A Vision for Convergence and Emergence in 21st Century Nano-STEAM+ Education

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National Academy Triennial Review of the National Nanotechnology Initiative July 30, 2015
U.S. State Department: Hidden No More Visit, JSNN, Greensboro, NC November 5, 2018
Waves of Innovation

www.naturaledgeproject.net
Every system is perfectly designed to get the results it gets.

- Deming, Berwick, and Betalden
Recommendations for Nano-STEAM+ Education

The JSNN Culture

Human Infrastructure for Nanotechnology

*Current, Convergent, and Collaborative Needs*

Triennial Review of the National Nanotechnology Initiative
National Academies, Washington, DC

July 30th, 2015

The Need for Convergence and Emergence in 21st Century Nano-STEAM+ Education

*Nanoscale Science and Engineering Grantees Conference*
Westin Hotel, Arlington, VA

December 10th, 2015

Global Perspectives of Nanoscience and Engineering Education

Early Days of Electronic Information Processing

On February 14, 1946, scientists at the University of Pennsylvania introduced ENIAC, the world’s first large-scale, general purpose electronic computer, which could process more than 100,000 calculations per second.

-1995 SRC Annual Report

My Dad, Donald L. Herr, was a member of the ENIAC Design Team.
Trends in Electronic Switches

Many ‘Ugly Ducklings’

Vacuum Tube (1946)
- www.wikiwand.com
- 1904 Audion

Transistor (1947)
- iriseze.wordpress.com
- commons.wikimedia.org

Integrated Circuit (1958)
- www.techspot.com
- www.thocp.net

Monolithic IC (1959)
- www.imageslides.com

I7 Chip (2014)
- www.wikiwand.com
- www.thocp.net

?
### Evolution of an Emergent Technology

*Typical time-scales for breakthrough ideas to impact society*

<table>
<thead>
<tr>
<th>Technology</th>
<th>Incubation Phase (Yrs.)</th>
<th>Innovation Phase (Yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid State Diode</td>
<td>1874 – 1900</td>
<td>1900 - 1913</td>
</tr>
<tr>
<td>Vacuum Tube</td>
<td>1883 – 1904</td>
<td>1904 - 1919</td>
</tr>
<tr>
<td>Transistor</td>
<td>1923 – 1948</td>
<td>1948 - 1959</td>
</tr>
</tbody>
</table>

**Mean Phase Duration (Yrs.)**

- Incubation: $22 \pm 6 \ (1\sigma)$
- Innovation: $12 \pm 3 \ (1\sigma)$

Revised from D. Herr and V. Zhirnov (SRC/2003)
Design Educational Ecosystems to Achieve Desired Results

*With Platform Enhanced Learning Opportunities*

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**Convergence** and **Emergence**

Convergence of Knowledge, Technology, and Society

New Socioeconomic Capabilities

- M. Roco, NSEG Conference (2015)
For Information Processing Technology, What’s Next?
With a 34 year latency, the next big wave should soon emerge.

Where should we look for the next wave of emergent opportunities?

D. Herr (2014)
Rec. #1: Leverage interdependent formal and informal expertise and infrastructures

Some Strategic Nano-STEAM+ Recommendations
From the NSEE Workshop – the Next Steps Report (10/29/15)

Diversity (in education) is a strategic advantage if there is a truly vibrant community, sustained by a web of relationships.

From: The Web of Life, Fritjof Capra [Physicist, systems theorist, and philosopher]
Rec. #1: Examples

“I was like a (child) playing on the sea-shore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.” - Isaac Newton
High Impact 3D Fabrication

Ex. Robohand

http://www.youtube.com/watch?v=WT3772yhr0o
Summer Science Camps

UNC-Pembroke Summer Campers at the JSNN

JSNN-Canterbury Summer Science Academy
Rec. #2: Engage natural learning networks
E.g. Hands-on Platforms to Bridge Disciplines and Engage Creativity

- Nanoscience and Nanoengineering
  - Physical, Bio and Health Sciences/Engineering
  - Math/Coding
  - Sustainability
  - Tinkering

- Industry
  - Jobs
  - Internships
  - Entrepreneurship

- Other Liberal Arts
  - Communication
  - Critical Thinking
  - Social Studies
  - History
  - Arts
  - Functional and Sustainable Nanosystems/Assembly

Community
- Service
- Engagement
- Conversation
- Tinkering

Nanobus
Summer Science Academy at the JSNN
*Nurture Tinkering, Creativity and Critical Thinking*

Rising 9th Graders

The 2015 Team

The 2016 Team
Summer Science Academy at the JSNN
*Nurture Tinkering, Creativity and Critical Thinking*

Rising 10th Graders

3D Design, Fabrication, and Testing of Hand-Held Aerial Vehicles
Rec #3: Nurture disciplinary depth and breadth, i.e., ‘+’ throughout the Interdependent Educational Ecosystem.
The JSNN’s Vision
Convergent Education, Research & Innovation Ecosystem
An Artificial Cicada Wing Surface

Image By: Kyle Nowlin
The Effects of Music on the Brain
https://www.youtube.com/watch?v=DeENTorAY8w

Arrows Show Liked and Disliked Music connect the Auditory Cortex and Hippocampus.
A Favorite Song fully connects the Hippocampus as a separate Module of Connectivity

Nanoart

An activated gene chip  F. Cerrina(UW-M)
Rec. #4: Share a common language and make Nano-STEAM+ accessible to all learners

e.g. Prosthetics, neuronal architectures, cognitive systems

Leverage Stakeholders Who Know the Local Environment
Hydroponics

A sustainable option for addressing food deserts

http://www.simplyhydro.com/system.htm
Smart Textiles:
Potential Hydroponic Functional Textile Platforms

Cotton

Flax
Nanomanufacturing of Functional Natural Textiles

Leverage Efficient, Flexible and Adaptive Biomimetic Factories

The ‘Ugly Duckling’ phase of flexible and wearable electronics, e.g. Functional natural textile composites

Ex. Light Generating Plant Composite
Advanced Hydroponics: Nutritionally Enhanced Foods
A Potential Solution For Local Food Deserts, Where the Distance to Healthy Food is >0.5 Mile

WFMY News2 [January 26, 2014]: 33% Of Greensboro Urban Pop. Lives In Food Desert

greensboroobserver.wordpress.com
USDA (May 2013)

archive.digtriad.com
USDA (January 2014)
Aeroponically Grown Asian Greens

Bok Choy Planted on December 26, 2016

Plant to harvest in <1.5 Months

15 Days
January 10, 2017

33 Days
January 29, 2017

42 Days
February 6, 2017
Nutritional Deficiencies in Soils

Southeastern United States [Green contours]

The 'red clay' soils of the southeastern United States are examples of Ultisols. Green contours represent low soil concentrations of calcium, phosphorous, manganese, strontium, zinc (and Potassium).
Let not what you do define what you are. Rather, let what you want to become define what you do.

- John Hurt, NSF (1997)
Create and Sustain A Collaborative Community

JSNN is a unique academic collaboration

Community

Enables

- Educational programs
- Discovery & Innovation
- Economic Development

Cortical neurons on multi-electrode arrays
S. Aravamudhan, JSNN
How small can we go?

Ultra-micro-bacteria (~200 nm)

Extracted from a glacial ice core sample, 120,000 years old  Miteva (2005)

Thank You

What if?

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