Brain-STEM: Merging Brain Research and STEM Education

GA STEM Conference (10-21-10)

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The brain is without doubt our most fascinating organ. Parents, educators, and society as a whole have a tremendous power to shape the wrinkly universe inside each child's head, and with it, the kind of person he or she will turn out to be. We owe it to our children to help them grow the best brains possible.

*What is Going in There?*

--- Lise Eliot
Brain-STEM

1. Where are we in science/STEM education?

2. How can we create “brain-considerate” learning environments in science? (the neuropsychological aspects of learning)

3. How can we modify classroom instruction to meet the goals of the CCSS and the NGSS based on our answers to the above questions? (STEM/S.T.²R.E.A.M. Schools)

Quick writes and table talks
“Let me keep my mind on what matters, which is my work, which is mostly standing still and learning to be astonished.”

-- “The Messenger” by Mary Oliver
Teaching is the most crucial of all professions because everybody who is anybody was taught how to be somebody by a teacher.

...it is also the most exhausting.

--- Art Costa

Teaching is the most crucial of all professions because everybody who is anybody was taught how to be somebody by a teacher.
Our best efforts in teaching requires a shift from…

“What am I supposed to teach?”

to

“How do my students learn?”
1900 Workplace Demands

Highly skilled

Low skilled

• Avg. age to enter work force 14
• Avg. age to leave work force 47
• Life expectancy 47
2014 Workplace Demands

Highly skilled

Low skilled

• Avg. age to enter the workplace 21
• Number of career changes 5-8
• Est. Life expectancy in 2100 107 -124!
Astonishing: Today’s Kindergartners…

• Will retire in the year 2074

• What foundations for learning must we establish for them?

• In what ways are you preparing them for success in the years between 2014 and 2074?
Which workplace will students in your school district be best suited for?

a) 1885?
b) 1925?
c) 1955?
d) 1985?
e) 2005?
f) 2025?
g) 2045?
STEM

The most recent 10-year employment projections by the U.S. Labor Department show that of the 20 fastest growing occupations projected for 2014, 15 of them require significant mathematics or science preparation to successfully compete for the job.

In 2012, nearly 70% of American HS graduates failed to meet college-readiness benchmarks in science.
Today’s College Students…

College Freshman are Well or Very Well Prepared

- High School Teachers - 89%
- College Instructors – 26%

Freshmen Needing Remediation

Two-year colleges – 51.7%
Four-year colleges/univ. – 19.9%

College Retention Rates in 2012: From 1st to 2nd year of higher education

Two-year colleges – 55.5%
Four-year colleges/univ. – 65.2%
Average Graduation Rates: 1983-2012

Two-year colleges in 3 years – 29.1%
Four-year colleges in 5 years – 36.6%
Your Major Matters

Bachelor’s Degrees Granted in the U.S.

1. Business
2. General Studies
3. Social Science and History
4. Psychology
5. Health Professions
6. Education
7. Visual and Performing Arts
8. Engineering and Technology
9. Communications and Journalism
10. Computer and Information Science

Source: National Center for Education Statistics
Your Majors Matter

Bachelor’s Degrees Granted in Competing Nations

1. Business (1)
2. General Studies (10)
3. Social Science and History (6)
4. Psychology (9)
5. Health Professions (4)
6. Education (5)
7. Visual and Performing Arts (8)
8. Engineering and Technology (2)
9. Communications and Journalism (7)
10. Computer and Information Science (3)

Bachelor’s–Competing Nations
Source: National Center for Education Statistics
13 Million Americans are unemployed.

However, 3.8 million jobs in the U.S. remain unfilled.
# 10 Highest-Paying Degrees

(Aug 2011)

The 10 college degrees that lead to the highest salaries.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Degree</th>
<th>Median Starting Salary</th>
<th>Mid-Career Average</th>
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<tbody>
<tr>
<td>1.</td>
<td>Petroleum engineering</td>
<td>$97,900</td>
<td>$155,000</td>
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<td>2.</td>
<td>Chemical engineering</td>
<td>$64,5000</td>
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<td>3.</td>
<td>Electrical engineering</td>
<td>$61,300</td>
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<td>4.</td>
<td>Materials science and engineering</td>
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<td>5.</td>
<td>Aerospace engineering</td>
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<td>6.</td>
<td>Computer engineering</td>
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<td>7.</td>
<td>Physics</td>
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<td>8.</td>
<td>Applied mathematics</td>
<td>$52,600</td>
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<td>9.</td>
<td>Computer science</td>
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<tr>
<td>10.</td>
<td>Nuclear engineering</td>
<td>$65,100</td>
<td>$97,800</td>
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</table>
In 2002 there were 4M 9th graders in the US. In 2011, what percentage of this group graduated from a (2/4 yr.) college with degrees in a STEM field?

A. 5.5%
B. 10.5%
C. 19.5%
D. 25.5%
Approximately what % of all US-granted doctoral degrees in engineering, mathematics, computer science, and physics (STEM) were awarded to foreign students in 2008?

A. 20%
B. 50%
C. 75%
D. 90%
From STEM to ST²REAM: Reassembling Our Disaggregated Curriculum

By Kenneth Wesson

Countless millennia before the acronym STEM—for science, technology, engineering, and mathematics—entered our modern lexicon, early man was already engaged in STEM endeavors. Our ancestors spent significant portions of their days experimenting, tinkering, and thinking their way through myriad problems and challenges. During those prehistoric periods, the dreamers, the designers, and the builders identified the urgent problems, and subsequently crafted tools, crude instruments, and strategies to resolve them, working collaboratively for both survival and human progress.

Columbus' historic trans-Atlantic journey in 1492 was
What is STEM/STEAM/S.T.²R.E.A.M.?
Good thinking is a matter of making connections, and knowing what kinds of connections to make.

---David Perkins
The human brain is the most sophisticated information-integration processing system on earth with over 40,000 miles of neural circuits connecting over 100 billion neurons and nearly 1 trillion other cells.

As brain cells develop into circuits, the brain makes no distinction between academic disciplines (there was no evolutionary basis for such a “need”.)
The Association Cortices Make up 37% of the Human Cerebral Cortex
“Science” - L. for “knowledge.” A scientist refers to someone who uses knowledge to explain natural phenomena in our universe and how they work.

STEM integrates content from four “disciplines” and focuses on the applications and practices in these “silos” → a new trans-disciplinary perspective that is meaningful, authentic and memorable.

STEM ↑ access to learning preparing students for post-secondary study, the 21st century workforce, and becoming well-informed STEM-savvy citizens.
Standards from Which Discipline: Math or Science?

1. Asking questions and defining problems
2. Obtaining, evaluating, and communicating information
3. Look for and make use of structure
4. Planning and carrying out investigations
5. Attend to precision
6. Analyzing and interpreting data
7. Model with mathematics
8. Using mathematics and computational thinking
9. Constructing explanations and designing solutions
10. Make sense of problems and persevere in solving them
11. Reason abstractly and quantitatively
12. Construct viable arguments and critique the reasoning of others.
13. Developing and using models
14. Engaging in argument from evidence
15. Use appropriate tools strategically
16. Look for and express regularity in repeated reasoning
1. Asking questions and defining problems (NGSS)
2. Obtaining, evaluating, and communicating information (NGSS)
3. Look for and make use of structure (M)
4. Planning and carrying out investigations (NGSS)
5. Attend to precision (M)
6. Analyzing and interpreting data (NGSS)
7. Model with mathematics (M)
8. Using mathematics and computational thinking (NGSS)
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12. Construct viable arguments and critique the reasoning of others. (M)
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14. Engaging in argument from evidence (NGSS)
15. Use appropriate tools strategically (M)
16. Look for and express regularity in repeated reasoning (M)
<table>
<thead>
<tr>
<th>Practices in Mathematics, Science, and English Language Arts*</th>
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<tr>
<td><strong>Math</strong></td>
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<td>M1. Make sense of problems and persevere in solving them.</td>
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<td>M3. Construct viable arguments and critique the reasoning of others.</td>
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* The Common Core English Language Arts uses the term “student capacities” rather than the term “practices” used in Common Core Mathematics and the Next Generation Science Standards.
When STEM professionals are engaged in producing knowledge, we frequently use/apply *principles, concepts, skills or tools* associated with other disciplines (top horizontal) during the course of research, in the academic day or in “real-world” situations. Identify where these disciplines merge, intersect or overlap.

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<th>Content Areas</th>
<th>Science</th>
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Scientists, Mathematicians and Engineers

- Do scientists, mathematicians and engineers communicate with one another?
- Do scientists, mathematicians and engineers write summaries of their work?
- Do they write reports?
- Do they write research papers?
- Do they give oral presentations of their research at symposiums? Interviews?

“Reading and writing comprise over half of the work of scientists and engineers.” (NRC 2011)
S.T².R.E.A.M.

Science

Technology

Engineering

Mathematics

Reading/Language Arts (Standards)
Reading, writing, discourse, argumentation, vocabulary development, comprehension, journals, note-booking, lab reports, summaries, oral presentations, recording interpreting and critiquing data and information

Visual Literacy

Art
Drawing/diagramming, visual spatial thinking, imagery, inferential thinking, 2/3-dimensional modeling, symbolic models, interpreting visual evidence, visual representations - illustrations, charts, etc.

Convergent/Integrative STEM T’ & L’
Learning: When “More” Becomes “Less”

- **Enrichment studies:** Examine the effects of enrichment or deprivation on brain development, neurogenesis, neuronal growth and synaptogenesis.

- While neurons generally grew in size, measures of:
  - (a) increased dendritic density
  - (b) increases in the number of glial cells
  - (c) myelination of the axons
  - (d) changes in brain weight and overall brain volume

- No toys or playmates ↓ all growth measures (impoverished)

- Playmates + a change of toys every other day ↑ (Enriched environments)

- **Changing toys every hour:** → similar ↓ neural connections in brain growth and development (your school day??)
Using Interdisciplinarity to Improve Our Minds and Our Schools
Merger Academic Disciplines to Find the Answers

Brainstem

By Kenneth Wesson, Ph.D.

"The illiterates of the future are not those who cannot read or write, but those who cannot learn, un-learn, and re-learn." — Alvin Toffler, Futurist

Students beginning kindergarten this fall will likely retire around the year 2075. An unpredictable world awaits them. How do we prepare our children for the future, with such an uncertain economy and rapidly evolving technology? According to Microsoft CIO Cameron Evans, current educational approaches were designed to prepare students for careers that don’t exist anymore, and may never exist again. It is estimated that this new generation of school-aged children may hold between five to eight different careers throughout their lives. The most recent projections by the U.S. Department of Labor indicate that 15 of the 20 fastest-growing professional occupations require a significant understanding of mathematics and science, two subjects where American students lag behind Europeans. Consider the following...
Brain-considerate Learning: PERC$^3$S

There are five BC elements that the human brain seeks while processing incoming stimuli for personal “meaning,” which makes the information “memorable” and worth remembering.

1. **Patterns** (derivatives of experience)
2. **Emotions**
3. **Relevance**
4. **Context, Content, and Cognitively-appropriate Sense-making**

Patterns, emotions, relevance, context, content and sense-making are critical factors in driving (1) attention, (2) motivation, (3) learning, (4) memory formation, and (5) recall. Collectively, these 5 factors are the primary criteria for transfer into long-term memory storage.
…not merely “academic problems” for the purpose of intellectual development, but global challenges to the very survival of our planet and our species. They will require new approaches, novel ideas, new solutions, and the complex merging of multiple disciplines.
The Anthropocene is not a healthy epoch in the earth’s geological chronology. The activities of human beings since the late 1800s (Industrial Revolution) have had a greater negative impact on this planet’s lithosphere than any other creature in the history of planet Earth. So much so that geologists have designated man’s destructive occupancy of this planet as a period: “Anthropocene,” to be precise. The rate of extinction suffered by other species during man’s residency on this planet, this anthropocenic age, has been anywhere between 100 to 1000 times more intense than beforehand.
Drugs Contaminate Lake Michigan

Prescription drugs have been found far from Milwaukee's sewage outfalls, suggesting the lake is not diluting the compounds as scientists expected.

By Brian Bienkowski and Environmental Health News | Thursday, September 5, 2013 | 5
Reverse Direction Decoding

vancomycin

cin

my-cin

co-my-cin

van-co-my-cin

antibiotic drug of last resort for hard-to-treat hospital-acquired infections
Revolutionizing How We Teach Reading
by Kenneth Wesson

A short list of humankind’s greatest achievements would undoubtedly include the use of tools, language and technology. Reading and writing have become so second nature to educated individuals that reading is taken for granted; but by readers only. Literacy can not only alter the success-trajectory of our lives, but the process of learning how to read “literally” alters brain circuitry, the physiology and architecture of the human brain. In addition to listening to words, we read words, use words in speech, and even think in words.

Phonics is the popular reading strategy commonly taught in preschool, primary and upper elementary grades, and sometimes still in middle schools. However, shouldn’t any technique used repeatedly for almost 10 consecutive years with only modest success warrant some suspicion? Worst of all, the word “phonics” does not conform to its own rules. The mere fact that it is not spelled phonetically should have generated suspicions about the theory! It has produced millions of “phonics-damaged children” according to some researchers.
Teaching Creativity and Innovation Through STEM and STEAM

How can we plan daily classroom experiences to meet the goals of STEM?
STEM education...

The easiest way to incorporate play and STEM into your curriculum is to identify the STEM in the content and activities that you are already teaching.

Some content is “STEM,” but not labeled as such, while other content lends itself towards STEM and play with just a few modest modifications.
Humpty Dumpty’s friend, the local fortune-teller, has predicted “a severe fall accompanied by multiple injuries.”

Mr. Dumpty recently saw you and your engineering expertise featured on the Six O'clock News. Design an engineering solution for him.
Engineering solutions for Humpty Dumpty...

- A light-weight titanium helmet
- A full-body padded suit
- A thick foam pit at the base of the wall
- A seat/seatbelt system securely fastened to the wall
- A “tip-o-meter” that sets off a siren when he leans 5-10 degrees in any direction
- Attach him to a motion-activated parachute
Re-engineering: The Three Little Pigs

NGSS:
“...develop a simple sketch, drawing or physical model to illustrate how you would solve this problem.” (Achieve, Inc., 2013)

Problem/situation: You have received an urgent text message from the Three Little Pigs, who are exasperated with “little pig-provocation” by their neighbor the Big Bad Wolf. You have been asked to engineer two safeguards to prevent further persecution from the Big Bad Wolf. What design and engineering solution can you propose?
1. A house with an aluminum rooftop.
2. Replace the chimney with a central heating system.
3. Wolves are afraid of snakes, so around the house...
4. Wolves are afraid of water, so install a motion-sensitive automatic water sprinkling system.
5. Build a solar-powered environmentally friendly fan that blows air away from the house, when the wolf blows air towards the house.
6. Build a house with a 35° angle rooftop (too steep).
7. Wolves are afraid of water, so build a houseboat and position it 20 yards from the shore.
Houseboat Solutions for the Three Little Pigs

“Arte/Scienza”

Only Your Imagination Can Set a Limit on Your Creative Thinking
• All ideas begin with a vision/visual image (a mental picture → drawing).
• All engineering begins with a design (→ diagram graphic representation of the initial idea).
S.T.²R.E.A.M.

Science

Technology (and **Thematic** trans-disciplinary instruction to extend student learning)

**Reading** and Language Arts

**Engineering** (“**Design and Engineering**”)

Art

Mathematics

(Maximizing connections and sensory experiences)
Why aren’t we spending more instructional time on drawing, abstract thinking and visualization?
Standardized Testing?

Teach your students to use the talents they *have*; the woods would be silent if no birds sang except those that *sing* the best.
N.C.L.B.

Non-educators Consumed by Legislation and Bureaucracy

No Considerations for human Learning and Behavior

Neuroscience, Cognition, Learning and the human Brain

Our role is to leave the next generation behind (not to take them with us) → leave them with the knowledge, skills and creativity to thrive.
Closest to

a) \( \frac{1}{2} \)  

b) 2  

c) 10  

d) 15  

Symbolic imaging for the young learner is far more difficult than object imaging.
VST = another way of “knowing”

\[ \frac{2}{3} + \frac{8}{12} = \]

Closest to
a) \( \frac{1}{2} \)

One must have a picture in mind before it can be connected to a symbol.

b) 2

c) 10

d) 15
...fractions, decimals, percents, and fractional parts of a circle, all represent the same part of a whole
We “see” with our eyes?

We see with our **brain**. Blind individuals read, learn, recognize objects, etc. without their eyes.
When taught to generate mental images as they read, students typically experience greater recall and enhanced abilities to draw inferences and make predictions.

(Gambrell, 1981; Gambrell & Bales, 1986; Pressly, 1976; Sadoski, 1983, 1985_)

Minds, Models, and Maps

By Kenneth Wesson

“Every child is an artist. The problem is how to remain an artist once he grows up.”

— Pablo Picasso

The solar system is too large to bring to school. Mammalian life cycles stretch well beyond the academic year, and tiny organisms are too small to examine closely. Prehistoric animals are, well, “prehistoric.” However, the forever fascinating world of science from the massive to the minute, of today and of years long gone, opens immediately to all students by way of sketches, models, simulations, maps, and other visual learning devices. Collectively, they allow young learners to make cognitive leaps from the intangible to the comprehensible.

learning. Once we “recognize” an object, separating image from name and the name from function becomes next to impossible. Vision is so central to factual certainty that our initial sensory impressions, and eventually our overall cognition, are validated by our eyesight. As we so often hear, children assure others that “I saw it with my own eyes!” underscoring a pinnacle in experiential confidence that cannot be humanly exceeded.

Visualizing is integral to reading for comprehension. To understand what they read, students must rely heavily on the “picture-making” mechanisms in the visual cortex in order to extract meaning from the text. The association cortex is charged with the task of making sense of the incoming visual information. Learners can only make sense of abstract information based on preexisting internal
The Generation Gap

We cannot always build a future for our youth, but we can build our youth for the future.

-- Franklin D Roosevelt

We are neurologically shaping young brains today for a future that is vastly unlike our own recent past.
### Popular Icons: 1950 - 1990

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Popular Icons: 2013
The Human Brain

1. Always engaged in “sense making”

2. Actively seeks connections that build on our prior experiences
Moving From Teaching Students to Be...

- Knowledgeable (facts)
  to
- Cultivating knowledge-ability (learning how to learn/re-learn/un-learn, how to process and use the available information resources – information literate/critical thinking), and
- Cultivating a wide range of problem-solving abilities
- Teaching students to memorize vs. teaching students to think.
The Knowledge Explosion

“The sum total of humankind’s knowledge doubled between 1750 and 1900. It doubled again between 1900 and 1950, again from 1950 to 1960, again from 1960 to 1965. It’s been estimated that the sum total of humankind’s knowledge has doubled at least every five years since then.

It’s been further projected that by the year 2020, knowledge or information will double every 73 days.”

Dr. James Appleberry - President, American Association of State Colleges and Universities
Figure 4. Percentage of fourth- and eighth-grade students who reached the TIMSS advanced international benchmark in mathematics, by country: 2007

“These STEM subjects don’t really go together, do they?”

The illiterates of the future are not those who cannot read or write, but those who cannot learn, *un*-learn, and *re*-learn.

--Alvin Toffler
Each year, new findings in cognitive psychology and neuroscience will be infused into teacher preparation, curriculum, instruction, student assessment, and the classroom environment. The works of Howard Gardner ("Multiple Intelligences"), Daniel Goleman ("Emotional Intelligence"), Kenneth Wesson ("Brain-considerate Learning"), and others have already been influential in reshaping the independent school classroom, while programs like Mel Levine’s Schools Attuned are assisting educators in using neurodevelopmental content in their classrooms to create success at learning and to provide hope and satisfaction for all students.
Teachers = Neuro-plasticians

Neuro-plasticians will shape the brains of the next generation.

• Being Robbed?
Our Mission is Bigger than “Content”

One of the most important things a teacher can do is to send a student home in the afternoon liking himself just a little bit better than when he came in the morning.

— Ernest Melby
“We don’t learn from experience, we learn by reflecting on it.”

-- John Dewey

Compose two “I will” reflections on this afternoon’s experience.
...growing the best brains possible!

Every time you think of STEM or S.T².R.E.A.M.,
I hope you’ll think of me, because I will be thinking of you.
The Gift

Yesterday is history,

Tomorrow is a mystery.

But, today is a *gift*.

That’s why it’s called

The *Present*. 
For additional professional development and other information, please see below:

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