ZOELLNER
ARTS CENTER

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School Show Study Guide:

THE PHYSICS EXPERIENCE

Enter a world controlled by physics!

Friday, September 29, 2017 at 10:00 a.m. and 12:30 p.m.
Baker Hall at Zoellner Arts Center

USING THIS STUDY GUIDE

Dear Educator,

On **Friday, September 29,** your class will attend a performance of *The Physics Experience* at Lehigh University's Zoellner Arts Center in Baker Hall.

You can use this study guide to engage your students and enrich their Zoellner Arts Center field trip.

Materials in this guide include information about the performance, what you need to know about coming to a show at Zoellner Arts Center and interesting and engaging activities to use in your classroom prior to, as well as after the performance. These activities are designed to go beyond the performance and connect the art to other disciplines including:

Physics	Footwork
Culture	Teamwork
Communication (verbal and non-verbal)	Choreography

Before attending the performance, we encourage you to:

- Review the *Know Before You Go* items on page 3, with your students.
- Discuss with your students the information on pages 4-5 *About the Show* and *About the Physicist*.
- Help your students understand the key physics terms on pages 6-7
- Engage your class in two or more activities on pages 8-12.

At the Performance, we encourage you to:

- Encourage your students to stay focused on the performance.
- Encourage your students to make connections with what they already know about physics
- Ask students to observe how various show components, like costumes, lights, and sound, impact their experience at the theater.

After the show, we encourage you to:

- Look through this study guide for activities, resources and integrated projects to use in your classroom.
- Have your students complete the reflection questions on page 13.

We look forward to seeing you!

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Section 1: KNOW BEFORE YOU GO

Be prepared and arrive early. Ideally, you should arrive at the Zoellner Arts Center 20-25 minutes before the show. Allow for travel time and bus unloading or parking and plan to be in your seats at least 15 minutes before the performance begins.

Be aware and remain quiet. The theater is a "live" space. You can hear the performers easily, but they can also hear you. You can hear other audience members, too! Even the smallest sounds like rustling papers and whispering can be heard throughout the theater; it is best to stay quiet so that everyone can enjoy the performance without distractions. The international sign for "Quiet Please" is to silently raise your index finger to your lips.

Show appreciation by applauding. Applause is the best way to show your enthusiasm and appreciation. Performers return their appreciation for your attention by bowing to the audience at the end of the show. It is always appropriate to applaud at the end of a performance, and it is customary to continue clapping until the curtain comes down or the house lights come up.

Participate by responding to the action onstage. Sometimes during a performance, you may respond by laughing, crying or sighing. By all means, feel free to do so! Appreciation can be shown in many different ways, depending on the art form. For instance, an audience attending a string quartet performance will sit very still while the audience at a popular music concert may be inspired to participate by clapping and shouting.

The artists may ask you questions or invite you to participate in the show by clapping or even joining them on stage. You should feel free to join or not, but if spoken to directly, please respond politely.

Concentrate to help the performers. These artists use concentration to focus their energy while on stage. If the audience is focused while watching the performance, the artists feel supported and are able to do their best work. They can feel that you are with them!

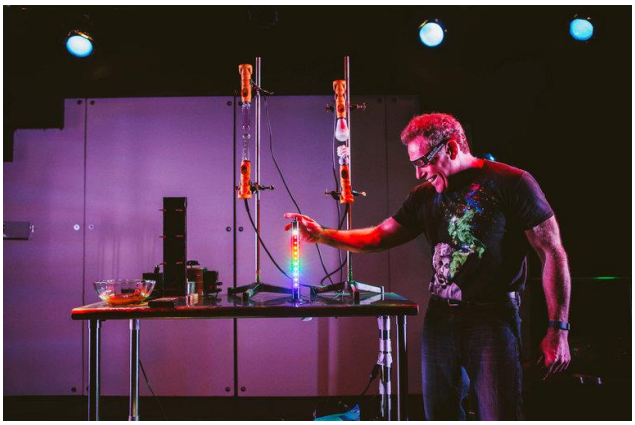
Please note: *Backpacks and lunches are not permitted in the theater. There is absolutely no food or drink permitted in the seating areas.* ***Recording devices of any kind, including cameras, cannot be used during the performances. Please remember to silence your cell phone and all other mobile devices***. The artists are performing challenging and sometimes dangerous work which can become more dangerous by outside distractions.

Section 2: ABOUT THE SHOW

David Maiullo is the star Physics demonstrator featured in an off-Broadway show similar to *The Physics Experience* that you will see at Zoellner Arts Center. Although it is called a different name, *The Physics Experience* presents some of the same demonstrations and principles as the off-Broadway production. Please read below.

Where Newton Meets Nitrogen

Graeber, Laurel. "Review: 'That Physics Show,' Where Newton Meets Nitrogen." *The New York Times*. The New York Times, 07 Apr. 2016. Web. 31 May 2017.



Dave Maiullo may have developed the perfect deterrent to theatergoers who text and tweet during plays: threaten to dip their smartphones in liquid nitrogen.

Mr. Maiullo never actually enforced this during a recent performance of "That Physics Show." But he did immerse other objects, including a hot dog, a banana and some spring blossoms. The results weren't pretty.

But what Mr. Maiullo does onstage is still extremely cool, and not just because the temperature of liquid nitrogen is more than 300 degrees below zero. As he explains, "Physics is the Supreme Court of the sciences." It determines the laws of the universe, and chemistry and biology have no choice but to fall into line. And like a Supreme Court hearing, physics is often accompanied by pyrotechnics. During the 90 minutes or so of this production, you'll witness electricity (controlled), explosions (minor) and flames (contained, I promise).

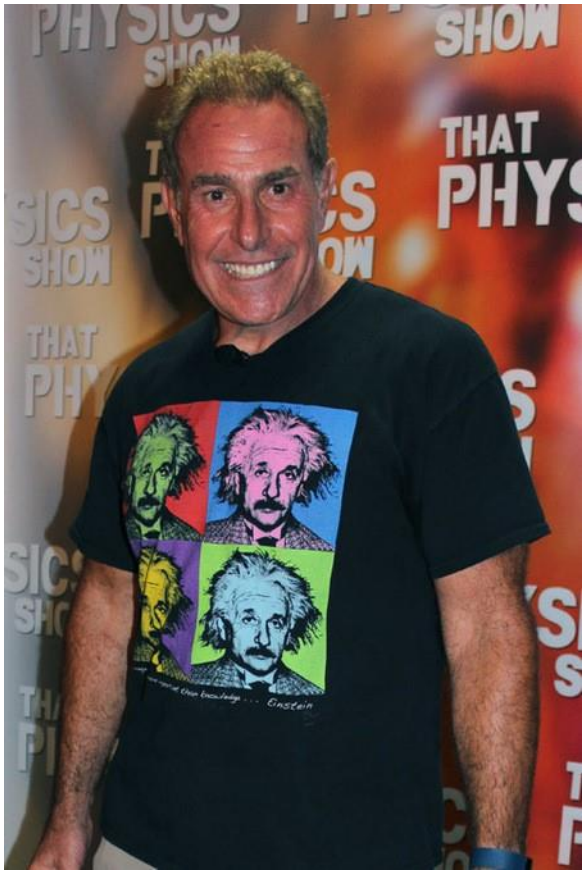
I first encountered Mr. Maiullo, who designs physics demonstrations for Rutgers, a dozen years ago, when he assisted in a presentation at the American Museum of Natural History. In this production he largely flies solo, though two assistants — and occasionally an eager young audience member — help. He dedicates his theater piece to demonstrating Newton's laws, which operate every day, but rarely this theatrically. How often do you get to see a child's wagon propelled by a fire extinguisher? Or a pickle become a light bulb?

The most intriguing moments in "That Physics Show," however, are when Mr. Maiullo makes the invisible visible. We can't see sound waves, but using a device called a flame tube, and a recording of Frank Sinatra singing "New York, New York," he translates their movement into a fiery pattern. And while we're not conscious of atmospheric pressure, we can appreciate its force when Mr. Maiullo creates a vacuum in a long cylinder containing a Ping-Pong ball, and then lets air back into the tube: The innocuous-looking little ball becomes a 700-mile-per-hour projectile, able to pierce a row of three empty soda cans.

Mr. Maiullo can go awfully fast himself, and occasionally I wished he had taken more time with his explanations. But, as he reminds you, there won't be a test. "That Physics Show" is like having your really hip uncle teach science class for a day. You may not completely master the lesson, but you'll love the lab.

Who is Dave Maiullo?

When Maiullo arrived on the job, he found a disorganized storeroom, low-tech audiovisual equipment and professors who didn't always have the knack of matching their demonstrations to their curricula. He took up residence in the physics lecture hall, an architecturally stunning building, he agrees, but "anytime your roof slopes inward, you're asking for trouble." He spent years helping the university's maintenance staff plug leaks and adjust the heating and air conditioning. He organized the storeroom to reflect the progression of the freshman physics curriculum, went on scavenger hunts for flashy but inexpensive equipment, and updated the foyer's display windows and boards to convey the excitement of modern-day physics. He also worked with professors to extend their use of demos and introduce the concept into upper-level classes. "I'm helping our professors hold the interest of their students and convey the excitement of physics," he says. "If I can make their teaching job easier, they'll do a better job."



While he never misses the chance to talk about the fun of his job, he fully understands its serious side. "It's not that I can't, or don't, make mistakes. In fact, those can turn into teachable moments. But if my demos don't work, or the professors can't perform them, then I've failed." Fortunately for the hundreds of students who file into the physics lecture hall each year, the show does go on, and always to rave reviews.

When he leaves the lecture hall workshop, Maiullo enjoys working out, puttering around the house and garden, hiking, and watching baseball and football, especially the Baltimore Orioles and Indianapolis (formerly Baltimore) Colts. He started rooting for both teams as a kid in 1968, a contrarian position for someone from northern New Jersey, he admits, but he liked their classy players and consistently good teams.

Section 4: TERMS TO KNOW FROM THE SHOW

As you study the terms and definitions, check the ones you memorize and understand.

- ☐ **Acceleration** - Increase in the rate or speed of something.
- ☐ **Centripetal force** - The component of force acting on a body in curvilinear motion that is directed toward the center of the curvature axis of rotation
- ☐ **Centrifugal force** – The apparent force, equal, and opposite to the centripetal, drawing a rotating body away from center. It is calculated as the mass (m) of an object, its distance from the center (r) and tangential velocity (v) are known
- ☐ **Displacement** - In physics, displacement refers to an object's overall change in position
- ☐ **Energy** - Energy is the ability to do work. The standard unit of measure for energy is the joule.
- ☐ **First law of motion** - The first law of motion states that any object in motion will continue to move in the same direction and speed unless external forces act on it.
- ☐ **Force** - Force is the measurement of a push or pull on an object.
- ☐ **Friction** - Friction is the resistance of motion when one object rubs against another. It is a force.
- ☐ **Gravity** - Gravity is a force caused when the mass of physical bodies attract each other. On Earth, gravity pulls down objects with an acceleration of 9.8 m/s^2.
- ☐ **Mass** - Mass is a measurement of how much matter is in an object.
- ☐ **Momentum** - Momentum is a measurement of mass in motion. Momentum is equal to the mass times the velocity of an object.
- ☐ **Physics** - the branch of science concerned with the nature and properties of matter and energy.
- ☐ **Second law of motion** - The second law of motion states that the greater the mass of an object, the more force it will take to accelerate the object.
- ☐ **Third law of motion** - The third law of motion states that for every action there is an equal and opposite reaction.

- **Velocity** - Velocity is the rate of change in an object's position. Commonly called speed.
- **Weight** - Weight is the force of gravity on an object. It is a force.
- **Work** - Work occurs in physics when a force acts on an object to move it some distance.

Section 5: CLASSROOM ACTIVITIES

Use the activities and experiments on pages 8 through 12 to better understand physics!

Adaptation of David Maiullo's Bed of Nails Experiment

This experiment is very similar to the experiment David Maiullo conducts with his bed of nails. In this experiment, however, instead of nails, we will be using thumbtacks. The secret to making this experiment a success is surface tension. Surface tension is a force present within the surface layer of a material that causes the layer to behave as an elastic sheet. This is the same principle that allows insects, such as water striders, and spiders, or fisher spiders, to glide across the surface of water.

Materials:

- Thumbtacks
- Balloons

Procedure:

First obtain one thumbtack and show students that it will pop a balloon because the pressure of the tack is applied directly to one space on the balloon which is why it pops.

Then gather many thumbtacks and place them close together on the table. How many thumbtacks you will need depends on the size of the balloon. The larger the balloon, the more thumbtacks needed to cover the surface area of the balloon.

Once there are many thumbtacks gathered under the balloon, proceed to push the balloon into the tacks. Students should see that the balloon is not popping.

Why doesn't the balloon pop?

The pressure of the nails is diffused all along the balloon's surface area equally. Just like the balloon, when a person lies on a bed of nails, their body is evenly distributed across the surface of the nails. The only real danger of being punctured by a nail is if the performer does not lie down or get up correctly and pressure points of the nails are concentrated on one area of the body.

Water, Weight, and Centrifugal Force

https://www.education.com/science-fair/article/how-slow-can-you-go-until-centrifugal/

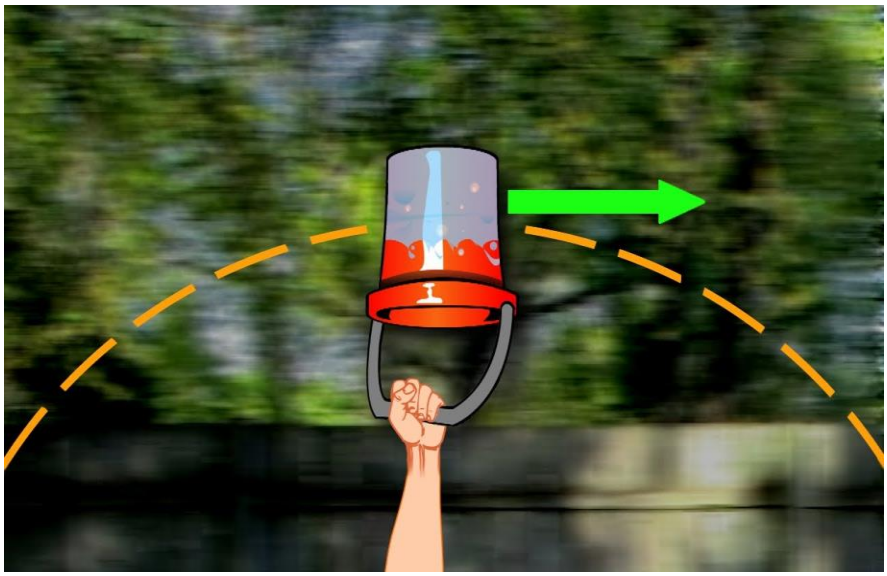
Materials:

- Plastic bucket with handle
- Scale
- Large jug
- Water
- Meter stick
- Notebook and pencil

Helpful tips and equations:

- 1 kilogram = 2.2 lbs.
- To calculate **Centripetal force**, you must identify the mass, (m) of the object; its distance (r), from the center; and the tangential velocity (v). This equation is based on the metric system; note that the centripetal force, f, is measured in Newtons. One Newton is approximately 0.225 lb.

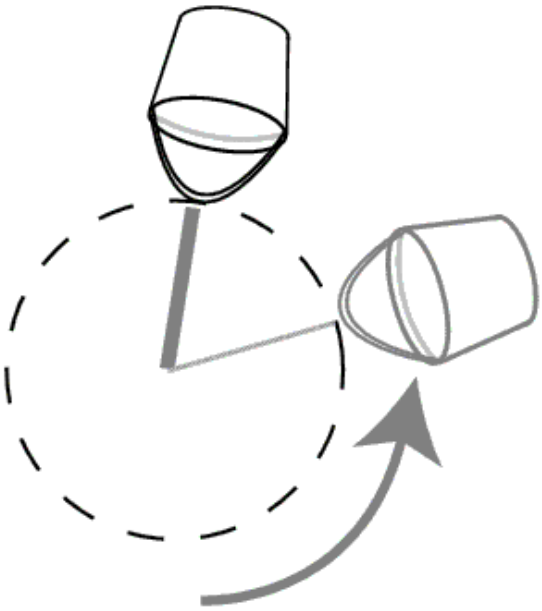
$$F_{centripetal} = m\frac{v^2}{r}$$



Procedure:

1. Measure your arm from the shoulder to your hand. When spinning the bucket, this will be the radius of the circle. Record the length in meters.
2. Weigh the bucket on the scale. Record the weight.
3. Place the large jug on the scale and record the weight.
4. Pour water into the jug and record the weight. Subtract the weight of the jug to get the weight of the water alone.
5. Convert the weight of the water into kilograms. *Why is it important that the mass is in kilograms?*
6. Pour the water into the bucket.
7. Go outside to an area where it is okay to spill water. With your arm fully extended, swing the bucket around in circles.
8. Swing the bucket slower and slower until the water spills out.
9. Using the centripetal force equation, calculate the velocity of your spin for the mass of water in the bucket. *How do you solve for velocity? What is significant about this force? This velocity?*
10. Repeat the experiment with different masses of water, or even different radii by tying a rope to the bucket handle.
11. Compare centripetal force to gravity exerted on the water. *How much water can you swing for a given velocity?*

Why?



Centripetal force exerted on a spinning object like our bucket of water also leads to an equal and opposite **centrifugal force,** an apparent force that draws a rotating object *away* from the center of rotation (thus holding the water in the bottom of the bucket as it passes overhead). Centrifugal force is a consequence of **inertia—**the tendency of a moving object to want to continue moving in a straight line. As we fling our bucket of water in an arc over our head, the water *wants* to continue traveling in a straight line, but our string constantly redirects the water so it travels in an arc instead! Water's inertia resists this redirection, leading to the apparent force that "pulls" the water into the bottom of the bucket. It's a great example of Newton's third law: The string pulls on the water to change its direction from a straight line to an arc (centripetal force), and the water's inertia pulls back (centrifugal force)!

Here's an analogous situation: Imagine you're riding as a passenger in your dad's car. He makes a really sharp turn, and as a result, you feel like you're being thrown against the inside of the car door. What's really happening is that your body wants to continue moving forward, but the turning car pulls your body in a new direction. Your body's inertia resists this pull, because like all objects, it wants to continue traveling in a straight line.

Now, let's take a look at the math.

To solve for velocity of your swinging bucket, you have to calculate the gravitational force that acts on the water:

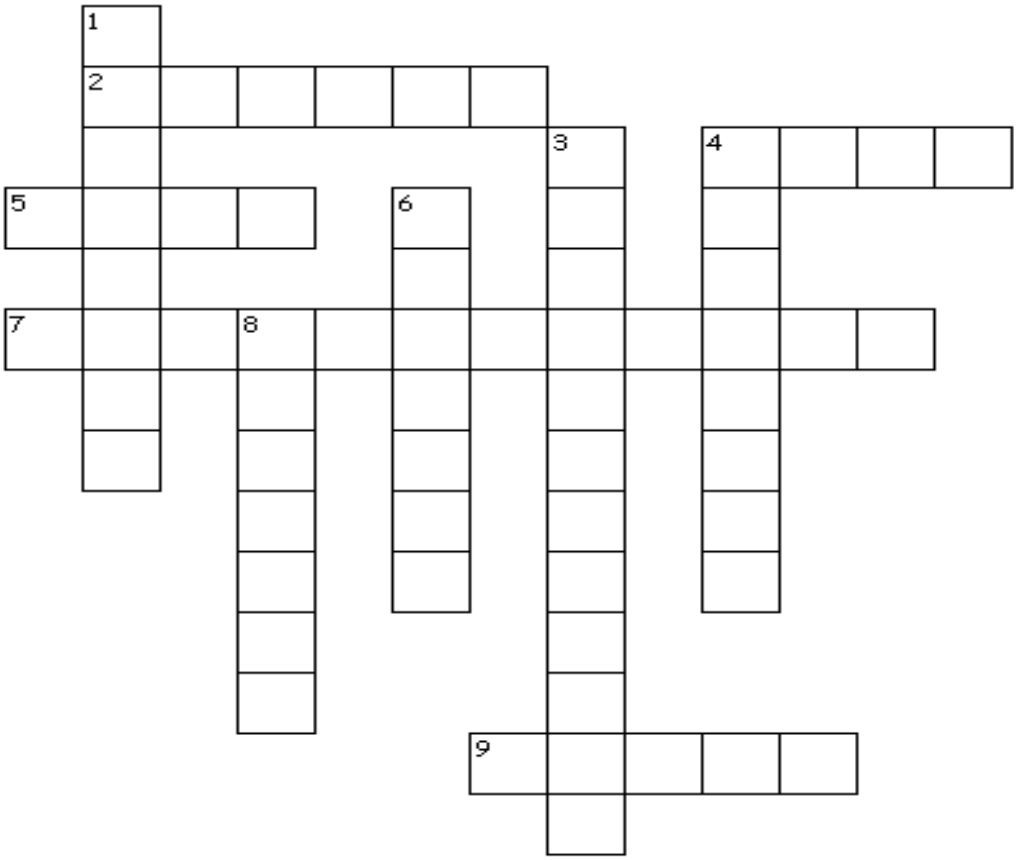
$Fg=mg$

Where Fg is the gravitation force in Newtons, m is the mass of the water and g is the acceleration due to gravity, which is 9.81m/s on Earth.

The water will spill from the bucket when the gravitational force is slightly greater than the centripetal (or centrifugal) force, so for simplicity they can be set to equal each other, the variables rearranged, and solved. It is important that weight (mass) is measured in kilograms because that the units in the equation must be consistent for the equation to be true.

SOLVE THE PUZZLE

Use the clues below to fill in the puzzle with the correct physics terms.



Created with Puzzlemaker at DiscoveryEducation.com

Across

2. The ability to do work
4. A measurement of how much matter is in an object
5. When a force acts on an object to move it some distance
7. An object's overall change in position
9. The measurement of a push or pull on an object

Down

1. The rate of change in an object's position
3. Increase in the rate or speed of an object
4. A measurement of mass in motion
6. A force caused when the mass of physical bodies attract each other
8. The branch of science concerned with the nature and properties of matter and energy

SOLVE THE PUZZLE – ANSWER KEY

Across

2. The ability to do work - ENERGY
4. A measurement of how much matter is in an object - MASS
5. When a force acts on an object to move it some distance – WORK
7. An object's overall change in position - DISPLACEMENT
9. The measurement of a push or pull on an object - FORCE

Down

1. The rate of change in an object's position - VELOCITY
3. Increase in the rate or speed of an object - ACCELERATION
4. A measurement of mass in motion - MOMENTUM
6. A force caused when the mass of physical bodies attract each other - GRAVITY
8. The branch of science concerned with the nature and properties of matter and energy - PHYSICS

Section 6: ALL ABOUT YOU

Now that you have seen the show, let's think about what you have learned and how physics applies to your daily life.

1) What did you learn from watching *The Physics Experience*?

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2) What was your favorite part?

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3) What questions do you have after watching the show?

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_____

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4) What are some ways you see physics at work in your life? Use a few of the key physics terms to describe what you see.

_____

_____

_____

_____

MARK YOUR CALENDARS AND GET YOUR TICKETS TODAY!

Zoellner Arts Center has more school shows coming in 2018!
Visit us again to check out:

- TAO Drum Heart (Monday, February 12, 2018)
- Erth's Dinosaur Zoo (Friday, March, 9, 2018)

Contact us at inzactix@lehigh.edu or 610.758.2787 for more information.
Also, visit us online: www.ZoellnerArtsCenter.org
See you soon!

ZOELLNER
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SCHOOL MATINEES

17-18 ACADEMIC YEAR

TAO, Taiko Drummers from Japan: *Drum Heart* — Monday, Feb 12 @ 10am

Drum Heart is the latest production from TAO, the internationally-acclaimed Japanese percussion ensemble. TAO's modern, high-energy performances showcasing the ancient art of Japanese drumming have transfixed audiences worldwide. Combining highly physical drumming on instruments from small and handheld to 900 lbs., with contemporary costumes, precise choreography, and innovative visuals, the performers of TAO: Drum Heart create an energetic and unforgettable production.

BEST FOR GRADES 3-9

The study guide will focus on percussion, non-verbal communication, martial arts, Japanese culture, teamwork, physical education, and sound vibrations.

ERTH: *Dinosaur Zoo Live!* — Friday, Mar 9 @ 10am

Erth's DINOSAUR ZOO LIVE guides your family on a breathtaking tour through pre-historic Australia. You'll observe, meet and interact with an eye-popping collection of amazingly life-like dinosaurs and other creatures presented in a theatrical performance. Brought to life by a team of skilled performers and puppeteers, and designed with the help of professional paleontologists, Erth's DINOSAUR ZOO LIVE's puppets are so extraordinarily realistic you may feel the urge to run and hide.

BEST FOR GRADES 2-6

The study guide will focus on earth science, evolutionary biology, puppetry, prehistoric sciences.

Each study guide meets National Standards in each area of study. You can download materials as well as show supplementary videos at www.ZoellnerArtsCenter.org. **To reserve tickets** and make a deposit, please contact **Ticket Services** by email: inzactix@lehigh.edu; or by phone: 610-758-2787. Please indicate the name of your school/organization, number of tickets, and name/phone number of the contact person (whoever is making the final arrangements). Written requests can also be faxed: 610-758-5093; or mailed: **Ticket Requests – Outreach Programs, 420 E. Packer Ave, Bethlehem, PA 18015.**

Can't afford the tickets? Need help supporting transportation costs? CALL or EMAIL US! We have limited funding support to help keep the arts in your students' lives! For all questions and comments, please contact Avery Gardner at avery@lehigh.edu or 610-758-5774.

Supported by LEHIGH UNIVERSITY COLLEGE of EDUCATION — PENNSYLVANIA COUNCIL ON THE ARTS