Develop Students' Scientific Literacy Using a Project-based High School Unit on Honey Bee Behavior

project NEURON

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NIH
National Institutes of Health
SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
Supported by the National Institutes of Health

Goals for Session

- Introduce Project NEURON
- Do two reading activities
  - editorial
  - adapted primary literature
- Reflect on the activities and apply them to your teaching

What is Project NEURON?

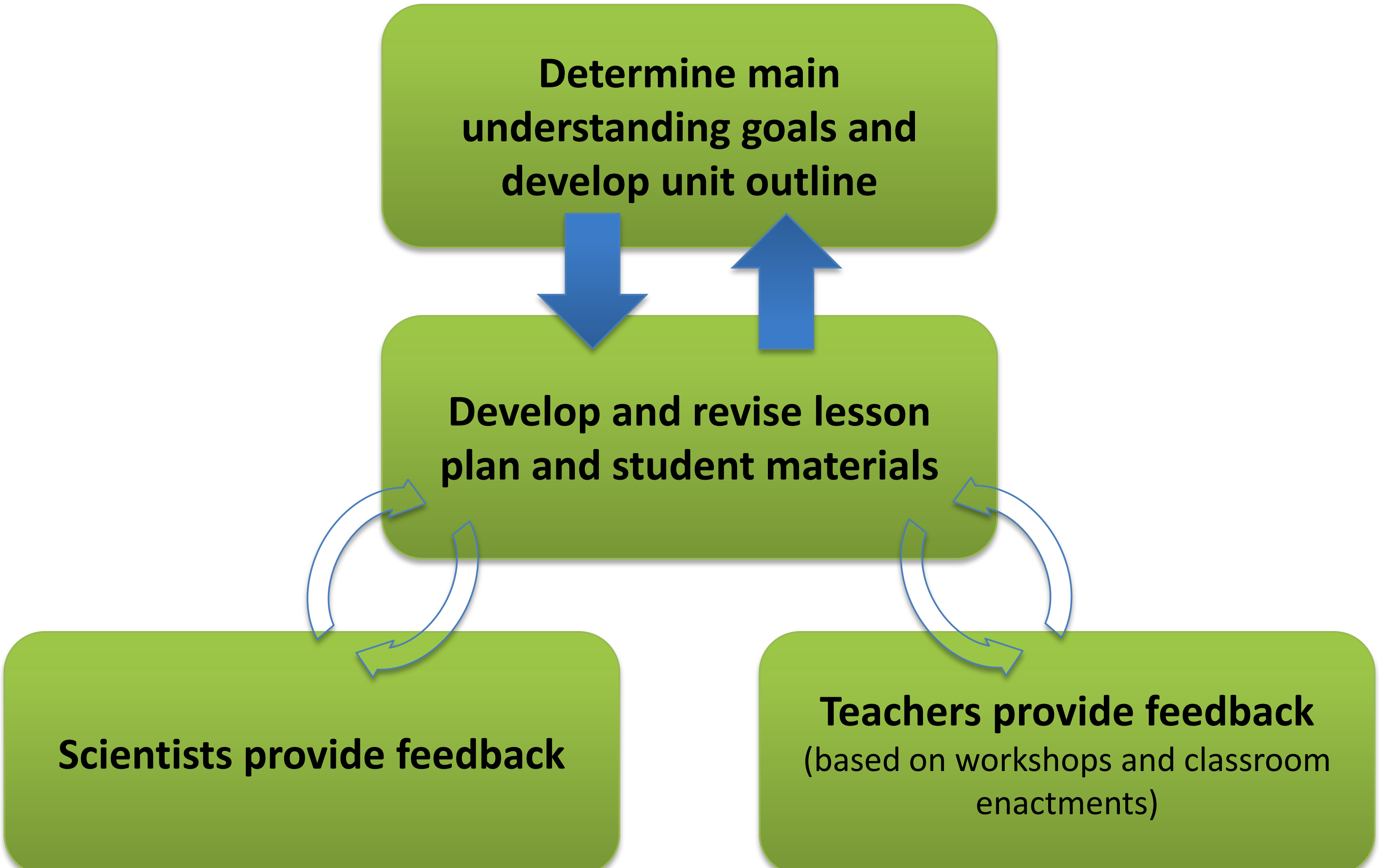
- Curriculum development
  - Inquiry
  - Standards
- Professional development
  - Summer institutes
  - Conferences

Project NEURON Curriculum Units

- **Do you see what I see?**
  - *Light, sight, and natural selection*
- **What can I learn from worms?**
  - *Regeneration, stem cells, and models*
- **What makes me tick…tock?**
  - *Circadian rhythms, genetics, and health*
- **What changes our minds?**
  - *Toxicants, exposure, and the environment*
  - *Foods, drugs, and the brain*
- **Why dread a bump on the head?**
  - *The neuroscience of traumatic brain injury (TBI)*
- **Food for thought: What fuels us?**
  - *Glucose, the endocrine system, and health*
- **What makes honey bees work together?**
  - *How genes and environment affect behavior*
- **How do small things make a big difference?**
  - *Microbes, ecology, and the tree of life*

Available for free at:
neuron.illinois.edu

Iterative Development



What is scientific literacy?

- "…a term that has been used since the late 1950s to describe a desired familiarity with science on the part of the general public" (DeBoer, 2000, p. 582)
- "reading and writing when the content is science [is] the *fundamental* sense of scientific literacy, and being knowledgeable and educated in science [is] the *derived* sense [of scientific literacy]" (Norris & Phillips, 2003, p. 224)

What makes honey bees work together?

- Lesson 1:

  What do honey bees do?

- Lesson 2:

  Why do honey bees have different jobs?

- Lesson 3:

  How do honey bees heat the hive?

- Lesson 4:

  What genes changed to make bees work together?

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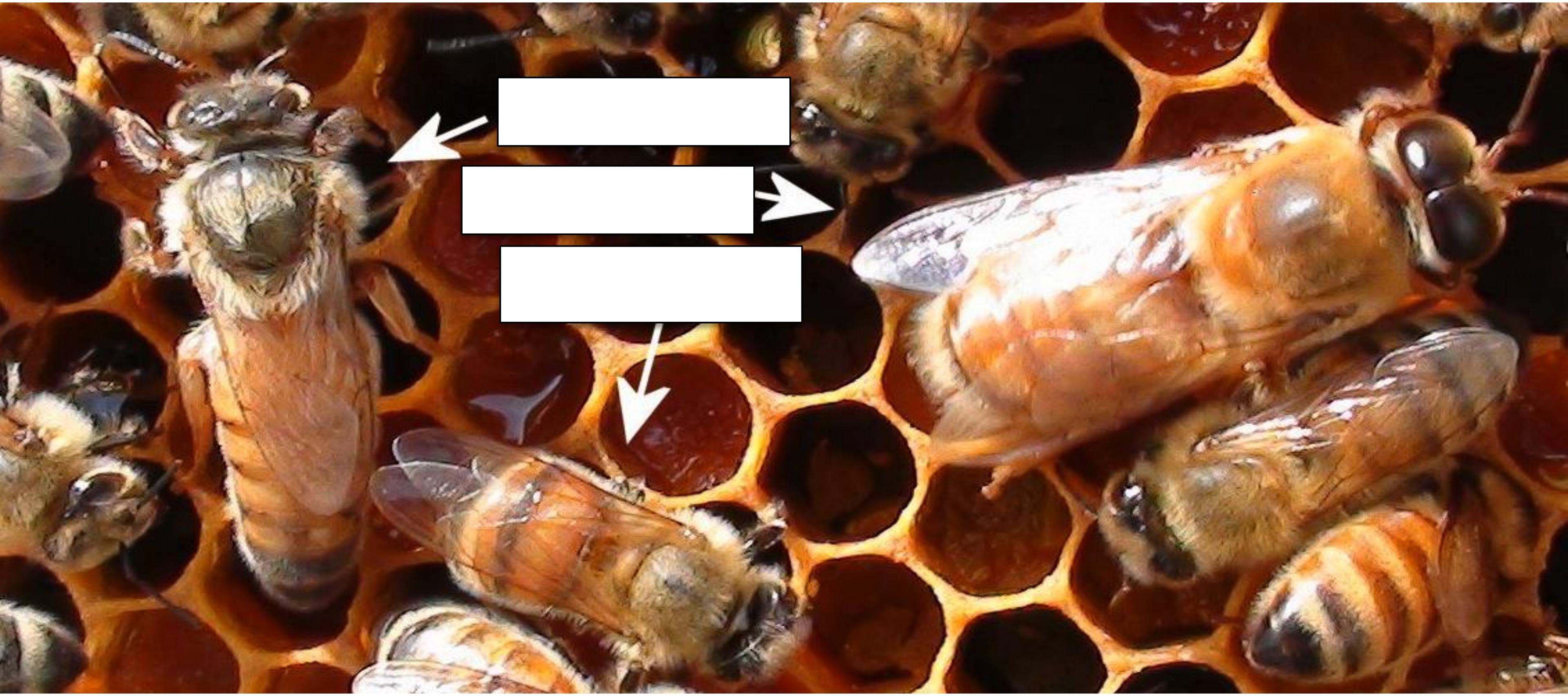
Lesson 1: What do honey bees do?

- Activity 1: “Introduction to Honey Bees” Video
  - Generate questions about honey bees
- Activity 2: Observing Honey Bees
  - Differentiate between honey bee castes
- Activity 3: “The Behavior of Genes” Reading
  - Describe influences on behavior




Queen
Drone
Worker

What makes honey bees work together?

- Brainstorm possible responses to this driving question.

Periodical

What makes honey bees work together?
Lesson 1: What do honey bees do?

July 2013

December 13, 2004
OP-ED CONTRIBUTOR

The New York Times
nytimes.com

The Behavior of Genes

By GENE ROBINSON
Urbana, Ill. — "The right genes make all the difference." Or so declares an advertisement, as a boy portraying the son of Andre Agassi and Steffi Graf holds his own in a match against Taylor Dent. While neither science, nor this television commercial, can explain much about how the genes of the tennis stars' son might affect his tennis game, people are comfortable linking genes to athletic prowess.

Many people, however, are leery of attributing other components of behavior to genes - personality or intelligence, or social traits like fidelity, for example. They're troubled by the ethical implications of genetic determination; it is as if giving a nod toward the genes automatically diminishes the role of the environment and free will. It is nature versus nurture: a debate that has spawned extremist views on both sides, from Nazism (nature) to Marxism (nurture).

The truth of the matter is that DNA is both inherited and environmentally responsive, and recent findings from animal studies go a long way toward resolving nature versus nurture by upsetting the assumption that the two work differently. The discoveries emphasize what genes do (producing proteins that are the building blocks of life), rather than simply who they are (their fixed DNA sequence).

The results hold the promise of breakthroughs in our understanding of human behavior and what factors might influence it. They also pose challenges for policy makers: new types of genetic profiling to try to predict behavior could produce more debates about balancing personal privacy with the need to protect the public.

The studies show that some genes cause the brain to respond differently depending on inheritance or environmental factors. For example, fruit flies inherit different versions of a gene that helps make them slow- or fast-paced foragers for life. But this very same gene that is fixed forever in these different types of flies can change in the honeybee depending on the needs of the hive, allowing a bee to shift from working inside the hive to collecting food from flowers.

Monogamy is another behavioral trait that is influenced by inherited factors, at least in voles. Some species of voles are more faithful to their mates than others. The genes show inherited differences in activity in the brain, but the activity is dynamic and dependent on the voles' experiences.

Some genes that are affected by environmental conditions even have lifelong consequences. Rat pups that are poorly cared for by their mothers show profound changes in brain gene activity and also prove to be bad moms themselves.

These animal behaviors may be simpler than human behaviors, but they are complex and are performed over days, or weeks, or lifetimes, with learned components. And they all involve molecules known to operate in human brains.

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Periodical

1. Mark the text.

! This is important.

✓ I knew that.

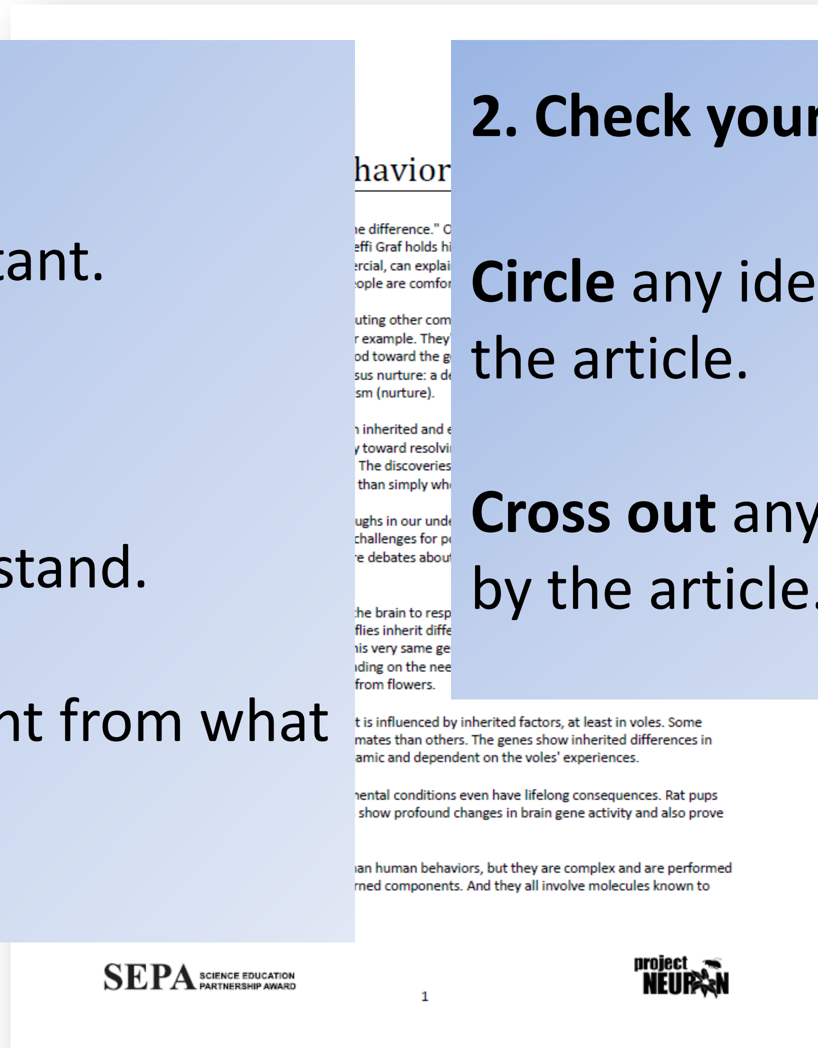
? I don’t understand.

X This is different from what I thought.

2. Check your lists.

Circle any ideas supported by the article.

Cross out any ideas ruled out by the article.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project NEURON

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What genes changed to make bees work together?

- Activity 1: Read adapted primary literature
  - Identify components of a research article
- Activity 2: Construct a phylogenetic tree
  - Provide a rationale for selecting a gene to compare between honey bees and other organisms based on adapted primary literature
- Activity 3: Compare phylogenetic trees
  - Compare the phylogenetic tree for a gene of interest to an established phylogenetic tree

Adapted Primary Literature


Genes involved in convergent evolution of eusociality in bees

S. Hollis Woodard[a,1], Brielle J. Fischman[a,1], Aarti Venkat[b], Matt E. Hudson[b], Kranthi Varala[b], Sydney A. Cameron[c], Andrew G. Clark[d], and Gene E. Robinson[a,c,e,f,2]

[a]Program in Ecology, Evolution, and Conservation Biology, Departments of [b]Crop Sciences and [c]Entomology, [e]Institute for Genomic Biology, and [f]Neuroscience Program, University of Illinois, Urbana, IL 61801; and [d]Department of Molecular Biology and Genetics, Cornell University, Ithaca, NY 14853

Contributed by Gene E. Robinson, March 12, 2011 (sent for review February 17, 2011)

Eusociality has arisen independently at least 11 times in insects. Despite this convergence, there are striking differences among eusocial lifestyles, ranging from species living in small colonies with overt conflict over reproduction to species in which colonies contain hundreds of thousands of highly specialized sterile workers produced by one or a few queens. Although the evolution of eusociality has been intensively studied, the genetic changes involved in the evolution of eusociality are relatively unknown. We examined patterns of molecular evolution across three independent origins of eusociality by sequencing transcriptomes of nine socially diverse bee species and combining these data with genome sequence from the honey bee *Apis mellifera* to generate orthologous sequence alignments for 3,647 genes. We found a shared set of 212 genes with a molecular signature of accelerated evolution across all eusocial lineages studied, as well as unique sets of 173 and 218 genes with a signature of accelerated evolution specific to either highly or primitively eusocial lineages, respectively. These results demonstrate that convergent evolution can involve a mosaic pattern of molecular changes in both shared and lineage-specific sets of genes. Genes involved in signal transduction, gland development, and carbohydrate metabolism are among the most prominent rapidly evolving genes in eusocial lineages. These findings provide a starting point for linking specific genetic changes to the evolution of eusociality.

social evolution | social insects | sociogenomics | molecular phylogenetics

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Proceedings of the National Academy of Sciences (2011). 108: 7472-7477.

Abstract
Eusociality has evolved at least 11 different times in insects. There are many types of eusocial lifestyles, ranging from species living in small colonies with open conflict over reproduction (**primitively eusocial**), to species in which colonies contain hundreds of thousands of highly specialized sterile workers produced by one or a few queens (**high or advanced eusociality**). Although the evolution of eusociality has been intensively studied, the genetic changes involved in the evolution of eusociality are relatively unknown. We examined patterns of genetic changes across three independent origins of eusociality. We did this by sequencing mRNA of nine socially diverse bee species, and comparing the sequence from each species with each other, and with **genome** sequence from the honey bee *Apis mellifera*. We found a group of 212 genes with changes in amino acid sequence indicating **accelerated evolution** across all types of eusociality studied. We also found unique groups of 173 and 218 genes with accelerated evolution specific to either highly or primitively eusocial lineages, respectively. These results demonstrate that **convergent evolution** can involve a complicated pattern of genetic changes in both shared and lineage-specific groups of genes. Genes involved in signal transduction, gland development, and carbohydrate metabolism are among the most notable rapidly evolving genes in eusocial lineages. These findings provide a starting point for linking specific genetic changes to the evolution of eusociality.

Eusociality: A highly organized form of animal society. A species of animal is considered eusocial if its individuals live in groups that meet three criteria: 1. Reproductive division of labor; only a few members of society get to have offspring. 2. Cooperative care of offspring; members of the society help care for offspring that are not their own. 3. Multiple generations (for example, parents and offspring) live together.

Evolution: Change in inherited characteristics of populations over generations. Multiple factors, including natural selection, contribute to evolution.

Convergent, divergent: In convergent evolution, two species that are not closely related evolve to have similar traits; for example, both some birds and some butterflies use plant nectar for food. In divergent evolution, two species that are closely related evolve to be more different; for example, the shape of beaks in different species of finches in the Galapagos have become very different over time, as species adapt to different food sources. These terms can be used to describe molecular evolution, as well as evolution on the level of phenotypes.

Accelerated rate of evolution: A quicker accumulation of evolutionary changes over time, often detected on the molecular level, in one species relative to another. Accelerated evolution can indicate an increase in the influence of natural selection on the evolution of a species.

What are components of a research article?

- Pick one color of post-its to use.
- List each component on a separate post-it.

What are components of a research article?

- Pick one color of post-its to use.
- List each component on a separate post-it.
- Place post-its on the article.
- Use a new color of post-its to place next to any components you did not originally think of.

Adapted Primary Literature

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We explored the genetic basis of eusocial evolution in bees, an ideal group for comparative studies of social evolution. There is a wide diversity of social lifestyles within this group, from solitary to intermediately social to elaborate eusociality (8). Additionally, eusociality has been gained independently at least six times (9–12) in the bees, more than in any other group. These features make it possible to compare multiple, independent origins of

2. Answer embedded questions.

[b]Department of Molecular Biology and Genetics, Cornell University, Ithaca, NY 14853

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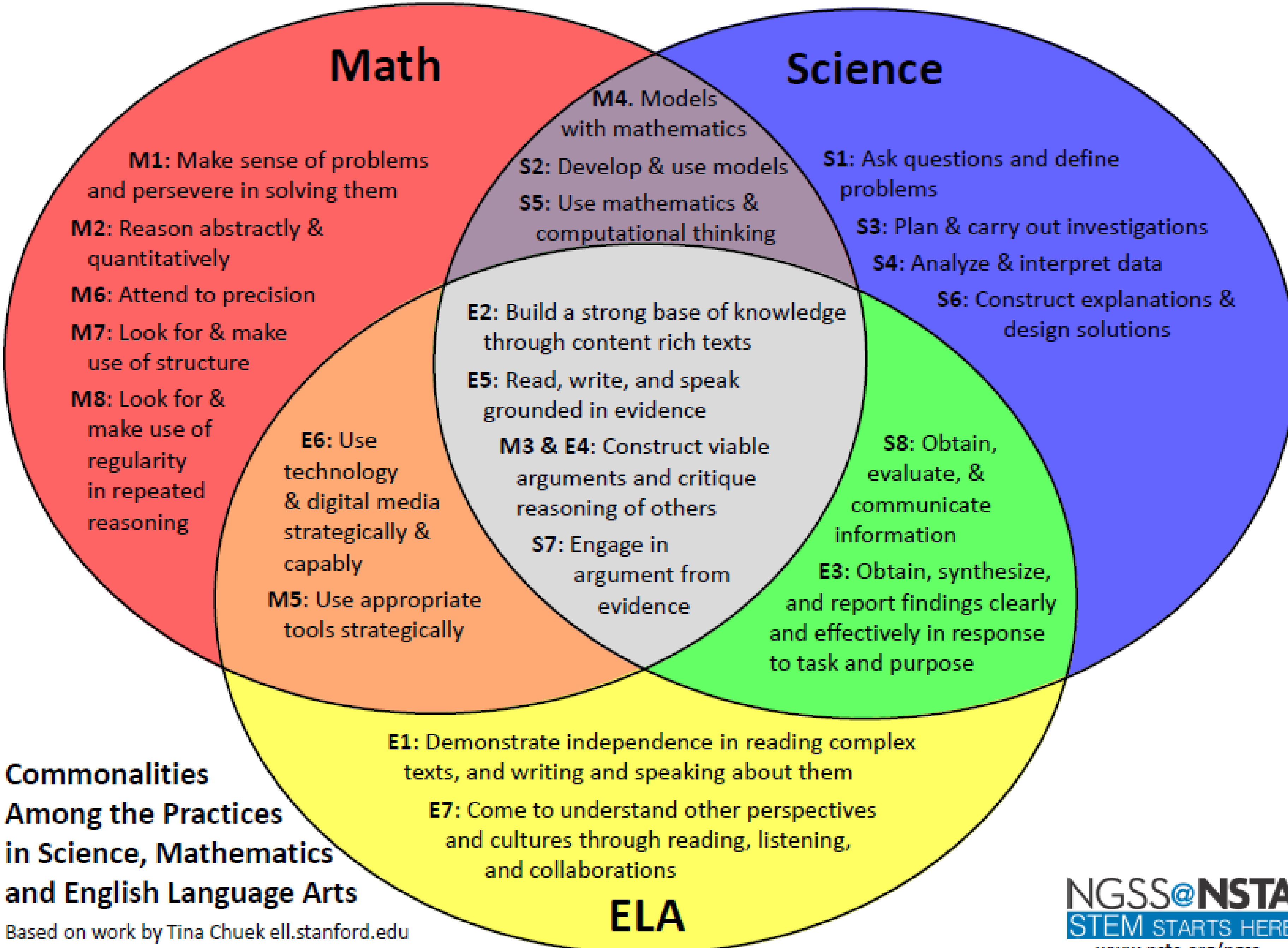
Connect to Your Classroom

- How do these activities relate to NGSS and Common Core Standards?
- How would you use these activities in your classroom?

Connect to Your Classroom

From *The Framework* description of Obtaining, Evaluating, and Communicating Information:

"…students need opportunities to read and discuss general media reports with a critical eye and to read appropriate samples of adapted primary literature to begin seeing how science is communicated by science practitioners" (National Research Council, 2012, p. 77)



Commonalities Among the Practices in Science, Mathematics and English Language Arts

Based on work by Tina Chuek ell.stanford.edu

NGSS@NSTA
STEM STARTS HERE
www.nsta.org/ngss

Additional Sources

- Periodicals
  - ScienceDaily - http://www.sciencedaily.com/
  - New York Times Science News - http://www.nytimes.com/pages/science/
- Adapted Primary Literature
  - Science in the Classroom - http://scienceintheclassroom.org/

Acknowledgements

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- University of Illinois

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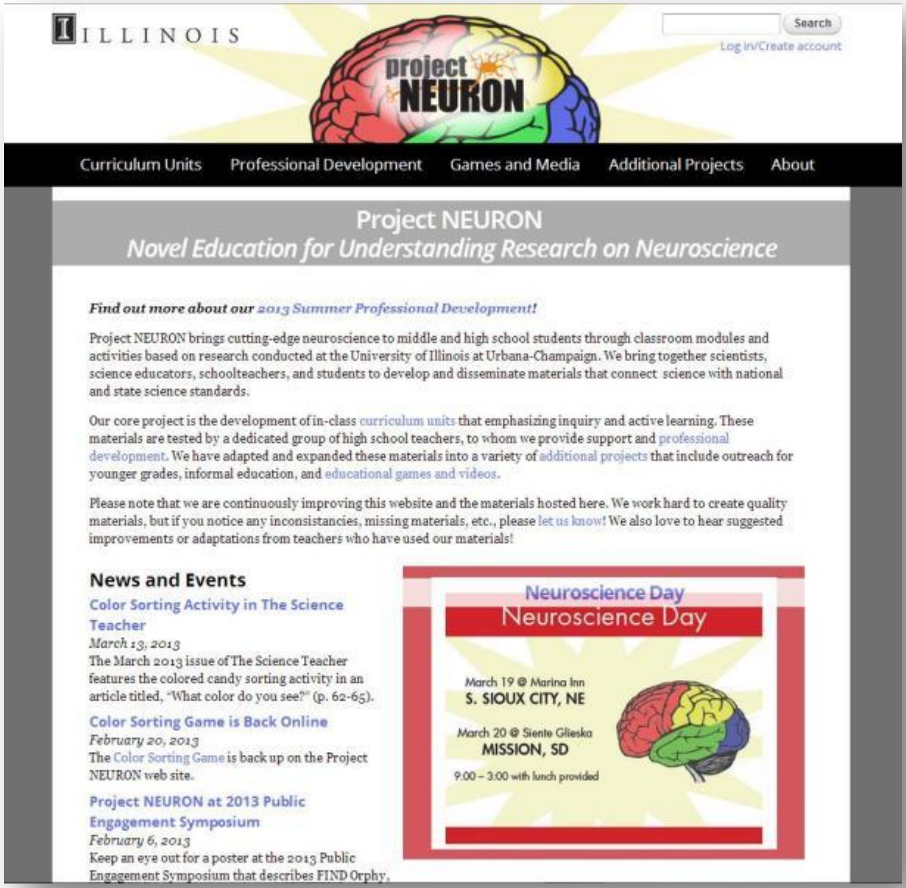

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