MATH

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It's many a time that an elementary or middle school student wonders why they are required to learn math. The first grader wonders why she needs to learn how to subtract, the fifth grader – to divide, and the eighth grader – to learn algebra. This math section takes the yo-yo, and through the use of its dimensions, spin speed, length of spin or percentage of string length, students learn in a fun way, how to determine a product's value…and, in turn, the value of mathematics. Throughout this section, you will see how mathematical calculations, measurements, and graphing can be learned, <u>and reinforced</u>, by performing various simple experiments with the yo-yo.

It's one thing to perform various experiments with the yo-yo – the most obvious to be the length of the spin – and by using the scientific method, determining and identifying which factors affected the outcome. The process of changing one factor at a time and tracking outcomes is a valid exercise, in and of itself. It is quite another exercise in learning, however, to determine not only what factors changed the outcome, but <u>how</u> they affected it and, more importantly, <u>why</u> the outcome changed.

The SCIENCE section of our curriculum describes how friction and mass distribution affects a yo-yo's performance. This MATH section reinforces these concepts and uses mathematical concepts to prove the findings.

Standards of Learning used:

4. Solve problems by applying mathematics
5. Conduct research and communicate findings
6. Understand and apply scientific concepts
8. Use information to make decisions

MEASUREMENT

Definition: Using various measurements tools to determine an object's size.

Activities:

Grade Levels: K-3

1. Measuring various yo-yos of different sizes.

a. Define the following:

- **Height:** Vertical distance above the ground. Distance upward.
- **Width:** Linear extent from side to side.
- **Depth:** Deepness. Distance measured downward, inward, or backward.

b. Measure the height, width, and depth of each yo-yo.

- Which is the largest?
- Which is the smallest?
- How much larger is the largest compared to the smallest?

- What similarities in measurements do you find between different yo-yos?
- What other objects do you think would ALWAYS have the same height and width? -Why? Give examples.

c. Define the following:

Diameter: 1) A line dividing a circle into halves.
2) In a circle, a segment that passes through the center and that has both endpoints on the circle.

Radius: The measure of a line from the center of a circle to a point on the circle.

Circumference: The distance around a circle.

d. Measure the diameter of a yo-yo 1) in inches 2) in centimeters.

e. Calculate the radius of the same yo-yo. (Half of the diameter)

f. Measure the circumference of the yo-yo 1) in inches 2) in centimeters.

g. What measuring tool are you using? What is the best measuring tool to use to measure this kind of object? Why? (tape measure)

h. Can you think of another way to measure a round object's circumference? (Mark the edge of the yo-yo, roll it on a flat measurement tool, such as a ruler, until the marked spot returns to where it started.)

i. **Sort** a group of yo-yos by their color, size, string length. Make a bar graph on paper (or the floor using the yo-yos as markers!!!)

Activities:
Grade Levels: 4-8

2. Measure the diameter of a yo-yo.

a. Can you calculate what the circumference would be?
b. What is the formula you used? (Answer: C = D * Pi)
c. Prove your answer by measuring the yo-yo's circumference.

(Note: About 3" of string is used for the finger loop. In the following exercises, we will ignore that additional 3".)

3. If one yo-yo string was 30" long and one was 40" long, what percentage of the longer string is the shorter string. How did you find the answer?

30 / 40 = .75 or 75%

4. What if the shorter string were 32" long? 36" long?

<u>ESTIMATION</u>

Grade Levels: K-3

1. Assume that your yo-yo string was the perfect length for you and it came from the floor to your waist. If it was 30" long and if you were going to send a yo-yo to your cousin who was about half your size:

a.) Do you think their string should be longer or shorter than yours? Why?
b.) About how long do you think their string should be? Why?

CALCULATIONS
Grade Levels: 4-8

String Length

1. If you stood 60” tall, and your yo-yo string was 36” long, what percent of your height would the string be?

36 / 60 = .60 or 60%

2. If this was the correct percentage for a yo-yo string compared to body height, how long should your string be if you were:

a. 75” tall?

b. 45” tall?

c. What formula are you using to determine your answer? (Use H=height, L=length of string) (Answer: H * .6 = L)

3. 60% of body height is the maximum length a yo-yo string should be to allow you to perform tricks efficiently. Given this fact, what is the maximum length YOUR yo-yo string should be?

4. Define the following:

Mean: Average. The number obtained by dividing the sum of 2 or more addends by the number of addends.

Median: The middle number in a group of numbers when the numbers are listed in order.

Mode: The number that occurs most often in a set.

5. Use the following chart of various yo-yo string lengths and determine the mean, median, and mode. (Answers: 33,32,30)

Yo-Yo #	Length of String
1	30 “
2	32 “
3	34 “
4	30 “
5	36 “
6	35 “
7	38 “
8	32”
9	30“

Suggested Grade Levels: K-3
4-8

Distance

1. If a yo-yo’s circumference was 7”, and you rolled it across the floor, how far would it travel in 5 revolutions?

2. What if the yo-yo was 8” in circumference? How far would it travel? Why?
3. Reversely, if your 8” yo-yo rolled down an incline and turned around, or revolved, 6 times, how far did it travel?

a. How many inches? (8” * 6 revolutions = 48 “)
b. How many feet? (48” / 12” per foot = 4 feet)
c. Convert your answers into centimeters.

4. What if it rolled 96 revolutions?

a. How many inches? Convert to feet.
(8” * 96 = 768 “ / 12” per foot = 64 feet)
b. Convert your answer into meters.

5. If you rolled two yo-yos of different sizes, which yo-yo would turn around, or revolve, more times in the same distance? Why?

(If it rolled 96”, an 8” yo-yo would revolve 12 times, while a 6” yo-yo would revolve 16 times).

CHALLENGE CALCULATIONS

1. Imagine that you stacked all of the yo-yos sold since the 1920’s, when they were first introduced in the United States, on top of each other. This means that you would be stacking about a half a billion yo-yos on top of each other. For simplicity, assume that the depth of each yo-yo (thickness) is 1 ½”.

a. How tall would your stack be?
b. How many miles high would it be?
c. How many centimeters?
d. How many meters?

ANSWER: 500,000,000 * 1.5” = total inches (750,000,000 inches)
Divided by 12” per foot = total feet (62,500,000 feet)
Divided by 5280 (feet per mile)
= number of miles (11,837.12 …round to 11,837 miles)

2. What if you were to tie all of these yo-yo strings together and each string averaged 35” in length.

a. How long would your string be? In inches? In feet? In miles?
(500,000,000 * 35 = 17,500,000,000 inches
/ 12 = 1458333333.33 feet
/ 5280 = 276199.49 or about 276,199 miles)

b. Lookup the circumference of the Earth and the Moon.
(Circumference of Earth: 24,902 miles at the equator)
(Circumference of Moon: 6,782 miles)
1. How many times could you wrap your string around the Earth?
2. How many times could you wrap your string around the Moon?

c. If the only fact that you knew in this exercise was that the radius of the Moon (call it R) was 1080 miles, could you calculate its circumference (call it C)?
(Answer: C = D (diameter) * Pi (3.14)

so C = ((R*2) * Pi) where Pi = 3.14)

d. The Sun is approximately 93,000,00 miles away. Describe your string in relation to the Sun.

DISTRIBUTION OF MASS

Grade Levels: 4-8
(Suggestion: Set up lab stations to perform these tests. Then move into discussion.)

(NOTE: These experiments were taken from the SCIENCE section, but are modified and used here as they relate to mathematical calculations to prove the scientific concepts discussed.)

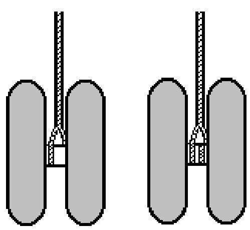
Definition: Where the weight of an object is placed.

The higher the percentage of the mass distributed to the outside circumference of a spinning object, the longer it will spin. This assumes that other factors are equal, such as friction, total mass and velocity of spin.

Activities:

String mechanics

Yo-yos of different designs can be used to demonstrate the concept of distribution of mass. The following exercises require the basic knowledge of attaching a string to a fixed-axle yo-yo. There are two ways to attach the string: double-looped or single-looped around the axle.



Single-looped Double-looped

A fixed-axle yo-yo with a double-looped string (string wrapped around the axle twice) will not spin or "sleep" at the bottom of the string when dropped, but will instead climb a distance back up the string once it reaches the bottom. A yo-yo which has been single-looped will spin or "sleep" at the bottom of the string once dropped.

Find two yo-yos of similar size and weight, one which is solid and one which is rim-weighted (i.e. the percentage of weight is greater toward the outside circumference).

1. Drop-Return.

Equipment:

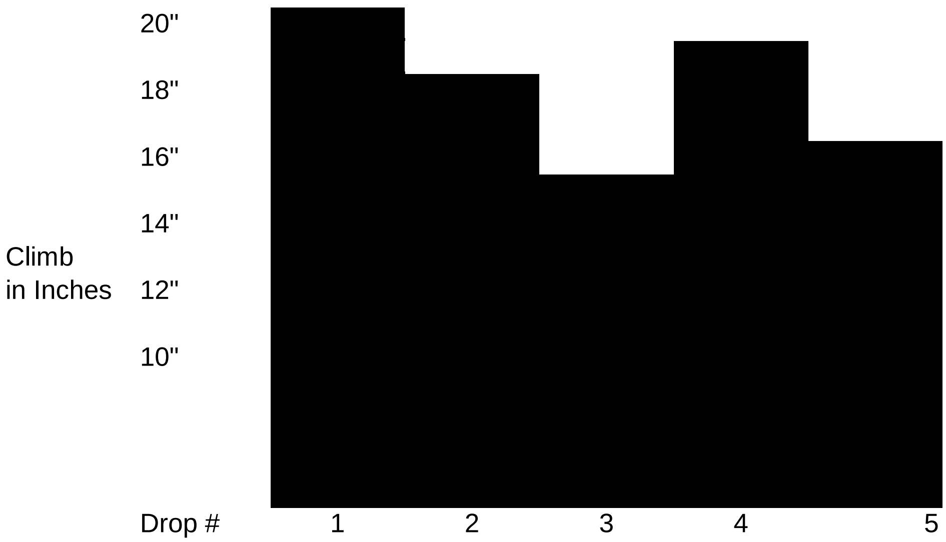
1. 2 yo-yos listed above, double-looped so that they will try to climb back up the string when dropped. Use strings of equal lengths.
2. Yardstick or other measuring device.

Procedure:

Drop each yo-yo from a fixed point and measure the height to which each yo-yo climbs back up the string. Repeat the exercise several times (average) to qualify your discoveries.

1. Record your answers in inches and convert to metric.
2. Make a **Bar Graph** for each yo-yo showing the various climb distance.
3. What was the average climb for each yo-yo? In inches? In centimeters?
4. Which yo-yo climbed higher up the string? How much higher?
5. What percentage higher did it climb?
6. Do you know WHY it climbed higher?

EXAMPLE OF BAR GRAPH
YO-YO "A"



2. Drop-Spin
Equipment:

1. 2 fixed axle yo-yos, as listed above, <u>single-looped</u> so that when dropped, they will spin at the bottom of the string OR 2 ball-bearing transaxle yo-yos (for longer spin times).

    Examples of transaxle yo-yos: Tornado or TigerShark by Spintastics, or Tom Kuhn SBII (rim weighted) and Yomega Raider or Tom Kuhn Roller Woody (non rim-weighted).

2. Stop watch or other timing device.

Procedure:
Drop each yo-yo from a fixed point and measure the duration of the spin by starting the time when the yo-yo reaches the <u>bottom</u> of the string. Stop the timer when the yo-yo stops spinning. Repeat the exercise several times (average) to qualify your discoveries.

1. Record your results.
2. Make a **Bar graph** for each yo-yo identifying the spin times.
3. What was the average spin time for each yo-yo?
4. Which yo-yo spun longer? How much longer?
5. What percentage longer did it spin?

6. Do you know WHY it spun longer?

3. Thrown Spin Time – same yo-yo.

Perform this exercise twice, with the same yo-yo, but modifying the percentage of mass at the rim. Use the same yo-yo for all players. It will be the easiest for players to make the yo-yo spin if you use a ball-bearing yo-yo.
(NOTE: This exercise does introduce an uncontrolled variable of inconsistent throws, however, multiple attempts will minimize this somewhat).

SUGGESTION: The TigerShark yo-yo by Spintastics Skill Toys, Inc. is an excellent yo-yo to use for this experiment. The reason is that it comes with "speed rings" to intentionally increase the rim weight of the yo-yo. These "speed rings" are removeable. Use one TigerShark with speed rings, and another with the speed rings removed. (To remove them, pop off the holographic side disk on each side of the yo-yo and remove the metal rings you find inside by lifting up from under them with a screwdriver or other such tool.) In order to correctly do this experiment, weigh the "speed rings" and use the same weight of clay or "Fun Tack" molded around the central hub of the yo-yo on each side. That way, the total mass will be the same and the only variable will be the distribution of the mass.

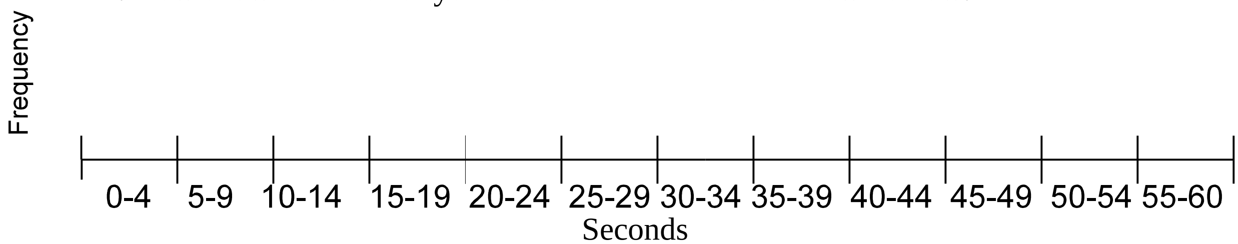
Procedure:
Have each student in the class throw a Spinner. Give them multiple tries and take the throw which resulted in the longest spin. Measure the duration of the spin by starting the timer when the yo-yo reaches the bottom of the string. Stop the timer when the yo-yo stops spinning.

1. What was the longest spin? Shortest? Average? Mode?
2. Make a **Bar Graph** for each yo-yo and summarize your results as in #1 & 2.

3. Now compile the results for the entire class in a **Frequency Table** like the one shown below.

Time (in seconds)	Tally	Frequency
0-4 seconds		
5-9 seconds		
10-14 seconds		
15-19 seconds		
20-24 seconds		
25-29 seconds		
30-34 seconds		
35-39 seconds		
40-44 seconds		
45-49 seconds		
50-54 seconds		
55-60 seconds		

4. Now show the data for your class in a **Line Plot** as shown below.



5. A frequency table and a line plot show the same information. What is the advantage in using a line plot? (Answer: More visual)

Now repeat experiment #3 with the "speed rings" re-installed. Compare results.

Summary questions:
1. Which yo-yo configuration resulted in the longest average spin?
2. Do you know WHY?
3. What % longer did it spin?
4. What similarities do you see between your results in experiment #1, 2, & 3?
Why?

CONCLUSION: Logging and graphing the results in exercises #1, #2, and #3 should have mathematically proven the effectiveness of the distribution of mass on a spinning object.

4. PERCENTAGES. Using strings of different length - same yo-yo.
Equipment:
1. 2 fixed axle yo-yos, as listed above, double-looped so that when dropped, they will try to climb back up the string when dropped. This time, use yo-yos with **different** string lengths.
2. Yardstick or other measuring device.

Procedure:
Drop each yo-yo from a fixed point and calculate the percentage of string length that each yo-yo climbed. Repeat the exercise a several times (average) to qualify your discoveries.

Example:
36" string length climbed 18" = 50%.

1. If a dropped yo-yo returns up 24" of a 36" string, how far will it return up a 30" string?

$$\frac{24}{36} = \frac{2}{3} = \frac{20}{30}$$

Answer: 30 inches

SPEED

Grade Levels: 4-8

The speed of a yo-yo varies, of course, with the player and how hard the yo-yo is thrown. Its measurement needs to be clocked in revolutions per minute (RPMs) and requires a strobe light digital tachometer.

In general, a beginning yo-yo player throws a yo-yo at about 3000 RPMs. An average player increases that to about 6000 RMPs. The highest records RPM measured was 14,300 RPM by Dale Oliver during the U.S. National Competition at Chico, CA in 1994.

In simple terms, RPM is calculated by counting the number of revolutions the yo-yo turns in one minute. For example, presume that a yo-yo had a 6" circumference. Therefore, it travels 6 inches in one revolution. Let's say, when thrown, it revolved 1000 revolutions in one minute. That would mean it traveled 6000 inches in that given minute.

- To calculate the number of feet, divide 6000" by 12" per foot
  = 500 feet per minute.
- To convert this to feet per hour, multiple 500 by 60 minutes per hour
  = 30,000 feet per hour.
- To convert to miles per hour, divide by 5280 feet per mile
  = 5.68 miles per hour. (MPH)

Exercises:

Assume the yo-yo has a 7" circumference:

1. How many miles per hour does the BEGINNER yo-yo player spin a yo-yo?
2. The AVERAGE player?
3. The yo-yo that Dale Oliver used when clocked at 14,300 RPMs was 2.25" in <u>diameter.</u> Can you calculate how many miles per hour his yo-yo was spinning?

ANSWER: 2.25 * Pi (3.14) = 7.065 inches
= circumference or distance in 1 revolution
* 14,300 (revolutions per minute) = 101029.5 inches
= inches per minute
* 60 (minutes per hour) = 6,061,770 inches
= inches per hour
/12 (inches per foot) = 505,147.5 feet
= feet per hour
/5280 (feet per mile) = 95.67
= MILES PER HOUR.

4. Can you think of other objects that travel at similar speeds as these? What?
5. Dale Oliver actually spun three different yo-yos.

a. A wooden yo-yo – spun at 8600 RPMs
b. A rim-weighted plastic yo-yo = spun at 11,400 RPMs
c. A rim-weighted ball-bearing yo-yo = spun at 14,300 RPMs

Calculate the miles per hour that yo-yo a. and b. traveled.

GRAPHING
Grade levels: K-3
4-6

We used various graphs (Bar Graph, Frequency Table, Line Plot) in the Distribution of Mass section as an aid to drawing the correct conclusions, but also to reinforce the steps involved in various graphing methods. This section gives suggestions of situations where various graphs can be used, with yo-yos as the subject. They go from the simple to the more complex.

Introduction to Cooperative Learning and Simple Graphs

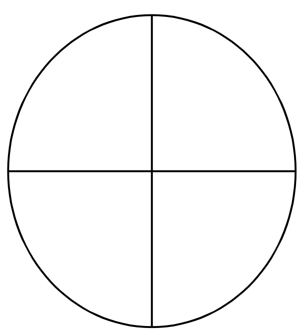
Steps:
1. Divide the class into groups of 4 students.
2. Give each student a title.
- One is the **Reader** (Reads the problem).
- One is the **Recorder** (Records results)
- One is the **Task Keeper** (Keeps the group on task and makes sure everone gets a turn)
- One is the **Reporter** (Reports results to the class)
3. Their assignment is:

> "You are to take a survey of the classmates in your group. Asks each student the following question:
> What color would you select for your own yo-yo if the choices were red, blue, green and purple."

4. They are to work together to decide on their own what kind of a picture, drawing, or graph they can use to show and report their results to the class.
5. Each group will present their findings to the class.

Once this exercise has been completed, review the different ways that the findings in each group were summarized and then have each group summarize their findings again in each of these formal methods.

Circle Graph



Color each quadrant with the favorite color of each student. Put the same color selections next to each other.

Discuss the concepts of:
1. Whole – what if everyone chose the same color.
2. Half – what if only two colors were selected.
3. Quarter – what if each student chose a different color.

(This exercise can even be extended to relate to basic concepts of money.)

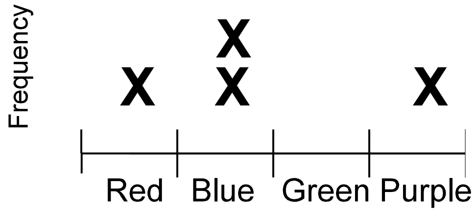
Bar Graph

	4				
Number	3				
of	2				
students	1				
	Color	Red	Blue	Green	Purple

Frequency Table

Color	Tally	Frequency
Red	/	1
Blue	//	2
Green		
Purple	/	1

Line Plot



2. For older students, this exercise can be extended to include a survey of the entire class with more color choices.

3. Dribbling activity.

Have each student in a group of 4 have 5 attempts at dribbling (maximum of 20 dribbles). **Bar graph** each person as a different color.

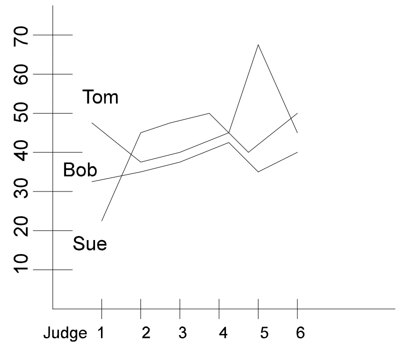
4. Contest Results Exercise. There are three final contestants in a yo-yo contest. They are to perform a freestyle routine, where they will be judged on performance, difficulty of tricks, and accuracy. There will be 6 judges.

Here are the raw results:

FREESTYLE COMPETITION							
		Judge 1	Judge 2	Judge 3	Judge 4	Judge 5	Judge 6
Sue		22	45	47	50	40	48
Tom		49	38	39	42	68	45
Bob		32	34	36	38	35	37

a. Order the numbers for each contestant.

b. Find the mean, median, and mode.
c. Draw a **Line Graph** of the results. Use a different color for each contestant.
Example:



d. What do you notice?
e. Who would have won the contest based solely on these results? (Tom)
f. Can you think of a way to make the contest more fair?
g. Do you see any value in dropping the highest and lowest score for each contestant? If so, what?
h. Who would win the contest if that was done? (Sue)
i. Throw out the high and low scores for each contestant.
- Now find the mean, median and mode for each.
- Why didn't the median change? Will it ever change?
- Why didn't the mode change? Will it ever change? When?

j. Which do you think is the better method?
k. What would happen if you only threw out the low score?
l. Can you think of any other sport where this is done? (Ice Skating, Gymnastics)
m. What was the average score of each contestant?
n. Give examples of when you may need to find the average of some numbers:
- grade scores
- sports (batting averages)
- weather (temperatures)
- credit cards (average daily balance)

SUPER CHALLENGE QUESTION

The Skyrocket is a trick where the yo-yo is spun, removed from the finger, jerked as if it were going to be returned to the hand, but released precisely as the yo-yo reaches the hand, causing it to catapult into the air. Various contests have wanted to, and even attempted to, run a "Skyrocket contest" to determine which player could "catapult" his yo-yo the highest.

1. How would you determine the height the yo-yo traveled?
2. Could it be determined by elapsed time?
3. Is there a formula that could be used given the speed at which objects fall?

* END *