Make to Learn: Invention Through Emulation

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Make to learn: invention through emulation

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Abstract

The Make to Learn coalition was established to identify effective pedagogical approaches for employing makerspaces for educational innovation in schools. The Make to Learn coalition is anchored by the Make to Learn Laboratory in the Curry School of Education at the University of Virginia and the Laboratory School for Advanced Manufacturing in the Charlottesville City Schools, working in collaboration with the Joseph Henry project at Princeton University, advanced manufacturing programs at Midlands Technical College, and the Smithsonian Institution. This paper describes a key consortium initiative, American Innovations in an Age of Discovery. Participating students use school makerspaces to reconstruct working models of transformational inventions. The reconstruction process is grounded in a method employed by historic inventors, invention through emulation. The benefits of this approach, updated to take advantage of modern technologies, are discussed in the context of maker education.

Collaboration: Schools of Education and Engineering, Smithsonian, Public Schools
Employing Makerspaces for Educational Innovation
Re-creation of Historic Inventions using 3D Printers, Laser and Die Cutters, CNC Mills
CEE 102 “Engineering in the Modern World”

PERSPECTIVES

Scientific  Formulas
Social     Context
Symbolic  Meaning

CATEGORIES

Structures  Civil
Machines   Mechanical
Networks   Electrical
Processes  Chemical
CEE 102 “Engineering in the Modern World”

**PERIODS**

Iron, Independence, and Industry  
1776 - 1855

Connecting the Continent  
1830 - 1883

Rise of the Great Industries  
1876 - 1939

Regional Restructuring  
1921 - 1964

Information and Infrastructure  
1946 - present

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How do innovations happen?

Scientific: How does it work?
Social: What is it good for?
What is the context?
Symbolic: Why should I care?
Person: Who did what?
Motivation: Why did they do it?
History: When and Where?
What is the impact?

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• Inspirational people
• Inspirational objects and systems
19th Century American Innovators
20th Century American Innovators
“Good artists copy, great artists steal”

“Les Demoiselles d’Avignon” - 1907
Galileo Galilei (1564 – 1642)

Medical Doctor
Mathematics Professor
Instrument maker
Physicist – theory and experiment
Astronomer

Known for:
Pendulum analysis
Pendulum clock (about 1640)
Parabolic trajectories – free fall
Galilean Telescope
Moons of Jupiter; discovery
Advocate for Copernicus’s Ideas
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Pulsilogium of Santorius – first precise measuring device in medical history – uses length to quantify pulse rate
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Galileo estimated correctly that for small amplitudes that the period scaled with $\sqrt{L}$, but he was not correct in believing that the semi-circular path was a brachistochrone.
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Galileo’s parabolic studies are known to be motivated by experiment and the “law of the fall” – used inclined plane

His measuring device was a ruler
1. Independence of horizontal and vertical motion
2. Conservation of horizontal inertia
3. Independent acceleration in the vertical ("law of the fall")

1. Period varies with the square root of length; the Law of Length
2. Period is independent of amplitude; the Law of Amplitude Independence
3. Period is independent of weight; the Law of Weight Independence

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Pendulum clock - sketch by Viviani, a young student of Galileo – clock model constructed by son, Vincenzo Galilei
Copia esatta del disegno che rappresenta il primo esempio dell’applicazione del pendolo all’orologio,
detto da Galileo già circa al figlio Vincenzo e al disegno Viviani,
lasciata dall’originale esistente nei manoscritti Biblioteca della Biblioteca Nazionale F.IV. T.IV.
3D Printed Model of Galileo’s Pendulum Clock
Charles Grafton Page (1812 – 1868)

Medical Doctor
Chemistry Professor
Instrument maker
Patent Examiner
Electromagnetic Inventions

Known for:
Shocking Coils (iron wire bundle instead of solid core - 1836)
Commutated electric motor (1837)
Axial engine – solenoid motor (1845)
Electric Locomotive
Commutated DC motor – 1837 – Charles Grafton Page
Charles Grafton Page (1812 – 1868)

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Electric Locomotive
Animation of Page’s Axial Engine
Smithsonian Invention Kits – in Collaboration with University of Virginia and Princeton
3D solenoid motor inspired by Page’s Axial Engine
Galileo Galilei
- Pendulum Clock
- Measure Human Pulse
- Determine Longitude

Charles Grafton Page
- Electric Motor
- Electricity for motive power
DEMO using AutoDesk Fusion 360
FlashForge Inventor
Bantam Tools OtherMill

CAD Design
3D Printer
CNC Mill
Use examples – not all bridges – but the Golden Gate Bridge
Tell a story – show how it works – let them do it (auditory, visual, tactile)
Put a face on it – biography – who did what, and when and where and why
Highlight inspirational innovators and their inventions
Teach the teachers – Learn from teachers
Keep it simple – use original instruments if possible
Explore big picture – technical, social, legacy
... then, challenge kids to build on key ideas – make their own inventions

Not just communicating, but getting response:

I can do that!
I want to do that!

Replicate – Modify – Apply
END
imitation – emulation - invention

1. STEM education – target middle school and high school
2. CEE 102 – course objectives – put a face on the work
3. Picasso
4. Galileo - clocks
5. Page - motors
6. 3D Printing and CNC Milling
7. Approach

1. Don’t just talk about bridges – use a specific one
2. Who did it?
3. Why did they do it?
4. What was the environment? Inspiration ...
5. What is the impact?
6. Replicate – modify – apply Not just to communicate ...
7. tell – show - do Response: I can do that I want to do that