STEAM Challenge
Digital Storytelling Unit

Big Ben, Marimbas, and the Speed of Sound

Designed for Middle and High School Students

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	• Human Skills: Creativity, Collaboration, Critical Thinking, Presentational Skills

Introduction

This Digital Story Telling Challenge will take two to four weeks to complete. This Challenge targets key Human Life Skills – creativity, collaboration, critical thinking, digital literacy and presentational skills – in equal measure with the curricular content. Delivering on all those learning goals requires student immersion and time. The results, as based on our research, are a high level of student engagement, deep learning, and 100% teacher endorsement.

The following Challenge:

- Should be completed by collaborative teams of two to four students but can be completed independently, if desired.
- Is aligned to nationally recognized Curricular Standards.
- Contains an Evaluation Rubric that allows the teacher to clearly score and appraise the students' work.
- Is designed to be integrated into the classroom in alignment with existing curricula.
- Can be assigned as an extra credit project to teams of students that you think would benefit from this kind of immersive, deep learning experience. Additionally, will work well in informal educational settings.
- Should follow the rules of Digital Citizenry in their proper usage and/or citation of images, music and text taken from other sources. See the Digital Rules area in the free Media Resources section of the Meridian Stories site for guidance.

The **Media Resources** section also contains many other **free support materials** from short videos featuring professionals in the field – Artists and Innovators– to short written documents that cover everything from storyboarding to creative brainstorming, interviewing techniques to game design.

While it is helpful to have a Technology Integrator involved, they are not usually necessary: the students already know how to produce the media. ***The teacher's primary function in these Challenges is to guide the students as they engage with the content. You don't need to know editing, sound design,***

shooting or storyboarding: you just need to know your content area.

At the end of the Challenge, it is often fun and useful to have a screening of all the media productions – they are all designed to run under 4 minutes each. Students can vote for their favorite videos that can then be screened in a larger assembly-like setting for the whole grade to see. Or this work can be presented as part of a student showcase for parents and friends. Presentational Skills is another Human Life Skill that this project enables.

Our research indicates this to be a really useful exercise for two additional reasons:

1. Students actually learn from their peers' presentations – it is useful to hear a perspective that is not just the teacher's; and
2. The public setting – painful as it is for some students – provides them with an opportunity to 'own' their work and to be more accountable.

Finally, if you are interested to learn more about the community of schools who annually participate in the **Meridian Stories Competitions** – a community that is characterized by a friendly competitive spirit; feedback from Mentors on each submission; and the rewarding of digital badges in content, storytelling and digital literacy – please return to the Competitions section of the website or inquire at info@meridianstories.com.

Let's get started.

The Challenge

The clock tower known as Big Ben houses bells that plays one of the world's most recognizable short tunes. Your task is to study Big Ben and its music-producing chimes, then contribute to the tune by accompanying the clock tower with your own, homemade marimbas. Your goal is to play the same notes at the same time – from thousands of miles away! Your team has to frame the performance scene within a creative context: for example, pretend that you have an incomplete band for which Big Ben is filling in; present the performance as an act in a variety show; or create a Big Ben cover band… it's up to you! You will use algebra, geometry, unit conversions, arithmetic, and concepts borrowed from physics to complete this challenge.

Deliverables include:

- Big Ben, Marimbas, and the Speed of Sound video
- Final script (at teacher's discretion)

- All calculations and computations, clearly worked (at teacher's discretion)
- Resource Citation Paper (at teacher's discretion)

Process

Below is a suggested breakdown for the students' work.

During Phase I, student teams will:

Research and coordinate with Big Ben, laying the groundwork for "performing" together. You will conduct general research to collect the data necessary to perform computations that will allow you to synchronize your music with that of Big Ben, overcoming the logistical difficulties of differences in time zones and locations. You will also familiarize yourselves with the tune you've been asked to play: the notes and rhythm.

- Research Big Ben. When bands are joined by a guest musician, they typically practice together to get to know how he/she plays. Consider this your "rehearsal," and get acquainted with Big Ben's musical habits.
    - Timing. How often does Big Ben play? How long does it take for the clock-tower to play its tune?
    - Tune. In order to play the same song, you need the same music! Find the notes played by Big Ben, and their interval (timing).
        - NB: Big Ben plays slightly different tunes depending on the quarter hour. Your team may choose whichever tune it prefers.

- Coordinate with Big Ben. For the sake of this challenge, you may want to consider your performance an act with one remote member, which means there are some tricky logistics to overcome.
    - Learn what time zone Big Ben is in, and calculate the time difference to your town
        - Keep in mind that to accompany Big Ben at the moment its bells are ringing requires you to compensate for the time difference (including daylight savings!).
    - Calculate a reasonable estimate of the distance from your town to where Big Ben stands: you will need this info in the next step!

        - *Middle school:* use geometric methods (hint: if you ignore the curve of the surface of the Earth, an isosceles triangle is formed by your town, Big Ben, and the core of the Earth).
        - *High school* (at teacher's discretion): use trigonometric methods to estimate this distance (hint: treat the segment from Big Ben to your town as an arc).
    - Account for time and space! This is a special, inter-continental performance. Choose a date for your performance, and a time on that date that Big Ben will be playing (you looked this up earlier):
        - Sound takes time to travel! Assuming that sound moves constantly at 343 meters/sec, and will take a direct route from Big Ben to your town (and vice versa), calculate the time you will have to play at so that the sound waves from your marimba and from Big Ben will be in the same place at the same time. Use the distance you estimated above.
        - Don't forget to account for the time difference!
        - The sound waves (if in reality they carried so far) from your instrument and Big Ben could meet in your town, in London, between the two in the Atlantic, or… they could pass each other and meet again on the other side of the world! Choose where you want them to meet, and consider that location to be your concert venue. Calculate accordingly!

During <u>Phase II</u>, student teams will:
Research methods and practices for the design, construction, and fine tuning of a simple marimba. It will only need as many bars as there are notes in the tune. This phase will involve selecting, acquiring, and crafting the materials into an instrument and <u>may require adult assistance</u>. Your team will be responsible for calculating the appropriate bar lengths that will generate the needed notes.

- Research marimba construction:
    - What materials will you need? How much of them? What tools will you need, and will you need adult help?

- Once you've chosen your material, you will need to collect certain data in order to calculate the length of each bar:
  - Thickness of the bar (*not width!*). Measure precisely.
  - Speed of sound in the bar. Sound travels at a different speed through every material. You will have to research the speed of sound through the material (i.e. type of wood) you are using.
  - Frequency of each note in the song. Research the frequency (measured in *Hertz*) of each note needed to play the tune.
  - Calculate the length of bar needed to create each note.
    - You will need to research the value of *c* (see below) for the material you are using.

Formula for the length of a bar, where *t* is the bar's thickness, *c* is the speed of sound in the bar, and *f* is the frequency of the note.

$$Length = \sqrt{\frac{3.011^2 \cdot \pi \cdot t \cdot c}{8 \cdot \sqrt{12} \cdot f}}$$

- Construct your marimba
  - Remember to tune your instrument. You can do this by sanding the bottom of each bar – many guides have tips for this step.
  - For help, see resources at the bottom, or conduct your own research online.
  - Add-On 1: If desired, build resonators to enhance your instrument's sound (http://www.craftymusicteachers.com/bassmarimba/resonators.html)
  - Add-On 2: If desired, build an additional set of bars for your marimba in a different octave. Play both octaves in your performance!

During Phase III, student teams will:

Produce a short video including your performance of the tune in synchronization with Big Ben. Your team is asked to introduce elements of drama, grandeur, showiness, and/or mystique into their performance and explanation thereof. Think in terms of a vaudeville act or a magic show that uses math as its magical foundation. In this video, you will also have to explain the calculations you performed, discuss the math inherent in the building of a marimba, and creatively present all the above material. For this, your team may want to use more documentary-style footage of your processes, to cut into the final product.

- Pre-produce your video.
  - Prepare your script.
    - Be sure to explain some of the narrative involved in the construction process, as well as explain the technical challenges of such a performance, including the calculations you performed, and why they were necessary.
  - Choose a setting: local theater, concert hall, street performance….
  - Choose an emcee/host to introduce the act. This may be your only dramatic character, so take some time to develop a personality
- Shoot your film and record your performance, making sure to note the exact time of day.
- Cut and edit your video and audio to produce your final, polished digital presentation!

Some resources that may help you along the way:

Note frequencies:
http://www.phy.mtu.edu/~suits/notefreqs.html

Meridian Support Resources

Meridian Stories provides two forms of support for the student teams:

1. Media Innovators and Artists – This is a series of three-to-four-minute videos featuring artists and innovative professionals who offer important advice, specifically for Meridian Stories, in the areas of creativity and production.
2. Meridian Resources – These are short documents that offer student teams a few key tips in the areas of creativity and production.

Recommended review, as a team, for this Challenge include:	
Media Innovators and Artists	**Meridian Resources**
On *Directing Comedies* – Davis Robinson ***On*** *Multimedia in Theatre* – Roger Bechtel ***On Sound Design*** – Chris Watkinson *On the Importance of Characters in Storytelling* – Scott Nash	"Producing: Tips for the Shoot" "Royalty Free Music and Sound Effects" "Time Management" "Creating a Short Documentary"

Evaluation Rubric – *Big Ben, Marimbas, and the Speed of Sound*

CONTENT COMMAND			
Criteria	**1-3**	**4-7**	**8-10**
Communication of Content – Marimba Construction	Calculations are inaccurate or not present Documentation is unclear, and little understanding is demonstrated	Calculations are accurate and documented, but may lack supporting discussion or insights	Calculations for the dimensions of the marimba bars are accurate, documented, and the intuition is explained in the video
Communication of Content – Logistical Computations	Calculations are inaccurate or not present Documentation is unclear, and little understanding is demonstrated	Calculations are accurate and documented, but the motivation, assumptions, and/or implications may not be well explained	Calculations regarding the coordination of the "performance" are accurate, documented, and well explained Assumptions are clearly outlined
Communication of Content – The Music of Math	The short film lacks the appropriate discussion relating math and music	Some insight is offered into the math-music relationships explored in this project	Students offer insight into the relationship between math and music Understanding is demonstrated beyond the application of the formula provided

STORYTELLING COMMAND			
Criteria	**1-3**	**4-7**	**8-10**
Overall Narrative of the Performance Presentation	The trajectory of the film is difficult to follow; the narrative is nonexistent or lacking development	The film has a clear style, but the narrative could be more engaging	The film is cohesive, with a consistent format and feel throughout The narrative is easy to follow, and goes beyond simple explanation to engage the audience
Scripting	The script does not service the content clearly or appropriately	The script services the content the content clearly	The script services the content effectively and imaginatively It adds to the depth of the video, and helps provide context for the scene
MEDIA COMMAND			
Criteria	**1-3**	**4-7**	**8-10**
Setting and Cinematography	Visual aids and shots of setting and other relevant images are lacking	Visual aids as well as shots of setting and props contribute to a positive viewing experience	Visual aids as well as shots of setting and props create a visually pleasing film A variety of cinematic techniques are used
Music and Sound	The music and sounds of the marimba are difficult to hear	The music and sounds of the marimba are captured, but some distractions may detract from the recording	The music and sounds of the marimba are clearly captured and well-integrated into the film Additional sound effects and music complement the recordings
Editing	The film feels patched together and the overall editing detracts from the narrative	The film flows, but there are occasional editing distractions	The film is edited cleanly and effectively, resulting in an engaging video experience
HUMAN SKILLS COMMAND			
Criteria	**1-3**	**4-7**	**8-10**

Collaborative Thinking	The group did not work together effectively and/or did not share the work equally	The group worked together effectively and had no major issues	The group demonstrated flexibility in making compromises and valued the contributions of each group member
Creativity and Innovation	The group did not make a solid effort to create anything new or innovative	The group was able to brainstorm new and inventive ideas, but was inconsistent in their evaluation and implementation of those ideas.	The group brainstormed many inventive ideas and was able to evaluate, refine and implement them effectively
Initiative and Self-Direction	The group was unable to set attainable goals, work independently and manage their time effectively	The group required some additional help, but was able to complete the project on time with few problems	The group set attainable goals, worked independently and managed their time effectively, demonstrating a disciplined commitment to the project

Essential Questions

1. Where do elements of mathematics intersect with those of music creation?
2. How has building an instrument from scratch changed your understanding of how music is formed?
3. What mathematical tools will enable students to accurately determine the necessary dimensions for their instrument?
4. How do differences in geographic location affect the coordination of actions between two or more parties?
5. What techniques make possible the measurement of distance between two points on the earth's surface?
6. How has immersion in the creation of original content and the production of digital media – exercising one's creativity, critical thinking and digital literacy skills - deepened the overall educational experience?
7. How has working on a team – practicing one's collaborative skills - changed the learning experience?

Student Proficiencies

1. The student will be able to identify and explain the components of music that relate to, or are explained by, mathematics: interval timing, distance between sound sources, how an instrument's form determines tone.
2. The student will understand intuitively how sound is related to the size and shape of the object (instrument) from which it is omitted.
3. The student will demonstrate mastery of algebraic techniques: order of operations, multivariate manipulation, working with exponents and square roots.
4. The student will be able to identify and account for differences in time zones and the distance between locations.
5. The student will be able to recognize that two points on Earth's surface lie on a plane with the center of the earth, thus distance can be calculated using only the Earth's radius and methods from trigonometry or geometry (for an estimation).
6. The student will utilize key 21st century skills, with a focus on creativity, critical thinking and digital literacy, in their process of translating STEAM content into a new narrative format.
7. The student will have an increased awareness of the challenges and rewards of team collaboration. Collaboration – the ability to work with others - is considered one of the most important 21st century skills to develop in students as they prepare for life after secondary school.

Curricular Correlations

The ***Big Ben, Marimbas, and the Speed of Sound*** Challenge addresses a range of curricular objectives that have been articulated by the **Common Core Curricular Standards – Mathematics.**

Below please find the standards that are addressed, either wholly or in part.

Common Core Curricular Standards – Mathematics

Overall Standards for Mathematical Practice

- Reason abstractly and quantitatively.
- Attend to the meaning of quantities.
- Construct viable arguments and critique the reasoning of others

Grade 6

- Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation. (6.NS.B.3)
- Solve real-world and mathematical problems by writing and solving equations of the form $x + p = q$ and $px = q$ for cases in which p, q and x are all nonnegative rational numbers. (6.EE.B.7)

Grade 7

- Solve real-life and mathematical problems using numerical and algebraic expressions and equations
  - Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (7.EE.B.3)
  - Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (7.EE.B.4)
- Solve real-world and mathematical problems involving the four operations with rational numbers (7.NS.A.3)

Grade 8

- Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities (8.EE.A.2)
- Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. (8.EE.A.4)

High School – Geometry

- Find arc lengths and areas of sectors of circles (HSG.C.B.5)
- Apply geometric concepts in modeling situations
  - Use geometric shapes, their measures, and their properties to describe objects (HSG.MG.A.1)
  - Apply geometric methods to solve design problems (HSG.MG.A.3)
- Apply Trigonometry to General Triangles
  - Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (HSG.SRT.D.11)

High School – Number and Quantity

- Reason quantitatively and use units to solve problems.
  - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units

consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (**HSN.Q.A.1**)

- Define appropriate quantities for the purpose of descriptive modeling. (**HSN.Q.A.2**)
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (**HSN.Q.A.3**)

