my weight):

I weigh 280 pounds according to my bathroom scale. I have 280 lbs of stuff in me. My weight on Earth is my mass, as that’s what scientists have to use to set the scale, so my weight is 280 lbs.

# Slide 11 – Your Weight on Another World

Read verbatim or paraphrase:

The moon is going to be different though. On the moon I still have 280 lbs of mass, but my weight is less, almost 1/6 of my current weight, because there is less gravity on the moon. As a result, I only weigh 46 lbs, less than a big bag of dog food.

# Slide 12 – Your Weight on Another World

Read verbatim or paraphrase:

So what do I mean when I say gravity is 1/6 of Earths? What is Gravity? According to Isaac Newton, Gravity is the force that pulls between two objects and is calculated with their masses and their distances apart. If you were floating in space with your friend away from any planets or stars, you would be pulled towards each other using this equation: Force between two objects equals the gravitational constant G multiplied by the product of both masses divided by the distance between them squared. No matter where we look in the universe, we see this equation hold true.

I also mention that it’s the masses of the objects. It’s important to know that size does not matter with mass. If you compare a human to a human, the bigger one likely weighs more, but if you compare an orange to a metal ball, the metal ball will be heavier. Size does not matter. Here’s a great example from space. A neutron star, the collapsed core of a supergiant, is only about 15 miles in diameter. Compare that to Earth’s which is 7000 miles in diameter. It would seem like the earth should be heavier, but the mass of the neutron star is 200 billion times what Earth’s is. Neutron stars are so heavy they can eat other stars, and yet can do the most amazing things like spin around up to 716 times per second. On a pulsar I would weight 56 trillion pounds, and would be as flat as a pancake.

# Slide 13 – Your Weight on Another World - Calculation

Read verbatim or paraphrase:

How do you figure out how much you weigh? Simple! First, you take your weight. Next, you divide it by the earth’s acceleration of 9.8 meters per second per second, and then you multiply by the other planet’s surface acceleration. That gives you what you would weigh on another planet. What is the surface acceleration of the other planets? And what is surface acceleration anyway?

# Slide 14 – Surface Acceleration

Read verbatim or paraphrase:

Acceleration is the change in speed over time, so if I were to drop a ball and it could fall, after 1 second it would be travelling at a certain speed. After 2 seconds that speed would double from the 1st second, after 3 it would triple from the 1st second, and so on. The surface acceleration of an object is calculated by its mass, so the more massive the planet, moon, or star, the faster the acceleration.

Pick any 3 planets on here and use the equation at the bottom to calculate how much you would weigh on that planet.

Give them time, help them calculate this. They will need a calculator because of the decimal math.

# Slide 15 – Calculate height

For this exercise, you will need a Protractor with a string and weight attached to it like shows below, and you will need a tape measure. Calculators would also be helpful unless you can do tangent math in your head. Read verbatim or paraphrase:

There’s a phrase called “Eye Level” which means that you can see something if you look straight ahead at it. If you wanted to calculate something’s height and you found it is at eye level, then you could measure the distance from the ground to your eyes. What if you wanted to measure something taller? A tape measure wouldn’t work here because you can’t get to the top of the tree to measure down, so instead we need to know angle and distance and then we can calculate the height. This is a type of math known as Trigonometry.

Using a tool to measure angles such as a protractor with a drop weight, we can stand straight up, hold the protractor at our eye level, and see what angle it is to the top of the tree.

Once we can calculate the angle to the top of the tree, we can use the equation Tangent of Angle Times Distance to the Object. Tangent is the value of the opposite size divided by the adjacent side, so we can simply reverse the equation to tell us what the opposite size of the triangle is, in this case the height. But we have to remember that the angle is from our eye level to the top, not from the base to the top, so we have to add in our eye level height too. Once we put all of these values together we should know the height of a tree building, flagpole, or any other taller object.

# Slide 16 – Calculate Volume

Read verbatim or paraphrase:

Many times in our description of things, we want to be able to describe a property called Volume. Essentially, how much stuff can we put inside of it. What are some examples of volume you use in your everyday lives? How big is your garbage bag? How big is your trunk? How much cough syrup should you take? Sometimes calculating volume is hard, but for a square room like this, we can pretty easily calculate the volume by having 3 distance measurements: Length, Width, and Height. For this room, I measured the length to be \_\_\_\_\_\_\_\_\_, the width as \_\_\_\_\_\_\_\_\_\_\_\_\_, and the height of \_\_\_\_\_\_\_\_\_\_. If I wanted to know how much carpet I needed, I would take length times width to give me the area of the floor. Multiplying the 3 dimensions, though, will give us the volume. Let’s do that to this room. Take the length, the width, and the height, and calculate the volume in cubic feed

<after calculating the volume of the room>

If calculating the volume of a room can be done by multiplying the 3 dimensions together, that’s great for squares and rectangles. Can anyone guess how to calculate the volume of an irregular shape, like <pop bottle, statue, backpack, etc>? It has nearly an infinite amount of sides, so there isn’t a way to measure and multiply anything. Instead, we can calculate it the same way that the greek mathematician Archimedes discovered: displacement. The story goes that he was tasked to figure out how to know if a gift that was given to king Hiero of Syracuse was made of gold. If it was a statue or something irregular, he couldn’t use math to figure it out for the same reasons. He spent much time trying to figure it out, and eventually said “I need to take a break” and went to take a bath. As he sat down in the water, he noticed that the water in the bathtub rose and he realized that he could calculate volume by measuring the water level before and after submerging the gift. The story also says that he shouted “Eureka!” and ran all the way through town naked. Morale of the story: get excited, but don’t get too excited when you discover something new

# Slide 17 – Cryptography

Read verbatim or paraphrase:

Let’s move on to the last bit that we will talk about with mathematics: cryptography. By the end of the next few slides, we are going to learn about what cryptography is, how it is mathy, and create a cipher that we can use to write secret messages!

# Slide 18 – Cryptography

Read verbatim or paraphrase:

Cryptography is defined as the art of reading and writing in codes. The word crypt in latin means hidden or secret, and the word ography means to write or study. The device on this screen is a secret message box of sorts. It is called an Enigma machine, and because of how complex it is, Germany almost won World War 2 with it. It used wires and rotating disks to change the encryption on messages which they would change daily. The word Hello could be written differently on each day, meaning that the US and British forces couldn’t find a common cipher to use to decrypt the messages. It was only by capturing one of these devices and studying it were they able to figure out how it works.

# Slide 19 – Types of Cryptography

Read verbatim or paraphrase:

There are 3 styles of writing secret messages. The first is called a substitution cipher. This is a easy one because it replaces all 26 letters with a different symbol, either a picture or another letter. In a few minutes we are going to learn one. Another type of secret message is a key algorithm. This is where we encrypt a message with one code, and can only decrypt it with a different code. Any time you sign into a webpage, get money from a bank, or even use a newer debit or credit card, a public key is encrypting the data and a private key is decrypting it. This is done with a lot of math and makes your data incredibly safe. The last kind of cryptography is called a hash code. This is where we take some block of data and use math to convert it into a small block of numbers and letters so that every time we get the same output, but we cannot reverse it to get the original data back. Hash codes are often used for digital signature validation and passwords.

# Slide 20 – Mathy

Read verbatim or paraphrase:

I mentioned that two of the code ciphers use math. How do they do this? (click) usually with a lot of sequences, special mathematics involving the binary numbers, and a whole lot of processing power. If you knew the equations, you could do it by hand too. It would just take a lot longer. I won’t get into the details of the math, you can save that for college, but just know that it is a lot of careful math so that it is always the same values and cant be easily decoded.

# Slide 21 – Pig Pen Cipher

Read verbatim or paraphrase:

Start with your blank piece of paper, <click> and make 2 large tic tac toe boards. <click> Now, about the same size, two large X symbols. The ones on the left are good, <click> but put dots in the ones on the right. It should look like this Each of these symbols, 26 in total, is going to represent a letter. Starting in the top left of the top left tic tac toe board, write the letters A through I. Now on the right hash, continue on and write the letters J through R, and then left and right Xs will get S through Z. 26 symbols to replace 26 letters. This is known as the Pigpen cipher. It is easy to memorize, easy to write out, and fun to write secret messages.

How do we use this? Take the sentence I’ve got written here. The first letter doesn’t have a dot, so immediately I know to look on the left side. Now I look and see it is straight lines and not angled lines, so I know it is in the top left. Given that it only has the top and left lines of the box, it matches where the letter G is, so the first letter is G. How about the 2nd? Straight lines with a dot in the middle, and the lines are top, bottom, and left. Which letter best represents that symbol?

Now, spell it all out. What does it say? <Go Cub Scouts!> Now it’s time for you to encrypt a message to me. Write it out and see if I can decode it.

Scouts will now write out their lines. Use the cipher to decode, and encourage those who are struggling to make it an easy one.

# Slide 22 – Thank you

Read verbatim or paraphrase:

This is the end. Close up the topic by discussing what math things they have learned through this adventure.

# Final Thoughts

Akela,

Thank you so much for running this. I hope that you have had as much fun as the youth. Be sure to turn in whatever documentation is required to your advancement chair so that the youth earn both their NOVA award and their adventure rank.