



The Defying Gravity Educational Outreach Program is funded by the National Space Biomedical Research Institute (NSBRI #00-02-013)

Thinking Big

Imagine a large jar filled with candies. You know, the small chocolate ones that melt in your mouth, not in your hand. How many candies would be in the jar? What if the jar was the size of the earth?

Now consider the problem facing scientists studying space. In estimating the number of celestial bodies, they must imagine a candy jar the size of the known universe - no easy task. To represent the sun, and stars like it, Defying Gravity is using rapeseeds, tiny seeds used to produce canola oil. One tiny rapeseed is used as a model for our sun. To keep relative sizes in mind, consider that it takes one million earths to fill the sun's volume.

In a 25 Liter bucket there are 7.225×10^6 rapeseeds. It would take half of a football field, crammed tight with 250 buckets full of rapeseeds, to represent the number of stars in our Milky Way galaxy alone. But in considering the total number of stars, quasars, pulsars and other types of celestial bodies, we cannot stop at the galactic football field. We must imagine even greater quantities of rapeseeds. Quantities that perhaps even the entire earth could not hold.

The quintessence of the first module of the Defying Gravity program, Thinking Big, lies in the concepts of size and quantity. That scientists have been able to measure a thing as tiny as the quark, a submicroscopic particle that exists in the nucleus of an atom, is amazing. But as we look to the other end of the spectrum, we see something equally as amazing: the size of the visible universe

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DEFYING GRAVITY ADVANCES TO BETA-TESTING PHASE IN NOVEMBER



The Defying Gravity professional staff.

Capitalizing on the productive successes of the Summer Institute, the Defying Gravity program is now shifting its focus to the classroom. Manhattan Center for Science and Math and Life Sciences Secondary School, both in Manhattan, are the new laboratories in which program directors will turn the lesson plans developed in the summer into a viable and exciting curriculum for young science students.

Students from both schools have signed up and begun attending after school

meetings at MCSM. Transportation to the Upper East Side location is provided for the students and teacher from LSSS.

The facilities available at MCSM include a recently remodeled physics laboratory and a very willing faculty including some already familiar with the DG program. Ms. SauLing Chan, one of the productive teachers who participated during the DG Summer Institute, brought many of her students into this second phase of the project.

Phase II will consist of sessions with thirty-six high school students, divided into nine groups of four, held twice each month. Eight modules will be presented, each of which will include a visit by a NSBRI scientist from Mount Sinai. Pizza and other foods are provided for students prior to each session.

Defying Gravity will utilize digital video and photographic equipment to record each session of this beta-testing phase (see article below for more details).

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First Module: Thinking Big - Magnitude and Powers of Ten

The Defying Gravity program conducted its first session at the Manhattan Center for Science and Math on November 28, 2001. More than thirty-five student volunteers stayed until well after the final school bell rang to see and hear the science bonanza in room 307.

Dr. Roopali Singh launched the beta-testing phase of the Defying Gravity program with a lesson on scientific notation and the expression of very large numbers using Powers of Ten. She used conventional teaching methods and commonly found props to illustrate scientific concepts. At one point, Dr. Singh used a basketball and a single M&M candy to represent the relative sizes of the Sun and the earth, respectively. Quiet murmurs from the crowd of nearly forty students, volunteers and faculty revealed the interest that Dr. Singh

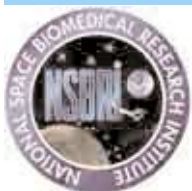


Crammed tight with 25L buckets, this field would hold twice as many seeds as there are stars in our galaxy.

evoked with this demonstration.

One of the highlights of her talk was a video called "Powers of Ten," by Charles and Ray Eames. The video was made in 1977 by the multitalented husband and wife team. The Eames were involved with many American cultural movements in the twentieth century, including such diverse fields as architecture, abstract art and science. Their video, projected digitally in the DG classroom, traverses the universe in

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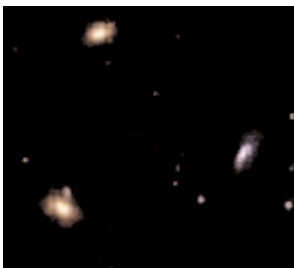
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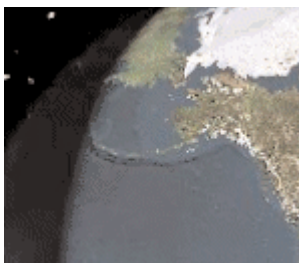
Principle Author
Roopali Singh

Galaxies with-
in our own
cosmic region:
Scale = 10^{23}
Meters or 100
Zetta-
Meters



A hundred
billion stars
of the Milky
Way Galaxy:
Scale = 10^{21}
Meters or 1
Zetta-
Meter

The earth
from nearby
space: Scale
= 10^7
Meters or
10 Mega-
Meters



Essential Concepts of PowerPoint Digital Presentation

- Magnitude of things around us
- Relative sizes of the sun and surrounding planets
- Relative distances from the sun to various stellar bodies
- Actual distance from sun to stellar bodies
- Expression of enormous distances in Powers of Ten notation
- Mars mission: how fast, how long, how far?

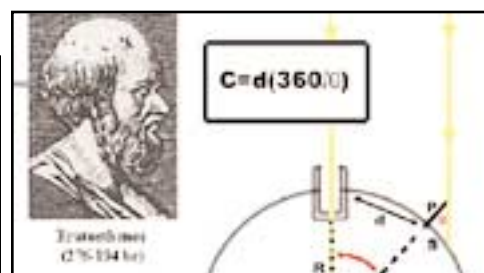
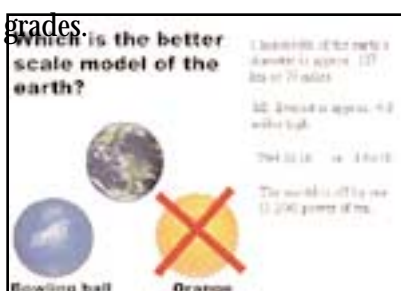
- Introduce concepts of size and Powers of Ten notation by having students imagine both large and small objects.
- Digital movie presentation - "Powers of Ten" by Charles and Ray Eames."
- Discussing using Powers of Ten to represent the long distances involved in space travel.
- Student Activity: using Powers of Ten to represent vast numbers, estimating extremely large numbers using known small quantities. Students are shown a piece of sod, 100 cm^2 . Given the number of blades of grass in the square piece, students must estimate how many blades of grass are in a football field (as in European football, field measures $100\text{m} \times 50\text{m}$). Using proportions, if 100 cm^2 contains 5000 blades of grass, the entire football field contains 2,500,000,000 blades of grass. How is this expressed using Powers of Ten notation? $X = 2.5 \times 10^9$.
- Demonstration: using a basketball to represent the sun and objects proportionately relative in size to represent planets, show the comparative sizes and distances of planets and our local star.
- Discuss upcoming Mars missions, emphasize the implications of distance on space travel for humans. For example, communications sent to earth from Mars would take four minutes. In case of a medical emergency en route, response and instruction from earth would take a total of eight minutes in radio wave travel time. What are the ramifications of this delayed communication. What must NASA do to countermeasure this obstacle? Students are asked to think critically about distance, time and representing large figures in concise, scientific form.

The Math Behind Powers of Ten by Benjamin Shemmer

Mr. Shemmer detailed the mathematics behind the concepts discussed previously by Dr. Singh. Below is an example of one slide used to elucidate the notion of measuring distance across a spherical surface. Mr. Shemmer also compared the earth to an orange and a bowling ball, and discussed the ramifications of the incredible distances involved in sending a manned mission to the planet Mars.

Below left is the outline for Mr. Shemmer's lesson. Though some of the material was elevated for the target grade level, the introduction to such complex ideas as linear regression ($y=mx+b$), provided a glimpse of how difficult it is to plan for and execute a successful interplanetary journey. This lesson also paved the way for mathematics to be learned in tenth and eleventh

Sequential digital slides helped Mr. Shemmer illustrate complex points.



Eratosthenes calculated the earth's circumference.

Defying Gravity Module 1: Magnitude - Powers of Ten

The Activity conducted with Dr. Patrick Gannon

Dr. Patrick Gannon explained the differences between **estimation** and **calculation** at the start of the hands-on activity. Between his fingers, he holds a tiny seed.



Dr. Sam Marquez demonstrated how he poured seeds into a monkey skull, using methods similar to those used by the students to calculate the volume inside the skull



Estimating the number of seeds in the 5 milliliter vial. Using this figure, students then tried to estimate the number of seeds in a 25 Liter volume.



Students measured out a 1 milliliter volume of seeds in the given syringe.



Using counting sticks and paper plates, students counted the actual number of seeds in 1 mL. Then they calculated the number in a 25 Liter volume.

In this activity developed by program director Dr. Patrick Gannon:

Students were given 5 milliliters of rapeseeds in a glass vial, paper plates, counting sticks, and an empty 3 milliliter syringe.

1. Each student estimated the number of rapeseeds in the 5 milliliter vial.
2. Based upon the initial estimate of the number of seeds in a small volume, students estimated the number of rapeseeds in the 25 Liter bucket (pictured with Dr. Gannon).
3. Working in planetary groups of four, students measured out 1 milliliter of seeds. Then, using paper plates and wooden stir sticks, they counted the number of seeds in this volume.
4. Using proportions, students calculated the number of rapeseeds in the 25 Liter container based on the true number of seeds in the 1 mL volume.
5. The average value calculated by all the teams was compared to individual estimates made before the lab started. Congratulations Pedro Salcedo for the closest calculated value!
6. **Critical Question:** How many 25 Liter buckets filled with seeds would represent the number of stars in the Milky Way Galaxy? **Hint:** There are 200,000,000,000 (2×10^{11}) stars in the Milky Way. **Answer:** 27,682 (or half a football field, tightly packed)

Essential Concepts in this Module:

1. Powers of Ten notation help scientists represent extremely large values in a concise manner.
2. Using appropriate mathematics, very large values can be calculated from very small known values.
3. The universe is enormous; scientists must use these concepts and Powers of Ten notation to gain understanding about our galaxy and beyond.

DG Advances to Beta-Testing Phase in November, 2001

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A powerful new Macintosh computer, the Audio-Visual industry standard, has been purchased for the purposes of piecing together and editing the various video content.

Furthermore, graduate assistants Jason Schneiderman, Craig Rothstein, and high-school program volunteer Zac Cederbaum are on hand to assist Drs. Patrick Gannon and Nancy Kheck as they run each session.

Students present at the introductory session were excited at the prospect of learning about space travel and its resultant

effects on the human body. The future scientists and doctors raised their hands to ask many questions about what this phase of the program held in store for them. Of particular interest were Mr. Schneiderman's and Zac's experiences at Space Camp and Space Academy.

MCSM faculty such as Ms. Irma Garceau, were on hand for the introductory session. Ms. Garceau has been integral to the realization of the project's desires to utilize MCSM as the host school for the testing phase. She will remain in close contact with DG faculty for the entire school year to facilitate communications and ensure procedural propriety.

Roopali Singh, a PhD in her native India and a science teacher at LSSS delivered the first lesson plan, Thinking Big. Understanding scientific notation is crucial to continuing studies in science, especially

when dealing with the astronomical figures that go hand in hand with space travel (try writing all the zeros in the distance figure from the earth to Mars). The lesson plan for this module has been revised numerous times by a panel of DG professionals, including program director Dr. Gannon, Dr. Kheck, Dennis Bassin and others. The combination of goal-oriented scientists and experienced teachers has resulted in the formation of a concise, detail-filled and attention-grabbing lesson for ninth and tenth graders.

The conjunction of the preliminary modules with the beta-test phase students' critical input should result in the achievement of an interesting and comprehensive web-based educational tool.

The DG Newsletter will provide monthly updates on program progress and will present each module in some detail.

Thinking Big

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as we know it is so large that we would need to write a "1" and 42 "0"s to represent it. In scientific notation we would represent this as 10^{42} . This number is so huge that it is impossible to visualize. Such is the nature of the science involved in measuring the size of our known universe.

By having students count for themselves a known small volume of seeds, and then asking them to estimate and calculate the number of seeds contained in a very large volume (25 L), Defying Gravity seeks to introduce them to the enormity of astronomical science. The hands-on activity gives students a chance to see for themselves how scientists study the sky. The laboratory is a good place to teach students about the techniques of science, but it is the idea of outer space and its unfathomable hugeness that Defying Gravity seeks to use to motivate students to learn.

Stare at the rapeseed in your hand. Then imagine a star-filled sky on a moonless night. Imagine the largest container filled to the brim with your seeds. Imagine how many seeds that must be. Returning to the night sky, think how your number of seeds doesn't even approach the number of galaxies, solar systems, suns and planets that exist beyond the realm of human understanding. It is the idea of this un-quantifiable enormity that drives scientists to search harder for answers and, hopefully, students to study harder

DG First Module - Thinking Big, Powers of Ten

Lesson Plan Principle Author: Roopali Singh
Presenters: Benjamin Shemmer, Sam Marquez,
Dr. Patrick Gannon

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The Rapeseed, source of canola oil and measuring instrument.

terms of powers of ten magnification, from the submicroscopic world of a human hand to the farthest reaches of the visible universe.

Dr. Singh conducted a rigorous classroom session, posing questions to the students and involving as many as she could in the answers. She used the blackboard extensively, outlining the points of her lecture as well as showing students, step by step, how to utilize the powers of ten notation.

Benjamin Shemmer, a faculty associate from a private school on the Upper East Side, took the reins from Dr. Singh in the second session of the Powers of Ten module. Using a very detailed PowerPoint presentation, Mr. Shemmer extrapolated on the

mathematical concepts presented in Dr. Singh's lesson.

Mr. Shemmer, like Dr. Singh before him, called on as many students as possible to answer his questions. No student was safe as he posed challenging mathematical problems and demanded answers from students around the room. Not so surprisingly, many students responded with excellent answers, showing that the group was up for the DG challenge.

Mr. Shemmer fascinated students with his demonstration of proper scale models for the earth and with stories of the ancient scholar Eratosthenes of Cyrene. Eratosthenes was born in North Africa and spent years studying in Athens. He made an accurate calculation of the circumference of the earth by comparing the noon shadow at midsummer between Syene, where the Aswan Dam in Egypt now stands, and Alexandria. Assuming the sun's light rays were for the most part parallel, Eratosthenes was able to measure the circumference of the earth.

Mr. Shemmer, using successive digital slides animating his point and Eratosthenes as his example, challenged the students to perform mathematical calculations using powers of ten notation. By the end of the lesson it was clear that Mr. Shemmer had tapped his students' math abilities and piqued their interest as well.