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An Elementary School STEMusical: Exciting the Future of STEM

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Introduction

Many science, technology, engineering, and mathematics (STEM) outreach programs target post-elementary (high school) students to inspire and encourage participation in engineering careers; however, evidence from the Department of Civil Engineering Freshman Engineering Orientation found that most students had already identified their interest in engineering at the elementary-grade level. Because of this, the educational outreach efforts of this project focus on elementary level students, hoping to inspire earlier enthusiasm in engineering and STEM fields. These efforts couple music education, songwriting, and science topics to provide a wide spectrum of learning frameworks and are described herein.

Previously conducted literature reviews by the PI's research group demonstrate positive influences of music in evoking human emotions and brain responses [1-5]. One study by Juslin and Vastfjall [6] indicates that hearing music can stimulate brain stem reflexes, recall episodic memories, and provoke visual imagery. Additionally, researchers have connected the effects of music to enhanced spatial skills of young students, and STEM professions rely heavily on spatial skills. Research suggests that when the brain processes rhythm a "mental rotation" occurs, which stimulates the brain's spatial-temporal ability [7]. It is also suggested that music can enhance learning due to the multiple types of thinking that are required.

This report describes the implementation of outreach efforts focussing on introducing young students to exciting maritime transportation and engineering concepts (lock passage, inland waterway navigation, Newton's laws of motion, energy concepts, etc.), while reinforcing fun concepts through a developed musical performance outreach program. Titled "An Elementary School STEMusical" the developed theatrical performance intertwines maritime engineering themes with a theatrical script and original songs to convey facts, principles, and engineering history to a broad audience. The implemented maritime themed STEMusical presented herein builds upon existing STEMusical outreach experiences and involves hands-on experiments conducted in elementary school classrooms, as well as music memory practice activities.

The overall objective of the presented educational outreach project is to educate, inspire, and excite elementary school children (i.e. kindergarten through 4th graders) on maritime-themed STEM topics and create enthusiasm for future opportunities in STEM fields. The following section describes the outreach efforts executed in this project, including in-class learning activities and experiments as well as a STEMusical performance at Root Elementary School wherein 4th grade displayed to their parents and the community what they had learned about physical science concepts using scripted performances intertwined with created science songs.

In-Class Experiential Learning Activities

In-class experiments were prepared specifically for keeping student interest during the presentation of fundamental science concepts related to the STEMusical themes. The experiments reinforce the concepts taught through song, and relate to concepts such as Newton's first law of motion (the law of inertia), conservation of energy, principles of kinetic and potential energy, and material fatigue. As an example, after describing/teaching about Newton's first law, the concept is connected to physical reality by placing an uncooked egg atop a cardboard cylinder, supported by a plate, which

is sitting atop a glass of water (see Figure 1a). The challenge given to the students is to get the egg into the water without touching the egg. During the activity, as the suspense builds and the student attention is focused on the egg, the plate is hit by the experimenter which sends the plate and tube flying sideways as the egg falls straight down into the glass. As the students cheer, the experimenter yells out "INERTIA" and continues to reiterate the the fundamental concept that an object at rest wants to remain at rest, and that objects with more mass have more inertia (or a greater desire to stay at rest). Concepts in the experiental learning classroom activities are reinforced through multiple experiments. Additional inertia experiments involve: 1) inferring object mass through stopping moving objects (as objects in motion want to remain in motion), and 2) cable break activities where a large mass is suspended in series between two cables, allowing the lower or upper cable strength to control (depending on the speed of pulling, which engages the dynamic inertial forces) (see Figure 1b). Additional experiments involve drop marbles through flexible piping and swinging pendulums to teach about potential-energy and kinetic-energy transfer. To teach the concept of material fatigue, metal paper clips are handed out to each student with instructions to different sections of the classroom to bend the paper clip at different angles. The different sections of the room then report back how many bend cycles each paperclip achieved and fatigue-life curves for the paperclips are developed. This fatigue experiment reinforces that materials subjected to repeated loads can fail (even when the individual loads don't cause failure. Figure 2 to Figure 5 show examples of the experiential learning activities being conducted in connection with the STEMusical music learning in a 4th grade elementary music classroom at Root Elementary School, in Fayetteville, Arkansas.

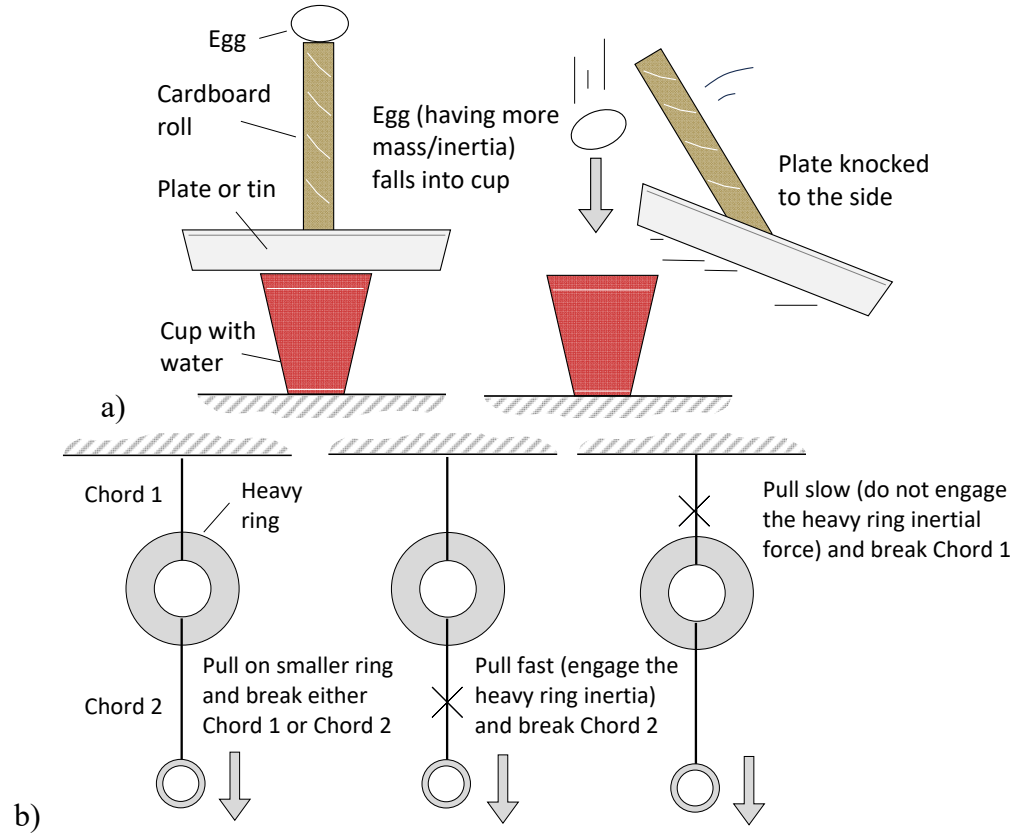

Figure 1. Experimental setup and execution for a) egg drop inertia test, and b) cable-break inertia test

Figure 2. In-class experiential learning example coupled with music memory activities. Egg inertia experiment shown.

Figure 3. In-class experiential learning example coupled with music memory activities. Inertia string break experiment.

Figure 4. In-class experiential learning example coupled with music memory activities. Kinetic energy marble and tube experiment

Figure 5. In-class experiential learning example coupled with music memory activities. Kinetic energy pendilum experiment.

STEMusical Script and Performance

The coupled science and music learning culminated in a student performance (delivered during a school assembly and separately to the community) titled a "Root Elementary School STEMusical" (see the STEMusical program used and the set design in Figure 6 and Figure 7 respectively). The STEMusical performance involved the students memorizing and delivering an informational science themed script related to the science facts they had learned (through song and in classroom experiments). Additionally, a new maritime themed song was deleveloped in this project related to waterway navigation (set to the tune of 'I love Rock-n-Roll'). The following presents the STEMusical script and updated maritime themed songs and ideas.

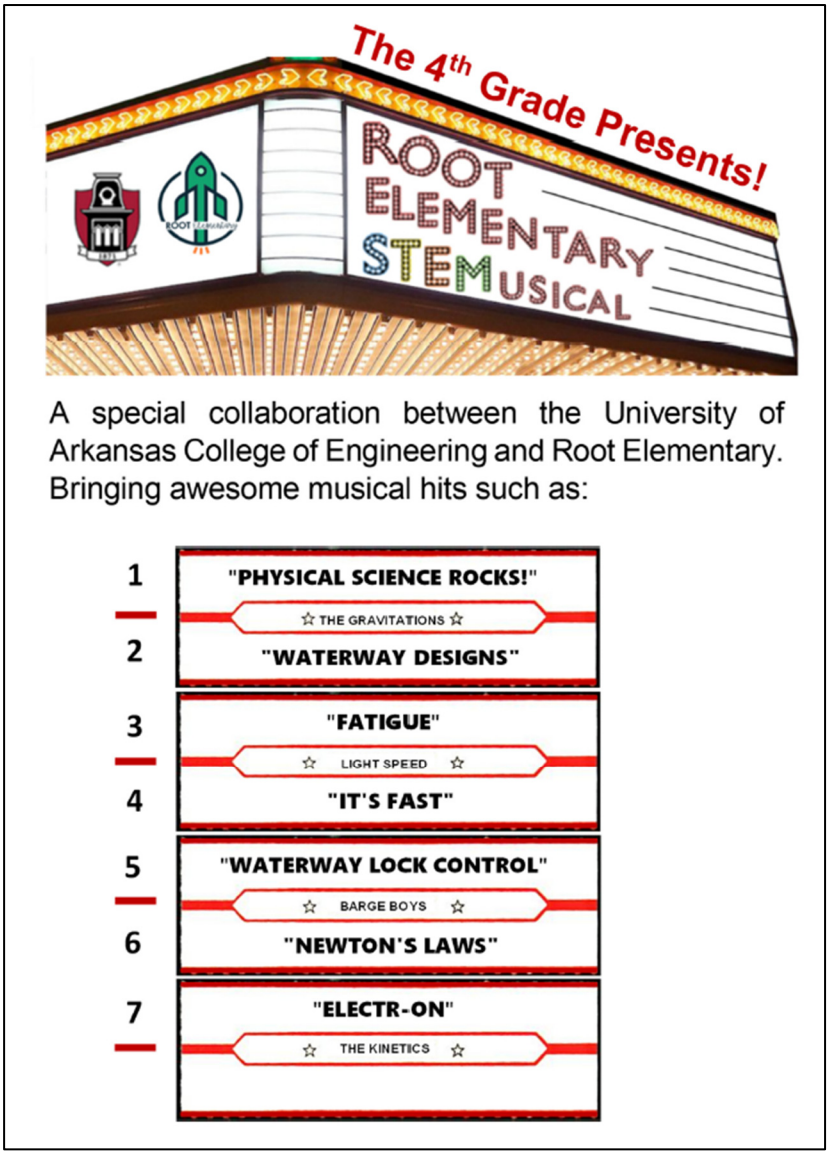

Figure 6. STEMusical program

Figure 7. STEMusical set design

"An Elementary School STEMusical" Script

The following script was adapted from previous outreach efforts by the PI to include a new maritime themed songs, it was taught to the entire 4th grade class, and then performed on October 29th, 2025 at Root Elementary School in Fayetteville, Arkansas. Lyrics to the songs "Physical Science Rocks" "Waterway Designs" "Fatigue" "It's Fast" and "Newton's Laws" are provided in Appendix A. The newly developed songs "Water-way Lock Control" and two songs related to the topic of "Inertia!" and dredging respectively are presented in this section following the STEMusical script. Figure 8 through Figure 11 shows clips of the resulting student musical performance and rehersal.

Show Introduction

- Hello, ladies and gentlemen! We're sooo excited you're here with us today/tonight.
- Our performance STEMs from a collaboration between science and music.
- By the way, STEM stands for Science, Technology, Engineering,… "and MUSIC!" *(said by one kid or all kids)*
- The learning and rhymes are about to flow
- and your knowledge is about to grow.
- We plan on bringing the energy and the funk.
- So embrace the gravity of this situation, sit back, enjoy the show,
- Because science rocks! *(said by all kids)*

Sing [Physical Science Rocks]

- Our focus tonight navigates the science of our inland waterways.
- Did you know that boats use water elevators to help them get over dams so they can keep shipping?
- Totally! The water elevators are called Locks.
- Just one of the many amazing waterway designs

Sing [Waterway Designs]

- We're now going to crack you up
- By singing about material science and the process of fracture
- With repeated stress
- [Student 1: Hey my mom has that!]
- Cracks can sometimes grow in our inland waterway infrastructure
- We call it FATIGUE!
- [Student 1: my mom has that too!]

Sing [Fatigue]

- We're now going to slow things down a bit…by singing about the fastest thing around.
- Even though you may be in a hurry, there is a speed limit that's impossible to break.
- *[Student 1:"Are you sure? My Mom breaks the speed limit all the time!"]*
- No, we're speaking about the speed of light, and it's really fast.
- Did you know, the speed of light is nearly 1 million times faster than the speed of our song to your ears.
- From early ship signaling, to our modern day radios, the speed of light really moves things along! It's FAAAASSST!

Sing [It's Fast]

- Many materials needed for our modern life are shipped by barges
- From coal and steel to critical chemicals, barge transport keeps our great nation running
- *[Student 1: "Hey, then why am I always told to stop running?!]*
- Barge transport is amazingly efficient
- All thanks to the careful control of our inland waterway infrastructure

Sing [Waterway Lock Control]

- Some laws are made by governments. Other laws are just natural.
- Newton discovered a few!
- [Student 1: "Hey I know him, isn't he that cookie guy?"]
- No, not Fig Newton, Sir Isaac Newton!
- He's the one that said when you kick a ball, the ball kicks you back!
- In 1686 he caused quite a commotion with his three laws of motion.

Sing [Newton's Laws]

- The atmosphere here tonight has been electric!
- Before you head home to recharge, we want to share a little bit about a fourth-grade science objective. It's all about energy!
- *[Student 1: "Energy…I know about that! In fact, I'm always told I have way too much of it!"]*
- Don't worry if you're feeling drained, your energy isn't lost, it's just transformed.
- And we're about to transform it back!
- Because our rhymes are poetic and this topic is kinetic!

Sing [Electr-on]

NEW SONG Lyrics (Included in the STEMusical Performance): Water-way Lock Control (tune: I Love Rock & Roll)

I saw a big barge floatin' steady up a narrow ravine
Arriving at a dam I had feared that it couldn't proceed
But the barge kept movin' on

All my doubts were soon withdrawn

And I could tell it wouldn't be long
'til it was at sea, yeah, sea
And I could tell it wouldn't be long
'til it was at sea, care-free, thanks to
Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
All these elevation changes seem routine

Ow!

Designed to go up and down, by pump or drain
Connecting water-ways into traveling chains
Army-Corps maintained and owned, so our ships don't get postponed

And these ships keep movin' on, to the sea, yeah, sea
Ships keep movin' on, out to the sea, yeah, sea, thankin'

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
All these elevation changes seem routine

Ow!

Corps maintained and owned, so our ships don't get postponed

The ships keep movin' on, to the sea, yeah, sea
And they'll keep movin' on and sailin' out to the sea, yeah, sea, thanks to

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
Makin' elevation changes seem routine

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
Makin' elevation changes seem …

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control

Makin' elevation changes seem routine

NEW SONG Lyrics (to be implemented in STEMusical script / program): Inertia! (tune: Tequila!)

While music playing, kids start setting up experiments on stage (see previous description for inertia experiments)…perform the experiment right on cue and shout…"Inertia!"

Updated script segment for new "Inertia!" song:

- It's the first law of motion, which caused quite a comotion.
- Any object at rest, wants to stay at rest
- And any object in motion, wants to stay in motion
- This describes INERTIA, and it's a property of matter!
- [Student 1: *"Hey, my mom is always telling me to stop, but I cant…I must matter a lot!"*]
- Sit, back, relax, stay at rest, and enjoy this science song all about INERTIA!

Sing [Inertia!]

NEW SONG Lyrics (to be implemented in STEMusical script / program): Deepening the Water (tune: Smoke on the Water)

The sediment had started to grow
on the port of Houston shoreline
The ship clearance sea-floor profile
It didn't leave much room

The bigger barges and the others
Were about to go and run aground
But some engineers idea won
A simple solution was found

Dredge in the water
de-sedimentify
Dredge in the water

They dug all the build-up out
It piled up an awful mound
the funky claw kept going in and out
Pullin'-out pound after pound
When it all was over
The barge had made a deeper place
But ocean time keeps a running on
The sediment would soon replace

Dredge in the water
de-sedimentify

Dredge in the water

Shipping transport is essen-chel
and clearance must be maintained with care
So any sediment or stone buildup outside
Must be removed with care
With a few spud barges, a few crane booms
We made a place to jet
Enough earth we can get out of this
Our ship, our ship will have the clearance

Dredge in the water
de-sedimentify
Dredge in the water

Updated script segment for new "Deepening the Water" dredging song:

- In ports or waterways, ships need to be able to get where they need to go.
- It's important for our nation's waterways to be deep enough
- As currents and tides bring in sediment…
- Important dredging operations help remove it to ensure our largest ships have the clearance they need.
- Keeping the flow of ships moving, dredging is essential for our waterway system
- It's now time to dig in and deepen your understanding of this essential waterway process of dredging!

Sing [Deepening the Water]

Figure 8. STEMusical Photographs during a performance for the school

Figure 9. STEMusical Photographs during a performance for the public

Figure 10. STEMusical Performance for the song "It's Fast" which teaches students about the speed of light

Figure 11. Root Elementary 4th graders perform memorized script lines at the STEMusical

Conclusion

This education outreach and development project focused on the communication of fundamental science concepts and maritime processes through in-class instruction and music-memory activities. The project focused on students at the elementary grade level (4th grade). Classroom experiments, music practice, lyric memorization, and performative choregraphy were conducted and implanted in a public performance at Root Elementary School in Fayetteville Arkansas. The STEMusical is being considered at other elementary schools throughout the Northwest Arkansas region with several elementary school music teachers having already reached out for implementation in their curriculum. The program, experiment descriptions, script segments, song lyrics, and set design ideas are presented herein to be re-purposed and used to meet the curriculum needs of elementary schools everywhere.

References

[1] M. F. Pignatiello, Camp, C.J., and Rasar, L.A. (1986). "Musical mood induction: an alternative to the Velten technique," *Journal of Abnormal Psychology*, 94(1986). pp. 51-63

[2] H. L. Bonny, and Savary, L. M. ((1973)). "Music and your mind," *Station Hill*,

[3] P. Evans, and Schubert, E. (2008). "Relationships between express and felt emotions in music," *Musicae Scientiae*, 12(2008). pp. 75-99

[4] P. Kenealy (1988). "Validation of a music mood induction procedure: Some preliminary findings," *Cognition and Emotion*, 2(pp41-48

[5] S. Koelsch, Fritz, T., Schulze, K., Alsop, D., and Schlaug, G. (2005). "Adults and children processing music: An fMRI study," *NeuroImage*, 25(pp.1068-76

[6] P. N. Juslin, and Vastfjall, D. (2008). "Emotional responses to music: The need to consider underlying mechanisms," *Behavioral and brain science*, 31(2008). pp.559-621

[7] L. Hetland (2000). "Learning to make music enhances spatial reasoning," *Journal of Aesthetic Education*, 34(3/4). pp.179-238

Appendix A. STEMusical Song Lyrics

Fatigue (to 'Happy' by Pharrell)

It might seem crazy what I'm 'bout to say
Repeated loads can create a break
When uh…phy-si-cal strength slow-ly decays
At low stress, cracks can progress and it's got a name

Refrain

We call it FA-TIGUE
When Cracks grow 'cuz they feel, large amounts of repeated stress
We call it FA-TIGUE
When cracks grow 'cuz they feel concentrations of load excess
We call it FA-TIGUE
When cracks grow 'cuz they feel distortions that are complex
We call it FA-TIGUE
When cracks grow 'cuz they feel, tip forces that just don't compress

Repeated loads can also be extreme
If loaded well past yield it's a new regime
Micro-voids grow quickly into cracks so fine
And we call it Fa-tigue when they combine

Here's Why!

Refrain 1 x

1) Bring stress down, just make the crack tip round
Stress level's too high so bring it down
2) Bring stress down, just make the crack tip round
Stress level's too high so bring it down
3) Bring stress down, just make the crack tip round
Stress level's too high, so bring it down
4) Bring stress down, just make the crack tip round
Stress level's too high, so bring it down

REPEAT REFRAIN 2x's

1) Bring stress down, just make the crack tip round
Stress level's too high so bring it down
2) Bring stress down, just make the crack tip round
Stress level's too high so bring it down
3) Bring stress down, just make the crack tip round
Stress level's too high, so bring it down

4) Bring stress down, just make the crack tip round
Stress level's too high, so bring it down

REPEAT REFRAIN 2x's

It's Fast (to 'At Last!' by Etta James)

"It's Fast….."
The speed of liiiight, it zooms along
670 million-miles… per hour
5 milliseconds tooo Tucson

Ooh yeah yeah
It's fast!.....

The liiiight that shines to you-ou…
Is a spectrum of shades, all over
And its scattering makes our sky all blue!

We found a beam…that we could speak through…
We found a beeeaam… to call our homes
We found a beam…to help us see through.
Oh such a speeeed… we've never known!

Ooh yeah yeah
It's fast!.....

"It's Fast….."
Speed of light, it zooms along
670 million miles… per hour

That light is really really
Faaastttt!

Electr-on (to "Dream On" by Aerosmith)

Energyyy, in mechan-ical motion,
Also light, heat and sound, what a notion.
It's all conserved
It just moves, from form to form
Oh this is the way,
All collisions have a sound they'd like to sayyyy!!!!

I know, when a mass moves slow,
Kin-etic en-ergy is low
And I know, there's potential in

Every turbine bla-ade, that spins

Energyyyy, the form's always changing
Light to heat, constantly re-aranging…
But its all conserved
All the joules, come back to you!

learn with me, energy is here
Moving all these molecules to your ear
learn with me, singing's the way
The energy we give, it wont go away

learn with me, energy is here
Moving all these molecules to your ear
learn with me, singing's the way
The energy we give, it wont go away

Electrons
Electrons
Electrons
Electrons carry energy too
Electrons
Electrons
Electrons
Electrons carry energy too
Electrons
Electrons
Electrons
Electrons

Electrons
Electrons
Electrons

oooohhhhhhhhh

learn with me, energy is here
Moving all these molecules to your ear
learn with me, singing's the way
The energy we give, it wont go away

learn with me, energy is here
Moving all these molecules to your ear
learn with me, singing's the way
The energy we give, it wont go away

Water-way Lock Control (to 'I Love Rock & Roll' by Joan Jett and the Blackhearts)

I saw a big barge floatin' steady up a narrow ravine
Arriving at a dam I had feared that it couldn't proceed
But the barge kept movin' on
All my doubts were soon withdrawn

And these ships keep movin' on
To the sea, yeah sea
Ships keep movin' on
To the sea, yeah, sea thankin'

Water-way lock control
Helpin' boats climb past dam stops, baby
Water-way lock control
All the elevation changes seem routine

Ow!

Designed to go up and down, by pump or drain
Connecting water-ways into traveling chains
Army-Corps maintained and owned, so our ships don't get postponed

And these ships keep movin' on,
To the sea, yeah, sea
Ships keep movin' on,
To the sea, yeah, sea, thankin'

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
All the elevation changes seem routine

Ow!

Carefully maintained and owned, so our ships don't get postponed

And these ships keep movin' on,
To the sea, yeah, sea
Ships keep movin' on,
To the sea, yeah, sea, thankin'

Water-way lock control
Helpin' boats climb past the dam stops, baby
Water-way lock control
All the elevation changes seem routine

Water Way Designs (to '9 to 5' by Dolly Parton)

Sputter to the lock usin' rutters for position
Locks provide that water transition
Movin' up or down to water's crown precise

Pump in the water and the boat starts jumpin'
Pump Out the water and level's start slumpin
Getting ships past dams on rivers by design.

Water-way designs, reduce delays when you are shipping.
We can, re-de-fine, elevations for dam skipping.
Locks will re-combine, locations of river edit.
Big enough to drive your barge through if you let it.

Water-way designs, lock gates close in all around you
If it feels confined, there's no other way to pass through
Want to move ahead, but that's a dam and not a jetty
But don't you worry, locks are at the ready.

In rivers and streams we got boat ladders
They're lock gates for shipping they matter
So we've got teams to ensure they stay ok.

The corps of engineers are a lock's best friend
They help ensure your ship can come in
To cross that dam and sail right on your way

REFRAIN X2

Physical Science Rocks (to 'Classic' by MKTO)

Hey mom and Da-ahd,
We're gonna teach you something ra-ad,
When we ride to school and back
In just one little song.

Science is lots of fun
Gravity, physics and su-un
A few things we have in store
To teach you a little more.

Hook

We're gonna teach you like Newton
Open your mind like Bohr
Shock your head like Tesla, and Edison
'Cause they open-ed the door!

Chorus

The world's so big full of gravity
Because of its' mass, we're so heavy
Our weight on this planet equals mass times "g".

That's why you're so hea-vy
That's why you're so hea-vy- - - - - -
That's why-y-y-y
That's why you're so heavy.

Earth's seasons change
Based on the planet's range
Or our distance from the sun
Due to the planet's tilt.

Rap 1

It is- angled at
Twenty -three -point -five
At- 4000- miles-
It's -so -very -wide
And- that
Tilt- is -why -earth's the only planet
Where any life can survive

Hook

Earth's got a big tilt
Look at the globe and you'll see
Because if it was up and down you'd have a frown
And land would become sea.

Chorus 2

Twenty three point- five degrees
Makes life work for you and me
The tilt of the earth is makin' life easy

The world's so big full of gravity

Because of its' mass, we're so heavy
Our weight on this planet equals mass times "g".

That's why you're so hea-vy
That's why you're so hea-vy
That's why-y-y-y
That's why you're so heavy

Newton's Laws (to 'Uptown Girl' by Billy Joel)

Newton's Laws
Describing motion, they're important because
3 little laws are all you need to know-ow
Until the physics power starts to flow

Yes we are learning about Newton's Laws!
For this achievement he deserves applause
First, any object that is resting sti-ll
Want to remain there and maintain it's chill

That's INER-TIA

For every action an equal opposite re-a-a-ction
And did you know when you jump up
The earth jumps down!

You see it's not so tough, just because I'm aware of,

Newton's Laws
Describing motion, they're important because
3 little laws are all you need to know-ow
Until the physics power starts to flow

That's how it goes…

Ohhhhhhh----------Oh----------

Newton's Laws
For this achievement he deserves applause
First, any object that is resting sti-ll
Want to remain there and maintain it's chill

That's INER-TIA
For every action an equal opposite re-a-a-ction
And did you know when you jump up

The earth jumps down!

You see it's not so tough, just because I'm aware of,

Newton's Laws
Describing motion, they're important because
3 little laws are all you need to know-ow
Until the physics power starts to flow

That's how it goes…

Ohhhhh----------Oh----------

Newton's Laws I'm in love with Newton's Laws
You know I'm in love with Newton's laws
I'm in love with Newton's Laws
You know I'm in love Newton's Laws