PA Science
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When it Comes to Learning
Only the Gray Matter Matters

- Our students come in a variety of colors, but all brains are basically gray. It is only the gray matter that truly matters in learning and memory.

- Maximizing student potential hinges on educators developing a robust knowledge reservoir for teaching with the developing brain in mind.
“What formal education for one child for one year depends on what his/her teacher believes, knows, and does – and doesn't believe, doesn't know, and doesn’t do”.

A Teacher’s Mindset
A Teacher’s Mindset

- Knowing **who** you teach (a child with 100B neurons capable of making an infinite number of learning **connections** for a lifetime) is just as important as **what** you teach (disciplinary content).

- “I teach science.” No, you teach **students** whose brains prefer to learn by actively making elaborate **connections** inside their brains.
Children/students (young brains)…

- **grow** at different rates
- **learn** at different **rates**
- learn in different **ways**
- reach proficiency in skills more effectively through different strategies/means
- They learn some content information **slowly**, and other types of information **quicker** and more deeply (with different **strengths**, **outcomes**, & on timelines)
- **Cannot** teach **all** students at the **same pace** in the **same way**, **assuming they all have the same dev’l history** (a **broad range of “diversity in learning”**).
Translational Neuroscience

Investigate the ways in which our emerging understanding of the latest scientific evidence from neuroscience can inform education and the teaching of science and other disciplines in the contemporary classroom.
How Children Learn Science

• How does the brain learn best? How does that answer overlap with STEM education?
• Implementing the NGSS for all children.
• Developing language competency through (FOSS) science and STEM.
• What is STEM and what should it look like in a learner-centered academic environment?

(... ↑ visual examples 6X )
Our educational system in many ways continues to guide students through the same career preparation that was initially designed for their parents (assembly-line workers for the Industrial Age), rather than guided by current 21st century demands of the Information Age **Innovation Age**.
We are tasked with preparing our children and students for future occupations that

1. have yet to be created
2. we have neither encountered nor envisioned in any detail
3. demand skills sets that are tethered together in the real world (but not in our classrooms). The most important skill of the future will be creative thinking.
When Did Humans Start STEM/STEAM?

- Human beings were (and still are) engaged in STEM/STEAM experiences *before* we had the new acronyms.
- All human *advancements* that we enjoy today depended on (1) an understanding of science – *knowing*
  (2) *visualizing* a method of problem solving
  (3) *creating* tools or processes to satisfy our human needs (and curiosities.)
**Practices in Mathematics, Science, and English Language Arts**

<table>
<thead>
<tr>
<th>Math</th>
<th>Science</th>
<th>English Language Arts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M1.</strong> Make sense of problems and persevere in solving them.</td>
<td><strong>S1.</strong> Asking questions (for science) and defining problems (for engineering).</td>
<td><strong>E1.</strong> They demonstrate independence.</td>
</tr>
<tr>
<td><strong>M2.</strong> Reason abstractly and quantitatively.</td>
<td><strong>S2.</strong> Developing and using models.</td>
<td><strong>E2.</strong> They build strong content knowledge.</td>
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<tr>
<td><strong>M3.</strong> Construct viable arguments and critique the reasoning of others.</td>
<td><strong>S3.</strong> Planning and carrying out investigations.</td>
<td><strong>E3.</strong> They respond to the varying demands of audience, task, purpose, and discipline.</td>
</tr>
<tr>
<td><strong>M4.</strong> Model with mathematics.</td>
<td><strong>S4.</strong> Analyzing and interpreting data.</td>
<td><strong>E4.</strong> They comprehend as well as critique.</td>
</tr>
<tr>
<td><strong>M5.</strong> Use appropriate tools strategically.</td>
<td><strong>S5.</strong> Using mathematics, information and computer technology, and computational thinking.</td>
<td><strong>E5.</strong> They value evidence.</td>
</tr>
<tr>
<td><strong>M6.</strong> Attend to precision</td>
<td><strong>S6.</strong> Constructing explanations (for science) and designing solutions (for engineering).</td>
<td><strong>E6.</strong> They use technology and digital media strategically and capably.</td>
</tr>
<tr>
<td><strong>M7.</strong> Look for and make use of structure.</td>
<td><strong>S7.</strong> Engaging in argument from evidence.</td>
<td><strong>E7.</strong> They come to understanding other perspectives and cultures.</td>
</tr>
<tr>
<td><strong>M8.</strong> Look for and express regularity in repeated reasoning.</td>
<td><strong>S8.</strong> Obtaining, evaluating, and communicating information.</td>
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</table>

*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.*
STEAM intentionally integrates content knowledge, skills and concepts from 5 “disciplines” and focuses on the applications and practices within these “silos” → a new trans-disciplinary approach to education that is active, meaningful, relevant, and memorable.

Art deserves inclusion in STEM
Interdisciplinarity

Good thinking is a matter of making connections, and knowing what kinds of connections to make.

---David Perkins
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
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’
One of the great ironies of formal education is that we expect students to put the various pieces of the curriculum together into something we call real-world knowledge that can be applied when they graduate, although we make no claim that we ever showed them how.
You will be planning, designing, and making each of the objects, structures or products listed below. Which of them require the skills that are developed in the STEM/STREAM subjects?

<table>
<thead>
<tr>
<th>Object</th>
<th>Science</th>
<th>Technology</th>
<th>Reading (ELA)</th>
<th>Engineering</th>
<th>Art/Design</th>
<th>Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running shoes</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Skateboard park</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Non-tipping Kayak</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Backpack</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>New i-Pod</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Amusement park</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Amusement park rides</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Racing bike</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>Sunglasses</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
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<tr>
<td>Electronic game</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Schools vs. the Real-world
(“Interdisciplinarity is like real life”)

“…school learning is abstract, theoretical and organized by disciplines, while work in the real world is concrete, specific to the task, and organized by problems/projects…” not by disciplines.

STEAM education…

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

Some content **is** “STEAM,” but not labeled as such, while other content **lends itself towards STEM/STEAM** with a few minor 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.
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?
Cognition and Making Connections

Cognition – from *L.* base “know together” – to make connections not to memorize information from one “silo” at a time (isolated *facts*, individual *skills*, and *concepts* presented in a vacuum without a real-world connection)
“Re-purpose” the same cells for participation on countless related brain circuits
Memory Test

We...

- Operate by generalizations: not every situation is identical, but neither is it completely novel → mathematical propositions = “It is similar to the last time that I encountered many of these same ‘pieces’ or ‘elements’” → we draw from what we recall from the past (patterns) to navigate the current conditions (“adaptation” → the history of species’ survival)

- Make inferences – “fill in the blanks” with common elements from existing memory circuits that seem to “fit” this new event or current experience (assess the “if-then” nature of things likely being similar to how we experienced them previously, assuming a “rational semi-predictable world.”) Learning connects the dots → “logical” and repeatable errors.
Our brain serves us best when it is

(1) predicting the future,
(2) anticipating the consequences of action – its own actions or that of others,
(3) saving us time.

It uses patterns and experience to help us create internal models of the world, in ways that allow us to survive (“habits of mind”).
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** (derivative of visual experience)
2. **Emotions**
3. **Relevance**
4. **Context, Content, and Cognitively-appropriate**
5. **Sense-making → models and stories**

The brain examines all learning experiences through the lens of PERCS → determines how much we remember, **how long** we remember it, and whether or not we understand it enough for subsequent **application** (transfer of knowledge).
Background Knowledge

High academic performance

- Less memory storage/retrieval and
- less ability to apply factual knowledge
Schemas: Non-conscious Hypotheses

- Schemas: “mental files” (expectations/stereotypes) that shape our perceptions of other groups as well as ourselves.
- All schemas influence each group members’ judgement of others and how he/she will be judged based on these stereotypes (what is going on in the minds of others.)
Many comprehension difficulties → schema-related problems:

a. has no schema for the topic
b. not enough context clues to select the appropriate schema
c. selecting the wrong schema for interpreting text
d. lacking the cultural or experiential background on which a particular schema is grounded.
The 10-80-10 Rule for New Learning

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Build</th>
<th>Extend</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>80%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Past content  New information  Preview
Learning Goal: Conceptual Change

• If the students’ initial exposure to a scientific phenomenon is not engaged, they may fail to grasp new concepts and information presented in the classroom or they may learn them for the purposes of the test, but revert back to their preconceptions (Bransford et al., 1999).

• Correcting a paper or an incorrect test item seldom modifies a student’s incorrect thinking or his/her immature misconception of a scientific notion.

• Their thinking needs a conceptual change that occurs most effectively by means of new experience(s) → connections.
“How *does* the human brain learn?”
The Role of Experience in Learning

Everything that we do, feel, say and experience from infancy to the end of life is reflected in the ways that circuits in our brains get “wired together” and subsequently determines what we are able to learn (conceptually grasp and process successfully) at any given time.
The neural basis of cognition rests in the work of the neurons.

**Ensemble of neurons**

100 billion = Number of neurons that we are born with (full-term)

**Learning** = building a neural pathways to store what we have experienced → a change in brain circuitry -- 24/7

**Infants…**
Human-to-Human Interface:
Transferring the electrical signals from one person’s brain to the hands of both people

270 = m.p.h. – the speed at which neuronal signals travel
Emotions and Learning

The S.A.I.L. Concept

The environmental preconditions that should be experienced by students prior to initiating formal instruction include...

- **Safety**
  - Physical and emotional

- **Acceptance**
  - No “put-downs”

- **Inclusion, Interactions and Involvement**
  - Interpersonal/social aspect of memory formation

- **Learning**
  - Students feel their immediate environment is secure enough for them to take risks, explore and discover

After satisfying these prerequisite neurophysiological and hierarchical conditions, students are biologically ready for...

Students who have chronic safety concerns also tend to **underperform** academically *(Pratt, Tallis, & Eysenck, 1997)*.
“I Have a Discipline Problem.”
No! You Have an Engagement Problem

Engagement

- Phenomena-based learning
- Inquiry (an onslaught of questions)
- Student-centered learning
- Social connections

Emotions → attention → learning → memory (integrated in the brain)

Cognitive deprivation: env.’s lacking in consistent sensory and cognitive stimulation, complexity, challenge and feedback
Experience Shapes the Brain

The brain is the only human organ that depends on experience to determine its development (how, where, when, and if it develops and when development is arrested.)

Author Joseph Epstein said, "We are what we read." Neuroscientists would modify that statement to say that “We are what we experience.”
How the Brain Learns Best: By Experience

What do you remember about the class(es) and why was the learning so unforgettable to you?
If they don't learn the way you teach,

Then, why not teach the way they learn?
Kenneth Wesson & The Science of Learning

Here’s a provocative question: If it’s your job to develop the mind, shouldn’t you know how the brain works? Hear the answer from the keynote speaker at an upcoming CTA event — meet Kenneth Wesson.

Kenneth Wesson says that understanding how the brain works and learns can make you a better teacher.

Wesson, a former higher education faculty member and administrator, is a proponent of using neuroscience to improve education. By developing an understanding of how the human brain works and how the brain learns, he says, educators can reach more students, not just those who have traditionally been successful.

“You cannot talk about learning without discussing what’s happening inside the brain,” says Wesson, who will speak at CTA’s Instruction & Professional Development pre-
1. People learn and remember best through real-world first-hand experiences, not through memorization.

2. Children are born investigators.

3. We attempt to “make sense” of all incoming stimuli through the senses, visualization, and through formal language development.
The real cause of failure in formal education is essentially the fact that one begins with language, instead of beginning with real and material action. (Piaget, 1976)
The brain moves best from **meaning-to-print**, rather than from **print-to-meaning**.

- **1st hand**: Concrete
- **2nd hand**: Visual representation (VST)
- **3rd hand**: Symbolic/Abstract

The most difficult means by which the brain learns...
So that **students understand the learning goals**, state *explicitly what* the language objective/science content goals are at the beginning of class.

“Today we will engage in an **experiment** where we will investigate **air resistance** by constructing *twirly birds* (a.k.a., paper helicopters.)”

- Who has *seen* a helicopter in flight?
- In what directions did that helicopter fly?
- What is different about how a helicopter flies and how an airplane flies? ("**critical competitor**")
Constructionism (Papert):

Once this object is properly folded, *predict* what will occur when you hold it as high as you can and *release* it?
There is a specialized way of communicating (talking/writing in the S-T-E-M fields that is different from other disciplines. In STEM communities and STEM careers, “linguistic precision” is one of the primary means of expressing and communicating ideas to build a clear understanding of ideas and procedures within the discipline, and to share what is understood (or newly discovered) with others. “Academic Language”
Engineering Challenge: 
Build a Twirly-bird

• Creating solutions to problems (the work of engineers who “engage in a systematic practice of design to achieve solutions particular human problems” - NRC, A Framework for K-12 Science Education, 2012, page 11)

• Engineers approach a design problem by looking for a solution. The success of their solution(s) is determined by how satisfactorily it solves the identified problem (criteria).

• Solutions are limited by constraints (e.g., the available materials, time, budget/costs, tools, conditions, etc.,) and solutions do not occur via a “light bulb experience.” Instead, they require a deliberate, thoughtful, systematic design process.
**Observation:** STEM practitioners ask questions and *pay attention* (Engineering):

1. In *what direction* did the propellers rotate, clockwise or counter clockwise? (compare the rotor blade patterns the Blue vs. the white helicopters?)

2. What *modification* could you make to your helicopter that would *cause* the propeller blades to rotate in the *opposite* direction (re-engineering)?
Patterns of Motion: Twirly Bird

3. How would you change the outcome if you added a second paperclip? Compare the systems with a one-variable change:

(a) one paperclip
(b) 2 paperclips
(c) no paperclip (tape).

How did changing this one variable effect outcome?

a. Record your results.
b. Share your group’s findings with the class. (Describe the cause-and-effect relationships you observed?)
c. What forces were at work when the helicopter was in motion?
“The adjacent possible” - advancements and improvements come by way of tinkering with the current technologies (and the resources immediately available) to make gradual changes, not quantum leaps that are several magnitudes “ahead of their time.” Innovative ideas are not conjured out of thin air – they are extensions of the adjacent “existing components” into new combinations (“thinkable” extensions on what currently is.) Pathways to “the adjacent possible” → Brain-storming dialogues, discourse and conversations (infrequently in schools)
2-PS1-1.
Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2-PS 1-2.
Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
Vocabulary in Science: Twirly Bird

Basic Parts of a Helicopter

- **Fuselage** -- The main body of the helicopter is known as the fuselage. A frameless plastic canopy surrounds the pilot and connects in the rear to a flush-riveted aluminium frame.

Why are these words important to student discourse?
On your Twirly Bird…
- Where are the rotor blades?
- Where is the fuselage (body)?
- Where is the tail?

Scale, proportion and ratios
In-depth Investigations: Claims, Evidence and Reasoning (CCSS and Vocabulary Development)

What are the parts and the important design characteristics on a Twirly Bird that allow it meet the criteria?

The parts of my Twirly Bird include the __________. The ____ is important because________________. Also, the __________ _____ helps the system work by ____________________.

One problem we encountered was ______________, but we solved it by____________________. However, we could not solve the problem of _______, because _______. In a future re-design, we could possibly_________ to correct this problem.
Introduce/reinforce vocabulary in an *active context.*

("Constructive expression" not phonics $\rightarrow$ vocab. dev.)

1. Helicopter  
2. Experiment  
3. Observe  
4. Compare  
5. Propeller  
6. Gravity  
7. Rotate  
8. Rotary blade  
9. Descend  
10. Drag  
11. Model  
12. Engineering  
13. Affect  
14. Motion  
15. Friction  
16. Standard  
17. Predict  
18. Modify  
19. Re-engineering  
20. Observation  
21. Outcome  
22. Extend  
23. Stationary  
24. Variable  
25. Controlled variable  
26. Manipulated variable  
27. Increase/decrease  
28. Clockwise/counter…  
29. Gravitational pull  
30. Mass  
31. Forces  
32. Interaction  
33. Cause-and-effect  
34. Modification  
35. Length  
36. Widen  
37. Design  
38. Materials  
39. Investigate  
40. Twirl  
41. Spin  
42. Findings  
43. Shaft  
44. Resistance  
45. Variation  
46. Vertical  
47. Optimal  
48. System  
49. Trials  
50. Practices
Vocabulary Development

4,000 – 8,000 words when entering elementary school

40,000 avg. when they exit high school

36,000 word difference

For 13 school grades (K-12) = 2,769 words/year

178 days for 2,769 = 16 words/school day

4K- 8,000 words when entering elementary school

87,000 exposed to/should have mastered upon exiting HS

79,000 word difference

For 13 school grades (K-12) = 6,076 words/year

178 days for 6,076 = 34 words/school day
Commonalities in CCSS & NGSS

**Vocabulary: Science-centered Language Dev.**

- Highlight *vocabulary integration* rather than “vocabulary acquisition” across the curriculum (not in the traditional “silo insolation” or only during Language Arts)

- Learn vocabulary by means of a broad range of multidisciplinary language experiences

- Students learn to appreciate the *utility* of his/her growing vocabulary *in the context* of
  - √ doing and discourse
  - √ speaking and listening
  - √ reading and writing

- **All teachers** must develop a level of comfort in providing *vocabulary instruction* in their subject-area.
How We Learn/Understand Vocabulary: Connecting Words with Meaning

• Words are used to **think**. The more words we know, the finer our understanding of the world. -- Stahl, 1999

• Language is **recorded thought**.

**Semantic dementia**: a neurodegenerative disorder → lose touch with the meaning of words. When they lose the word for a specific emotion, the patient can no longer recognize that emotion in other people.

Words are also used to **process** in-coming information, to understand and evaluate other’s ideas, and to understand still **other** words.
Phenomenon-based Learning

There are no “Seven Wonders of the World” in the eyes of a child.
There are seven million.

--Walt Streigtiff
“Student engagement” is predicated on the research indicating that learning is enhanced when students are curious, involved, and enthusiastically receive ongoing feedback from the activity itself (not the teacher).
The best way to engage students in STEAM is to introduce one or more scientific “FUNomena” (a focus question, a discrepant event, a demonstration, etc.), where we make science intriguing, personal and relevant (the catalysts for further research) – now, students want to investigate (and find out).
The “Three Dimensions” of the NGSS

Science and Engineering Practices (SEPs)  
(What scientists “Do”)

Disciplinary Core Ideas (DCIs)  
(What scientists Know)

Crosscutting Concepts (CCCs)  
(How scientists “Think & Link” concepts together)

Investigating Phenomena “FUN-omena”
3-5ETS1
Define a simple design problem reflecting a need or a want that includes specific criteria for success and constraints on materials, time or cost.

(Engineering, Technology, and Applications in Science)
Deep and Long-lasting Learning

1. **Instructivism** = teacher tells and student listens (the *transmission* of knowledge that gets memorized in isolation).

2. **Constructivism** (Piaget) = the student learns by “constructing knowledge” - making connections, inside the body-brain → building/constructing new brain circuitry.
3. **Constructionism** (Papert): learning comes by way of actively constructing knowledge through the act of constructing a meaningful product. Doing/making a tangible and shareable artifact (public) following a deep **investigation** that unfolds over multiple days.
Investigating Phenomena  
(Pheno-BL)

Same Q’s as ELA with the addition of powerful “scientific thinking questions”
• What if we changed/added/eliminated the____, what would occur?
• Under what other conditions is this conclusion valid/invalid?
• If the ______ was decreased/increased (or modified in some other manner), what changes could we expect in the outcome?
• Is this always true in all cases? (→ “principle” or new “law” in science)
3-PS2-2
Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.

Grade 3 NGSS PE
Students need to learn *the language of science* as a **tool** to both **comprehend**, and **communicate** what they learn/know about science investigations, oral discussion, writing, visual, and their mathematical representations.
What do you predict will occur when I release this linked disc system?

What did you observe?

When I repeat this, does the same motion happen?

Patterns
Spinning Tops: Balance, Force and Motion
Spinning Tops: Balance, Force and Motion

Spinning Tops are one of the oldest recognizable toys found at archeological sites around the world (Social Studies – CA HSS Framework).
Engineering: Wheel-and-Axle Systems

Construct the wheel-and-axle system (Investigate the accompanying questions and \textit{record your data using centimeters}.)

1. Insert a green stirring straw through the center hole of a red or yellow disk (identical to your spinning system) and roll it on the table. \textbf{What happened?}

2. Add a \textit{second disk} of the opposite color at the other end of the straw and roll your wheel-and-axle system on the table. \textbf{What happened? Why?}

3. Place two red disks at each end of the green straw (your former “spinning top” system now has \textit{two} disks at opposite ends of the straw instead of just one).

4. Now roll your wheel-and-axle system on the table. What happened when \textit{a second disk} of the same size was added? \textbf{Why?}

5. Will \textit{two large red disks} in a wheel-and-axle system \textit{roll farther than two small yellow disks}? How could you find out?
An unbalanced system

- Circumference
- Diameter
- Radius

(in context)

A balanced system

Large wheel travels farther with one rotation of the axle

How are these two systems different?

What do you predict will happen when I release the balanced system on the ramp?

What did you observe?

Is there a difference in how they move (motion)? If so, what is that difference?
Balanced axle system

16 cm around

16 cm around
Engineering: Build a Cart

Engineering challenge: Design and build a cart based on the knowledge you have gained from the wheel-and-axle system (the “adjacent possible”)

Criteria: design and construct a 4-wheeled cart that can roll 100 cm. with a small push.

Constraints: (1) use only the materials provided, (2) your cart must roll 100 cm. after given one small push, and (3) you have 10 minutes to construct your cart, and run your 1st test measuring the distance.
Ramp pushes on the car from beneath, while the gravitational pull sends the car downward along the ramp. The position above the Earth’s surface determines the car’s potential energy, which transforms into kinetic energy (energy of motion) when the forces are unbalanced, the car rolls down the ramp.
Learning Progressions: The “Adjacent Possible”

1. One disk + straw → Spinning top

2. Two disks + straw → a wheel-and-axle system

3. Four disks + straws → a pair of two wheel-and-axle systems and a wheel bearing system

   Large disks vs small disks
   Cardboard cart vs tongue depressor cart

4. Create your own cart (applications, math, design, engineering, art)

   (↑ reverse engineering)
From NGSS

3-5-ETS1 Engineering Design

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
What should STEM/STEAM look like in a classroom?

If you are teaching science (FOSS) with fidelity you are…

• Investigating Scientific phenomena found in the natural world
• Using science tools (science equipment) and Technology (calculators, cell phones, computers, measuring instruments, etc.)
• Learning and applying Engineering practices (SEPs)
• All engineering projects begin with a drawing = Art (a.k.a., “design and engineering”)
• Applying Mathematics and computational thinking (patterns and logic)
Re-engineering: Build a New Cart

- Students will now *improve* on their *original* cart design
- **Re-engineer** your cart to meet new criteria: Re-design a new cart that travels *25cm further* than your original cart (incorporating CCSS-Math).

...modify the slope by changing the angle?
Kolb’s Learning Styles 4-stage learning cycle theory
(focuses on perception and processing)
“Scientific Practices”

Concrete Experience (CE)

Active Experimentation (AE)  Reflective Observation (RO)

Abstract Conceptualization (AC)
Re-engineered cart data: Did your re-designed/re-engineered cart meet the criteria (+25 cm)?

Data Table:

<table>
<thead>
<tr>
<th>Trial #</th>
<th>Original Cart Results</th>
<th>Re-engineered Cart Results</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>78</td>
<td>114</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>78</td>
<td>118</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>117</td>
<td>37</td>
</tr>
<tr>
<td>Avg.</td>
<td>78.6</td>
<td>116.3</td>
<td>37.6</td>
</tr>
</tbody>
</table>
Writing in Science

• I can now **conclude** that _______ (offer a scientific explanation presented with appropriate and sufficient evidence, supported by science content information)

• Teachers: Look for all students to present **C-E-R** to guide their thinking towards an eventual **defensible endpoint** – a **viable conclusion** they arrive at, which they can **demonstrate their understanding** of the **DCI** *(Performance Expectation)*

• At a later date, I would like to revisit this phenomenon to find out (if, when, why, etc.) _______. *(Student-driven learning progressions → fill the science and STEM careers pipeline for our future.)*
<table>
<thead>
<tr>
<th>1. angle</th>
<th>21. friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. argumentation</td>
<td>22. graphing</td>
</tr>
<tr>
<td>3. average: mean, mode, median</td>
<td>23. gravitational pull</td>
</tr>
<tr>
<td>4. axle</td>
<td>24. gravity</td>
</tr>
<tr>
<td>5. axis</td>
<td>25. inclined plane</td>
</tr>
<tr>
<td>6. bar graph</td>
<td>26. length</td>
</tr>
<tr>
<td>7. bearing system</td>
<td>27. measurement</td>
</tr>
<tr>
<td>8. cardinal number</td>
<td>28. model</td>
</tr>
<tr>
<td>9. cardinality</td>
<td>29. motion</td>
</tr>
<tr>
<td>10. Cluster</td>
<td>30. motorize</td>
</tr>
<tr>
<td>11. constraint</td>
<td>31. multiple trials</td>
</tr>
<tr>
<td>12. construct</td>
<td>32. observation</td>
</tr>
<tr>
<td>13. criteria</td>
<td>33. obstacle</td>
</tr>
<tr>
<td>14. data</td>
<td>34. ordinal number</td>
</tr>
<tr>
<td>15. design</td>
<td>35. optimize</td>
</tr>
<tr>
<td>16. difference</td>
<td>36. outcome</td>
</tr>
<tr>
<td>17. distance</td>
<td>37. outlier</td>
</tr>
<tr>
<td>18. engineering</td>
<td>38. physics</td>
</tr>
<tr>
<td>19. enhancement</td>
<td>39. predict/prediction</td>
</tr>
<tr>
<td>20. feature</td>
<td>40. ramp</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>41. re-design</td>
<td>42. re-engineering</td>
</tr>
<tr>
<td>43. replicable</td>
<td>44. results</td>
</tr>
<tr>
<td>45. rotate</td>
<td>46. rotation</td>
</tr>
<tr>
<td>47. set, subset (data)</td>
<td>48. shaft</td>
</tr>
<tr>
<td>49. slope</td>
<td>50. solution</td>
</tr>
<tr>
<td>51. speed</td>
<td>52. standard</td>
</tr>
<tr>
<td>53. starting point</td>
<td>54. system</td>
</tr>
<tr>
<td>55. travel</td>
<td>56. trial</td>
</tr>
<tr>
<td>57. uniform</td>
<td>58. variables</td>
</tr>
<tr>
<td>59. velocity</td>
<td></td>
</tr>
<tr>
<td>60. wheel-and-axle system</td>
<td></td>
</tr>
</tbody>
</table>
More than 100 years of research supports the importance of vocabulary development for student success (Graves, 2006). The quickest and most effective means of closing the Achievement Gap is by closing the Vocabulary Gap through active learning experiences where students engage in an abundance of academic conversations.
Developing Literacy through STEAM

Reading comprehension skills that can be reinforced during active science instruction:

- prediction
- clarifying
- making inferences
- summarizing
- activating background knowledge
- questioning
- visual imagery
- problem and solution
- cause-and-effect
- compare and contrast
- Sequence
- description
3-Dimensions of Learning Science

❖ **Eight Practices**

- Asking questions and defining problems √
- Developing and using models √
- Planning and carrying out investigations √
- Analyzing and interpreting data √
- Using mathematics and computational thinking √
- Constructing Explanations and Designing Solutions √
- Engaging in argument from evidence √
- Obtaining, evaluating, and communicating information √

➢ **Seven Crosscutting Concepts**

- Patterns √
- Cause and effect √
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: Flows, cycles, and conservation
- Structure and function
- Stability and change

• **Four Disciplinary Core Ideas:**
  ✓ Life Science,
  ✓ Physical Science √
  ✓ Earth and Space Science
  ✓ Engineering, Technology and Applications of Science
Crafting Explanations

Describe the practice and its components

Scientific Explanation:
A written or oral response to a question about how or why a phenomenon occurs that is supported by evidence.

Components of the Practice:
A scientific explanation has 3 essential parts –

- **Claim**: a testable statement or conclusion that typically answers the question
- **Evidence**: scientific data that supports the claim; consisting of appropriate and sufficient evidence
- **Reasoning**: a justification that shows why the data count as evidence to support the claim and includes appropriate scientific ideas/principles
Agree and Disagree Statements

• I can **visually represent my thinking** with the following drawing(s).

• My formal **claim is** ______.

• My **initial thoughts** are _____.

• How would I design an **investigation to prove** (support) my claim? (work with a partner/group and consult others, including outside “experts”)

• The **evidence/data** I gathered allowed me to conclude that_______ (reasoning). This permitted me
  • confirm my thinking
  • make minor changes to my thinking
  • revise my thinking
Early research:

→ exchange students’ writing → each student can read the writing of his/her peers describing their shared experience(s).

Frequent writers rapidly improve as competent readers when:

(1) the writing is at/near their reading level
(2) they have background knowledge about the content, because of their shared experience (science investigation)
(3) students maintain a cross-disciplinary “Vocabulary Journal”
Argument from Evidence

“One characteristic of high-performing schools is an emphasis on teaching non-fiction writing.”


(Another key factor in high-performing schools is an unwillingness to accept state or district test scores as the sole measure of student achievement.)
Cognitive Rehearsals
(→ consolidation)

When playing with objects, learners are simultaneously manipulating/playing with ideas (internal dialogues attach words and meaning to actions – the “mind’s eye”) building the brain’s fundamental circuitry

Exploring and experimenting involve examining relationships, interactions and systems, where learners formulate their own personal “theories” (mental constructs)

Thinking is a cognitive rehearsal for discourse

Discourse is a cognitive rehearsal for writing (phonological loop or “inner voice”)
Cognitive Rehearsals

“You can't make the *words or ideas*

come out of your *pencil,*

until you can get them
to come out of your *mouth.*”
Cognitive Rehearsals

Playing with objects and ideas, exploring and experimenting, thinking, talking, drawing, and writing become cognitive rehearsals (background knowledge) for reading.

Writing and reading clarify one’s thoughts, generate coherent thinking, and cultivate precision in expressing one’s inner thoughts (→ LT/P memory consolidation)

Discourse and writing become cognitive rehearsals for assessment

• EQ = 2X more accurate as a basis for predicting an individual’s lifetime accomplishments than IQ.

CQ = 3X

 Creativity
Afraid to “fail”
Performance avoidance

“Failure is not an Option”

Failure is nearly always a prerequisite for future learning, success in learning. Most initial learning and discoveries occur via trial-and-error strategies.
Teaching Thinking vs. Lecturing

Who is more inclined to say the others “talk too much!” – Teachers or students?

Lecturing, the 2\textsuperscript{nd} oldest form of teaching, comes from the Latin \textit{lecture}, meaning "to read aloud."

Books - the earliest form of ed-tech (few and $$) \rightarrow$ combined with the lecture ("\textit{Audi} – torium” not a “\textit{Think-a-torium}”)
Students and Teachers Engaged in Active learning every Minute of the school day, where the content is finally connected and the learning finally made sense to me today!
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