By the Numbers
Study Guide

By the Numbers

A Mathematical Musical for Young Audiences

Book & Lyrics by Mark Amenta

Music by Wolfgang Amadeus Mozart
Orchestrated by Ernest Ochoa

Presented by
Face to Face Productions

The Story of the Play

Albert Einstein uses his Theory of Relativity to travel through time to help his distant relative, 10-year old Eddie Einstein. Eddie is the nephew of the great granddaughter-in-law of the third cousin twice removed of the world-famous mathematician, so everyone expects him to love and excel at math. But Eddie doesn't even feel math is relevant. As far as he's concerned, all the professions he's considering—such as ace detective, star athlete, chef, hip hop artist—don't even use math. So, Albert Einstein puts his new "Theory of Relevance" into effect, arranging visits from The GR-8 Enumerator, Adam Up, and Mama Meter. They and the audience help Eddie explore the fun you can have with math, as well as its relevance to "what you want to be when you grow up."

Educational Goals

- Develop and/or refine mathematical problem-solving skills
- Apply a knowledge and sense of numbers and mathematical operations
- Measure, estimate, and compare quantities, and show outcome probabilities
- Identify number patterns to solve problems
- Encourage creative and imagination skills
- Inspire a fascination in math and its relevance to future careers

Curriculum Applications

- Math: Numbers and number sense; mathematical operations (+, -, x, ÷); estimation; probability; measurement
- Science: Applications of the Theory of Relativity, such as time travel
- Social Studies: Albert Einstein; maps and mapping; and the comparison of periods of history
- Language arts: vocabulary studies; the explanation of math calculations; and coding

Educator Comments

"The mode by which you educate and entertain children is so valuable. As an educator and a parent, I truly appreciate what you have to offer."

-Allan Molby, Principal, Hillside School District 93, Hillside, IL

"As usual, your production was a huge success. I have requested our PTA to book 'Face to Face' every year from now on, since your annual visits to us have truly become an integral part of our culture."

-Dale F. Kuester, Building Assistant, Hunting Ridge School, Palatine,IL

Events that Coincide with the Play's Themes

(See if you can book *By the Numbers* around the time of these events.)

- Math Projects
- Einstein's birthday: March 14 (1879)
- Career events, such as when visitors explain their career
- Your Science Fair or "Invention Convention"

Other Information

- Recommended audience age: K-6
- Length of performance: 45 minutes
- For further information, call 773-631-2013 or visit us at www.FacetoFaceProductions.com

Social Studies & Science Connection: Time Travel

Einstein's Theory of Relativity provided for the possibility of traveling through time. One concept of the theory, which has developed into what we now call String Theory, purports that different time periods can exist at the same time.

- Set the scene for two historical figures from different times periods to meet—what would be different between them: clothing, style of home, language, view of the world? Choose a topic they could discuss from their different vantage points
- Compare time periods—what are the similarities among time periods? Our current culture may be very different from, say, the early settlers. But what are the similarities?

You can also create a time traveling machine in the classroom (use your imagination!) on which students "ride" to another time period. Combine this with social studies lessons so students can travel to meet notable people in history. In the process, students can calculate things like:

- The difference in years between now and a year in the past or present
- Using birth and death dates to determine how old a person in history grew to be
- How long a certain period in history lasted
- The speed of your time traveling machine (years per second?)
- Miles vs. years for a historical figure from another country – i.e. how far away they are geographically and temporally

Art Connection – Making Posters for Einstein

Materials

- Poster board or paper
- Markers, crayons, colored pencils, etc.

Instructions

1. Divide the class into groups of two or three.
2. Have each group imagine that it is the early 1900's and they have been hired by Einstein to make special posters that advertise the importance of math.
3. Let the groups know that it is important to make the posters interesting and easy to understand. Each poster will need to have these parts:
   - A title (example: "Math's a Must!")
   - A drawing of math elements, such as numbers and operational symbols
   - Show one practical application of these math elements (example: calculating change due)
4. Students may also adorn the poster with descriptive and enticing words to get people's attention. They may also use Einstein's famous name and face (the wilder the hair, the better!).

Social Studies Connection: Time Line

If your class studies events that occur between 1879 and 1955, have students construct a time line that includes some of Einstein's key events (below) as well as other historical events during this time period. Have the students point out how Einstein's achievements coincided with what was happening in the world at the time.

1879 Born to Hermann and Pauline Einstein in Ulm, Germany.

1884 Receives his first compass, inspiring a lifelong quest to investigate mysteries of the natural world.

1889 At age 10, begins reading as much about science as he can.

1894 Stays on in Munich to finish the school year after his parents move to Pavia, Italy. Lasts only one term on his own and then follows his family to Italy.

1895 Takes an entrance exam to the Swiss Polytechnic, a top technical university, but fails the arts portion. His family sends him to the Swiss town of Aarau to finish high school.

1896 Graduates from high school at 17 and enrolls at the Federal Polytechnic School (ETH) in Zurich.

1900 Graduates from the ETH.

1901 Becomes a Swiss citizen and searches for work.

1902 Einstein takes a job at the Swiss Patent Office. Hermann Einstein becomes ill and dies.

1905 Publishes, at age 26, five groundbreaking papers, making this his "annus mirabilis," or miracle year. One of the papers introduces his theory of relativity and another $E = mc^2$.

1906 Continues working as an examiner at the Swiss Patent Office in Bern.

1907 Begins applying the laws of gravity to his special theory of relativity.

1911 Given a full professorship at the German University in Prague. Attends the first world physics conference; he is the youngest physicist there.

1912 Moves to Zurich, where he becomes a professor of theoretical physics at the ETH.

1913 Works on his new theory of gravity.

1914 Becomes director of the Kaiser Wilhelm Institute in Berlin and professor of theoretical physics at the University of Berlin.

1915 Completes the general theory of relativity.

1917 Collapses from exhaustion and falls seriously ill.

1919 On May 29, a solar eclipse provides proof of the general theory of relativity.

1922 Awarded the Nobel Prize in Physics for 1921.

1927 Attends fifth Solvay Conference and begins developing the foundation of quantum mechanics.

1928 Begins pursuing his idea of a unified field theory.

1932 As a Jew, begins to feel the heat of Nazi Germany. Now, at 53, at the height of his fame.

1933 Moves to Princeton, New Jersey, where he assumes a post at the Institute for Advanced Study.

1939 Writes a famous letter to President Franklin Roosevelt not long after the start of World War II that warns of the possibility of Germany's building an atomic bomb and urges nuclear research.

1940 Becomes an American citizen (retains his Swiss citizenship).

1955 Dies of heart failure on April 18.

Music Connection: Mozart

The music in *By the Numbers* is from several Mozart pieces:

- Einstein's song, "Math is the Key," is from the first movement of *Symphony No. 40*
- Eddie's song, "What I Want to Be," is from *Rondo Alla Turca*
- The GR-8 Enumerator's "Numbers Song" is from *German Dance No. 4*
- Adam Up's "Calculation Song" is the *Rondo* from *Serenade for strings in G major* or *Eine Kleine Nachtmusik*
- Mama Meter's "Measurement Song" is from the Allegro movement of *Eine kleine Nachtmusik*

Mozart music was chosen because Mozart was Einstein's favorite composer. But, like all music, there is also the math/music connection. Have students find all the concepts and terms that are used in both math and music (don't forget the musical term "measure")

Also, you may want to play each of the Mozart pieces listed above. See if the students can determine why the writer of *By the Numbers* chose each piece: what about the piece relates to the character singing it, the concepts presented, and/or the mood of the moment?

For example, several measures of *German Dance No. 4* have notes that step down the scale, creating a perfect form for counting: "Oh I can think of one, two, three, four, five, six, seven hundred ways that numbers can amaze." The first movement of Symphony No. 40 is very brooding, and Einstein, as he sings, is worried about Eddie not liking or seeing the importance of math.

Math Connection - Restaurant

You can tailor this activity to any K-5 grade level, and can be as simple or as involved as you want to make it. The premise is that the students are either patrons of a restaurant or the people working there. Set up the classroom like a restaurant, with an area for the kitchen, the entrance (host desk), and the dining room. Some ideas of how to incorporate math into the restaurant are:

- Those students in the kitchen will have to follow recipes, and in doing so, will have to measure quantities of ingredients and the lengths/widths of bakeware. They will also calculate the time it takes to cook or bake items.
- The managers of the restaurant can calculate the prices of items based on the prices of ingredients and the time it takes to make the items (time multiplied by hourly rate of the cooks).
- Hosts can calculate how many people the restaurant can seat, and how to arrange tables and chairs to accommodate specific groups who have reservations.
- Servers and patrons can add up patrons' bills and determine the changed due.

Check out the website: **www.nsa.gov/teachers/es/frac01.pdf** – it has a detailed lesson plan for a fourth grade restaurant activity.

Math Connection: The Magical Number 9

In *By the Numbers*, the GR-8 E. Numerator shows Eddie how the number 9 is "magical." Whenever you multiply nine by another number, the numbers of the result always add up to nine:

1 x 9 = 9 → 0 + 9 = 9
2 x 9 = 18 → 1 + 8 = 9
3 x 9 = 27 → 2 + 7 = 9
4 x 9 = 36 → 3 + 6 = 9
5 x 9 = 45 → 4 + 5 = 9
6 x 9 = 54 → 5 + 4 = 9
7 x 9 = 63 → 6 + 3 = 9
8 x 9 = 72 → 7 + 2 = 9
9 x 9 = 81 → 8 + 1 = 9
10 x 9 = 90 → 9 + 0 = 9

Also, you can see that the nine-times table results …

09
18
27
36
45
54
63
72
81
90

… form an interesting pattern. The tens digits start at 0 and go to 9, and the ones digits start at 9 and go to 0.

The GR-8 E. Numerator goes on to say that ***any*** number multiplied by 9 results in a number whose digits will add up to nine. Have your students try this with very large numbers—it's great multiplication practice—or have them use their calculators. Then, for addition practice, have them add the digits of the resulting number. For example:

3,957,824 x 9 = 35,620,416

3 + 5 = 8 8 + 6 = 14 14 + 2 = 16 16 + 0 = 16 16 + 4 = 20 20 + 1 = 21 21 + 6 = 27

Then, the 2 + 7 (from the 27) = 9

Math Connection – More Magic with Numbers

Something magical happens when you add and subtract three-digit whole numbers and their reverse (i.e. the three-digit whole number that has its digits in the reverse order). If you follow the scheme below, the result is always either 1,089 or 198.

Ask students to write down a three digit whole number , for example 832. Ask them to reverse the number—in this case, 238—and to subtract the smaller number from the larger:

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  832
- 238
  594
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Now ask them to reverse the total and to add both numbers together:

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  594
 +495
 1,089
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Try this with various numbers. For some smaller three-digit whole numbers, the answer will always be 198.

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  221
- 122
   99

   99
  +99
  198
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Math, Geography & Language Arts Connection – Mapping

In *By the Numbers*, Eddie Einstein and Adam Up have to complete a map that has missing parts. They use a measuring device and existing points on the map to determine how long the final stretch of a route is. You can do similar exercises with two and even three-dimensional maps in class:

- Have a treasure hunt where the treasures are planted throughout the classroom. Create a map that shows a starting point, the routes to the treasures, and the length of these routes in either paces, inches, or centimeters. Students find the treasures by using the scale and following the routes in the classroom.
- After reading a book that has one or more characters traveling or taking a trip, create the map for that character. Measure the parts of their route and note them on the map. If the students are old enough, devise a scale that translates miles into inches, using math skills to create and use the scale.
- Use the map scale idea on actual maps, and determine the distance between two places you're studying
- Create a live map of the Midwest with each student representing the capital of each state. Use a scale to determine where each student must stand to accurate represent the distance between capitals.

Math & Language Arts Connection – Secret Codes

In *By the Numbers*, Eddie Einstein has to crack two number codes. One is a number sequence problem involving finding the missing number. The other is a cryptogram in which each number represents a letter of the alphabet. You can use the same kinds of number codes in your classroom to help with the following topics. In each case, choosing the correct number or number sequence can result in a prize:

- Help with spelling – Using a cryptogram as described above, students have to determine which number code represents the correct spelling of a word.
- Help with homonyms – For example, use cryptograms, having one number sequence spell out "blue" and another spell out "blew." Then, students have to match number sequences to pictures that relate to these words.
- Help with counting and odds/evens – Using a basic number sequence like consecutive even numbers, have student determine a missing number. For example, 2 - 4- 6 - __ - 10. Then, use that number, 8, to count out eight keys that have odd numbers on them. Have more than eight keys, but only seven of the total are all odd numbers, and one is blank. Have the students put the keys in order: 1 - 3 - 5 - 7 - __ -11 - 13 - 15. Then have them determine the missing number. And so on.

Language Arts Connection: Vocabulary

Many words in *By the Numbers* are mathematical (and part of the math standards vocabulary). But there are other non-mathematical words with which students may be unfamiliar. Have your students look up the words below and present their definitions to the class.

benefit	enhance	indispensable	occupation	similarity
bracing (adj.)	enumerate	intention	overjoyed	stance
cinematic	essential	investor	precisely	supersonic
countless	evidence	lasso	quantum	touchdown
doubly	fussbudget	latitudes	rarity	troublesome
duress	grave (adj.)	multiple (adj.)	reckon	various
engrossed	inclined	navigate	relevant	"wunderbar"

Language Arts Connection: Phrases & Idioms

In *By the Numbers*, the characters use many meaningful phrases and idioms with which your students may be unfamiliar. See if the students can determine what the phrases mean, and then to use the phrases in their writing:

be fluent in something
be inclined
be world renowned
behind the scenes
commanding lead
crime doesn't pay
down the line
fall in line
just for kicks
measure up to something
putting on the heat
rustle up something
scratch the surface
something "is key"
strike the right chord
suit someone well
take a pass on something
the tools of the trade

Language Arts Connections: Word Search

N	E	Q	U	A	L	S	A	D	S	E	D	Y	R	N
O	P	T	N	E	I	T	O	U	Q	L	I	G	E	O
R	P	O	I	U	N	C	S	F	U	C	V	F	C	I
E	J	R	N	S	E	X	Z	G	A	R	I	E	T	T
T	V	B	O	U	U	V	M	H	R	I	S	L	A	A
E	J	N	G	B	F	M	K	J	E	C	I	G	N	C
M	E	W	A	T	A	D	D	I	T	I	O	N	G	I
I	T	F	X	R	B	B	A	S	D	D	N	A	L	L
R	A	R	E	A	V	K	I	W	E	E	T	I	E	P
E	M	B	H	C	J	F	N	L	L	N	M	R	B	I
P	I	V	W	T	B	T	H	G	I	E	H	T	V	T
N	T	H	G	I	E	W	N	B	N	T	K	T	C	L
J	S	K	N	O	G	A	T	C	O	V	Y	Z	A	U
V	E	L	E	N	G	T	H	V	T	N	I	O	P	M

Find the words listed below in the box above—either left to right, right to left, upward, downward, or diagonally.

ADDITION	SQUARE	AREA
SUBTRACTION	RECTANGLE	PERIMETER
MULTIPLICATION	TRIANGLE	SUM
DIVISION	CIRCLE	ANGLE
QUOTIENT	OCTAGON	WEIGHT
PROBABILITY	HEXAGON	HEIGHT
ESTIMATE	POINT	LENGTH
EQUALS	LINE	MATH

Language Arts Connection: Einstein's Quotes

Below are some of quotes from Einstein that tell us a lot about the person he was as well as his philosophies of science and work. You can use these quotes in an activity in which you:

- Have students write a short essay or story that relates to one of the quotes
- Have students write their own adage about math, science, mystery, time, etc.

Imagination is more important than knowledge.

Reality is merely an illusion, albeit a very persistent one.

The only real valuable thing is intuition.

A person starts to live when he can live outside himself.

I never think of the future. It comes soon enough.

Sometimes one pays most for the things one gets for nothing.

Anyone who has never made a mistake has never tried anything new.

Everything should be made as simple as possible, but not simpler.

Science is a wonderful thing if one does not have to earn one's living at it.

Do not worry about your difficulties in Mathematics. I can assure you mine are still greater.

Equations are more important to me, because politics is for the present, but an equation is something for eternity.

The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science.

Not everything that counts can be counted, and not everything that can be counted counts. (Sign hanging in Einstein's office at Princeton)

References: Math, Mozart & Einstein Websites

Topic	Website
Albert Einstein Biography	712educators.about.com/cs/biographies/p/einstein.htm
Albert Einstein, a Science Odyssey	www.pbs.org/wgbh/aso/databank/entries/bpeins.html
Albert Einstein's voice	www.aip.org/history/einstein/voice1.htm
Math & Music	www.math.niu.edu/~rusin/uses-math/music/
Math Activities	www.aplusmath.com/
More Math Activities	www.apples4theteacher.com/math.html
Math Lesson Plans	www.col-ed.org/cur/math.html
More Math Lesson Plans	mathforum.org/teachers/elem/lessons-collections.html
More Mozart for Children	www.surfnetkids.com/mozart.htm
Picture Books about Math	www.barbsbooks.com/picture_books_about_math.htm
Teaching Math	www.canteach.ca/elementary/math.html