

Battle of the Electric Marimba Bands



David Harmon¹, Shawn Willis², Richard St-Pierre¹, Nick Caiano³ and Charles Griffin¹

1 Make It Science and IBM Systems & Technology,

2 Essex Middle School, and

3 NickTheGuitarTeacher.com, Essex Junction, VT USA

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- A pilot program jointly developed by *Essex Middle School (Essex, Vermont)* and *Make It Science*, working in conjunction with the *IBM Technical Education Outreach* program.

Goal:

To enhance 7th/8th grade STEM education

In such a way that

all students are motivated

So that

**they are better prepared to manage
Design/Build challenges in high school...**

...and in the real world



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Educational Design Components:

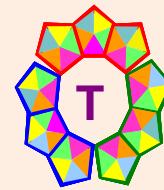
- (1) Motivate with Hands-on Demos & Activities exploring Vibration, Waves & Sound



- (2) Engage nearly all students by integrating the **Arts** into **STEM** => **STEAM**



- (3) Create Hierarchical Teams with diverse interests & Unite them with a common purpose



- (4) Introduce the Design Cycle as the form of the Scientific Method for Project-based Learning



- (5) Coach students through Brainstorming and Design Focusing exercises



- (6) Provide real-world application of Mathematics

$$\sqrt{\frac{f_1}{f_2}}$$



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Marimbas are wooden xylophone-like instruments that have roots in various parts of the world. The heritage surrounding the marimba makes it a natural topic for historical study in addition to scientific inquiry & mathematical modeling.



Prototype 1½ octave, fully chromatic marimba with offset “floorboard” tone bars



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Orchestral vs. “Battle” Marimbas



Vintage Instrument Center, 6/04/12, Vintage Marimba
<http://www.vintageinstrumentcenter.com/vintage-marimba/>

Team 2 bass, tenor and alto marimbas

- Multi-octave, floor-standing Instruments
- “Piano” Tone Bar Placement
- Resonator Tubes for Acoustic Amplification
- Table-top Alto, Tenor & Bass Instruments (1-1½ Octaves Each)
- In-line Tone Bar Placement
- Piezoelectric Sensors and Electric Amplification



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Electric Marimbas !

Piezoelectricity:

- Extremely Useful Material Property
Mechanical Stress \Leftrightarrow Electrical Potential
- Provides a simple hands-on demo for teaching energy conversion concepts
- Not familiar to most people... but commonly used for sensors & output devices: e.g., microphones, buzzers, earphones and... MARIMBAS ! ?

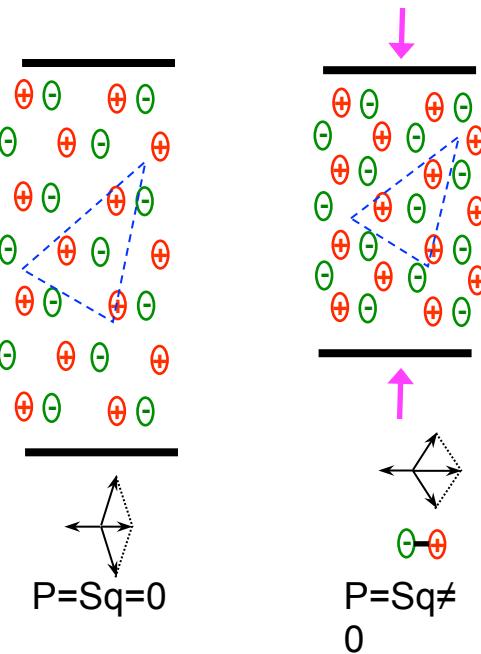


Standard
Piezoelectric
Disk



Marimba Tone Bar

"[In piezoelectric materials] a mechanical stress will result in voltage being developed ... The effect also works in reverse so that a voltage applied will result in a mechanical deformation. The effect ... is found with materials with an asymmetric crystal structure. The important factor is the charge distribution".



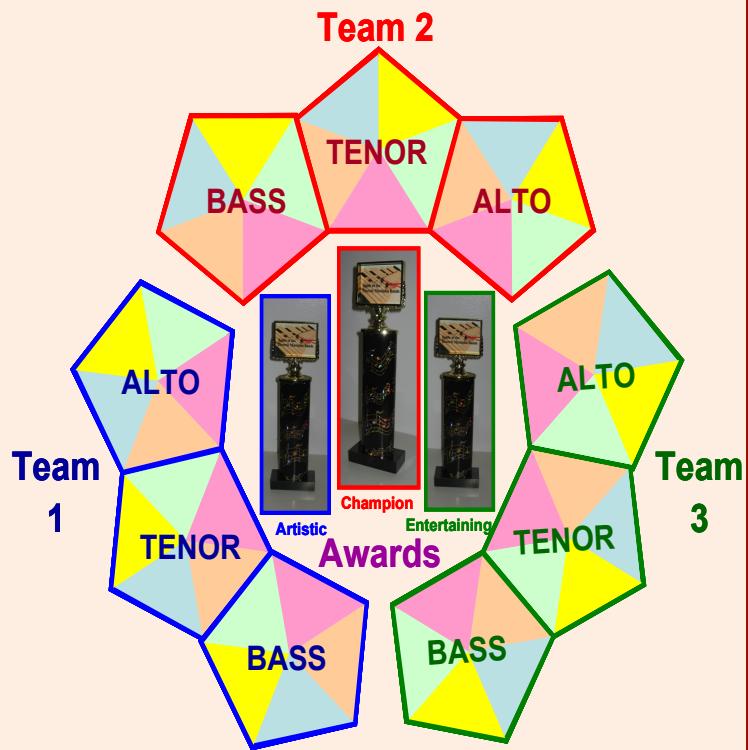


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Hierarchical Teams !

- Teams were composed of 3 Subgroups, each with 5 - 7 students
- Subgroup Members were selected for diverse interests and Skills
 - Each Subgroup united by building a marimba: Bass, Tenor or Alto
- Teams were united by the performance and competition



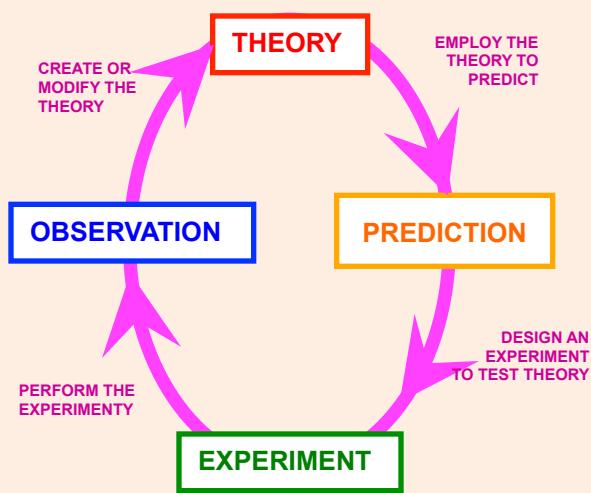


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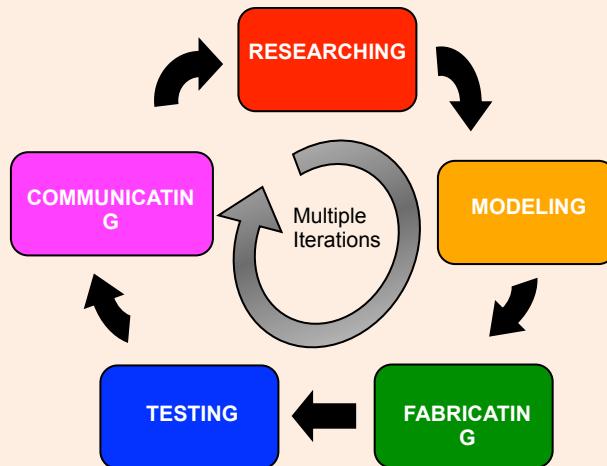
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Design Cycle !

Scientific Method⁽¹⁾



Design Cycle⁽²⁾



(1)

<http://www.tomatosphere.org/teacher-resources/teachers-guide/principal-investigation/scientific-method>

(2) Product Design Funda!, Importance of Research in Engineering Design, 4/23/12, <http://www.productdesignfunda.com/technology/importance-of-research-in-engineering-design>

- The Design Cycle is a natural fit for Project-based Learning



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Brainstorming !

Question: As a consumer, what would make you want to buy this product?

Answers:

- Handle(s)
- Marimba Stick Holder
- Simpler Wiring
- Paint / Finishing
- Backing Board
- Wheels
- Lights
- Music Stand



Team 1 ‘storming marimba upgrades



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Design Focus !

Question: What is the benefit/value and the cost/difficulty for each idea?

Answers:

P: Handle(s)

P: Marimba Stick Holder

I: Simpler Wiring

I: Paint / Finishing

C: Backing Board

C: Wheels

K: Lights

K: Music Stand

Benefit / Value
+
↑

P.I.C.K. Chart



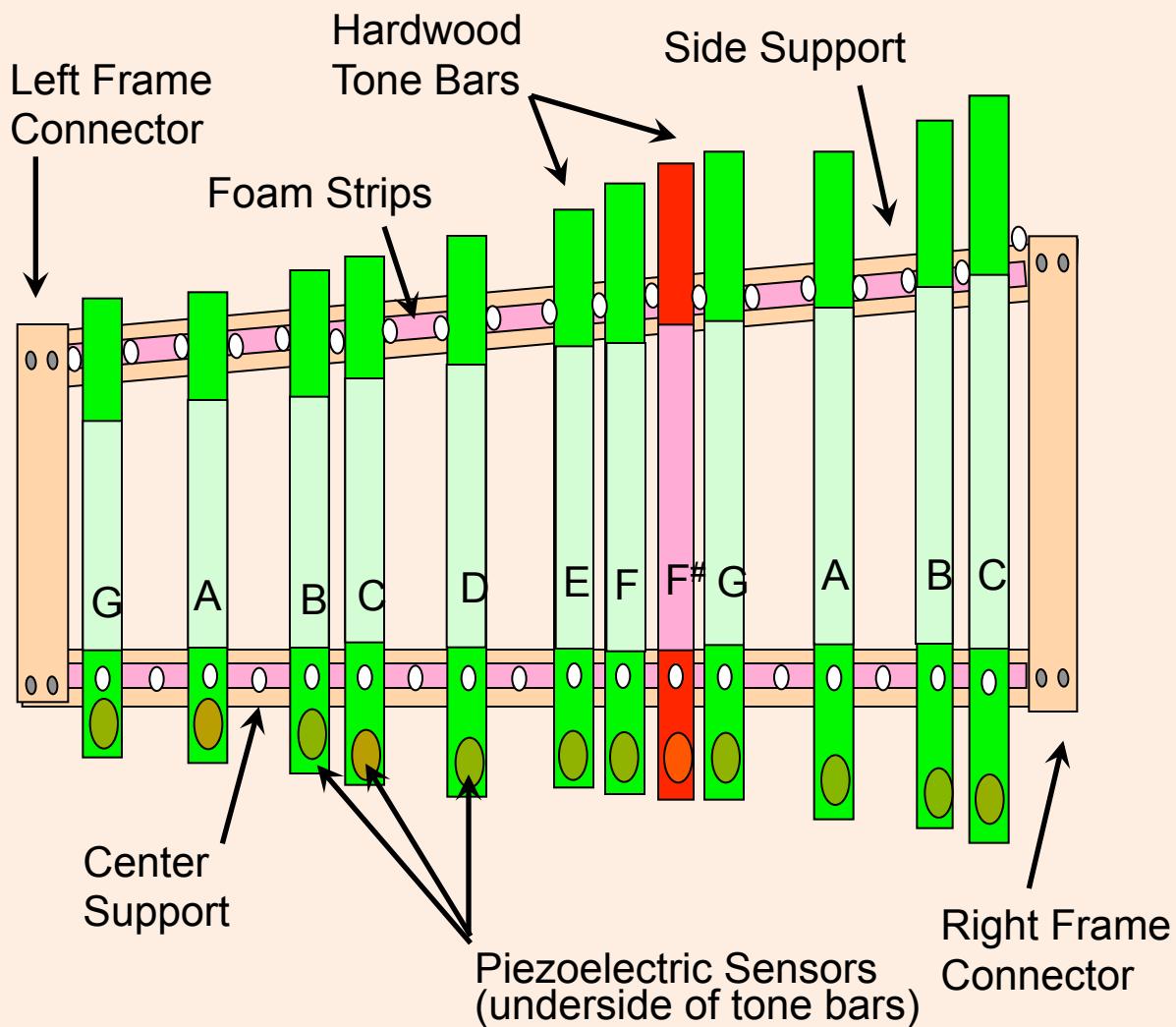
Cost / Difficulty +
→



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Construction!



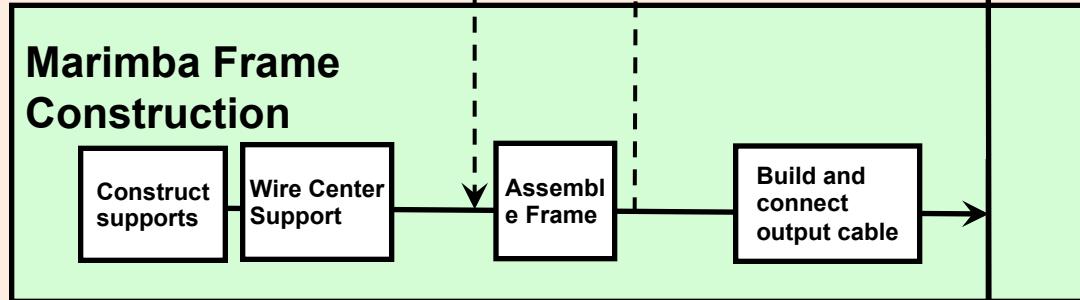
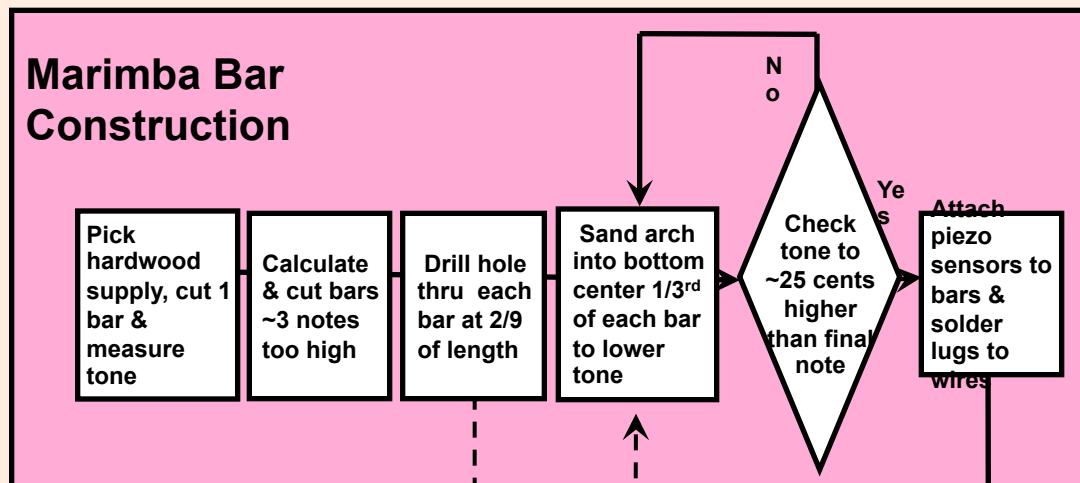
1½ Octave Marimba Populated for Keys C and G



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Flow Diagram/Value Stream Map



- Marimba bar and marimba frame construction occurs in parallel with focus groups handling piezoelectric sensor attachment and soldering

- Marimba stick construction, artwork and music selection could also be run in parallel

Place bars on support and connect solder lugs to wire bus

TEST !



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Math!

$$\frac{\text{Next Bar Length}}{\text{First Bar Length}} = \text{First Frequency} * \sqrt{\frac{\text{First Frequency}}{\text{Next Frequency}}}$$

~Start Note	Freq (Hz)	Meas/Calc Length (cm)	2/9th Length (cm)	1/3rd Length (cm)
A#	466.16			
B	493.88			
C	523.24			
C#	554.36			
D	587.32			
D#	622.24			
E	659.24			
F	698.44			
F#	739.98			
G	783.98	32.6		
G#	830.60			
A	880.00			
A#	932.32			
B	987.77			
C	1046.5			
C#	1108.7			
D	1174.7			
D#	1244.5			

FINAL TUNING
→
First Bar

Final Note	Freq (Hz)
G	392.00
G#	415.30
A	440.00
A#	466.16
B	493.88
C	523.25
C#	554.36
D	587.33
D#	622.25
E	659.25
F	698.46
F#	739.99
G	783.99
G#	830.61
A	880.00
A#	932.33
B	987.77
C	1046.5



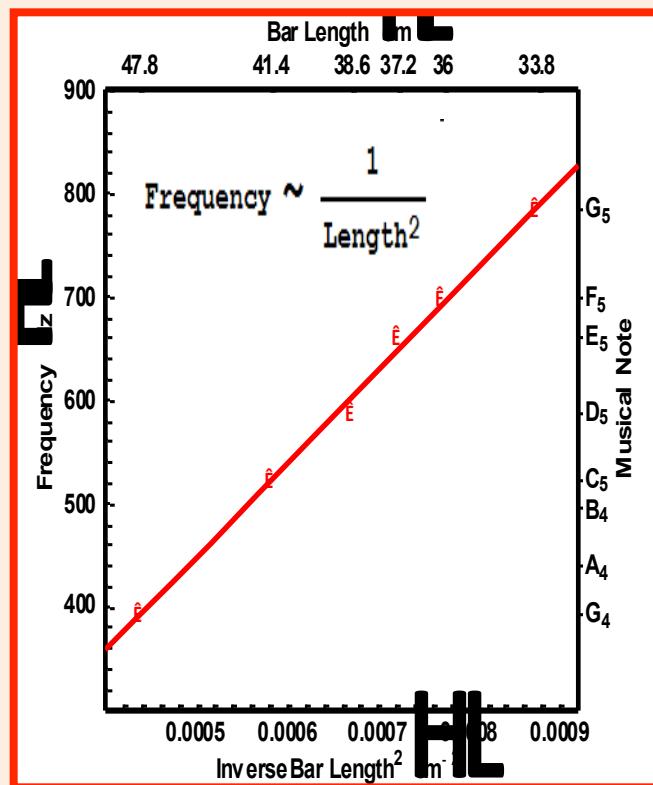
Marimba math in full “swing”



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Graphs!

- Graphing skills can be exercised and enhanced by studying frequency dependence on bar length
- Linear regression of Frequency(Length^n), for various n values, allows determination of the best fit model ($n = -2$)





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Marimba Bar Construction



Cutting tone bars to length



Final tuning of bars by sanding the midsection of the back side

- Students acquired fabrication skills: hand saws and drum sanders



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Frame Construction



Drilling wire bus pass-thru holes in center support



Hammering in bar-separation nails into side support

- Students acquired fabrication skills: drill presses and hammers



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Wire Bus Construction



Attaching binder clips for the piezoelectric disk connections



Wiring the “binder clip” bus on the center frame support



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Soldering Specialists



Attaching solder lugs to piezoelectric sensors



Building output cables from recycled phone lines



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The Arts !



Team 1 playing *La Bamba* on their Latin American-styled marimbas

Subgroup *Marimba del Fuego* at “play” on their fiery bass marimba

Collaboration with Music, Art & Social Science Departments is desirable



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Competition!

Deliverables:

- (1) Team Presentation
- (2) Musical Performance
Using
All 3 Subgroup Marimbas

Evaluation:

- Project/Award Rubric
- Validation by External Judges

Rubric Categories

Project Presentation	Delivery
	Content
	Preparation
Musical Performance	Rhythmic Accuracy
	Enthusiasm
Construction	Craftsmanship & Creativity
Teamwork & Individuality	



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Rehearsals!

Alto + Tenor + Base => Melody + Harmony + Bass Line



A musician from *Les Ninjas Volants* mastering the harmony



Team 3 subgroups uniting to play *Tequila* (D. Flores)



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Awards!



Team 2 - Champions



Team 3
Most Entertaining



Team 1
Most Artistic



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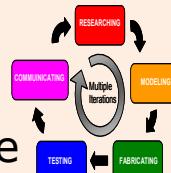
Summary:

- The pilot marimba project successfully engaged all the students through use of hands-on demos, project-based learning and integration of the Arts into STEM

- The students...



- Applied their classroom knowledge & gained new fabrication skills
- Gained experience brainstorming and idea focusing as part of a Design Cycle
- Employed math in a real world application
- Worked hierarchically, making a marimba in a subgroup and a presentation as a full team
- Gained confidence in their ability to build something useful



$$\sqrt{\frac{f_1}{f_2}}$$





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Recommendations:

- Allow more time for implementation of new marimba ideas emerging from the brainstorming session
- Revise the process flow to improve efficiency of the construction and music selection phases
 - Marimba stick construction and artwork could occur in parallel with tone bar and frame construction
 - Music selection could be simplified if a full set of marimbas were available for early rehearsals
- Consider expanding the tuning phase to include a lab
 - Model marimba bar frequency as a function of length
- Initiate collaboration early with Music, Art & Social Science Departments



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Thanks!

Organization

Mary Harmon*

Material Doners

Chad M Burke(hardwood)
Thomas Burke (hardwood)
John Cohn (piezo disks)
Mark Jaffe (hardwood)

Wood Preparation

Michael Hauser*
Greg Massey
Charles Musante

Marimba Guides

Cathryn J Christiansen
Paul Garrett
Bart Green*
Brian Kessler
Kendra E Kreider
Charles Larow
Jeff Mogielnicki*
Laura J Schutz
Vishwa Shah
Timothy D Sullivan
Frank White

Students

NOVA Team at
EMS, Essex,
VT

Judges

Michelle Badji
Lisa Barry
Neal Camp
Patricia Dodge
Larry Laush

* Core team member of *Make It Science*