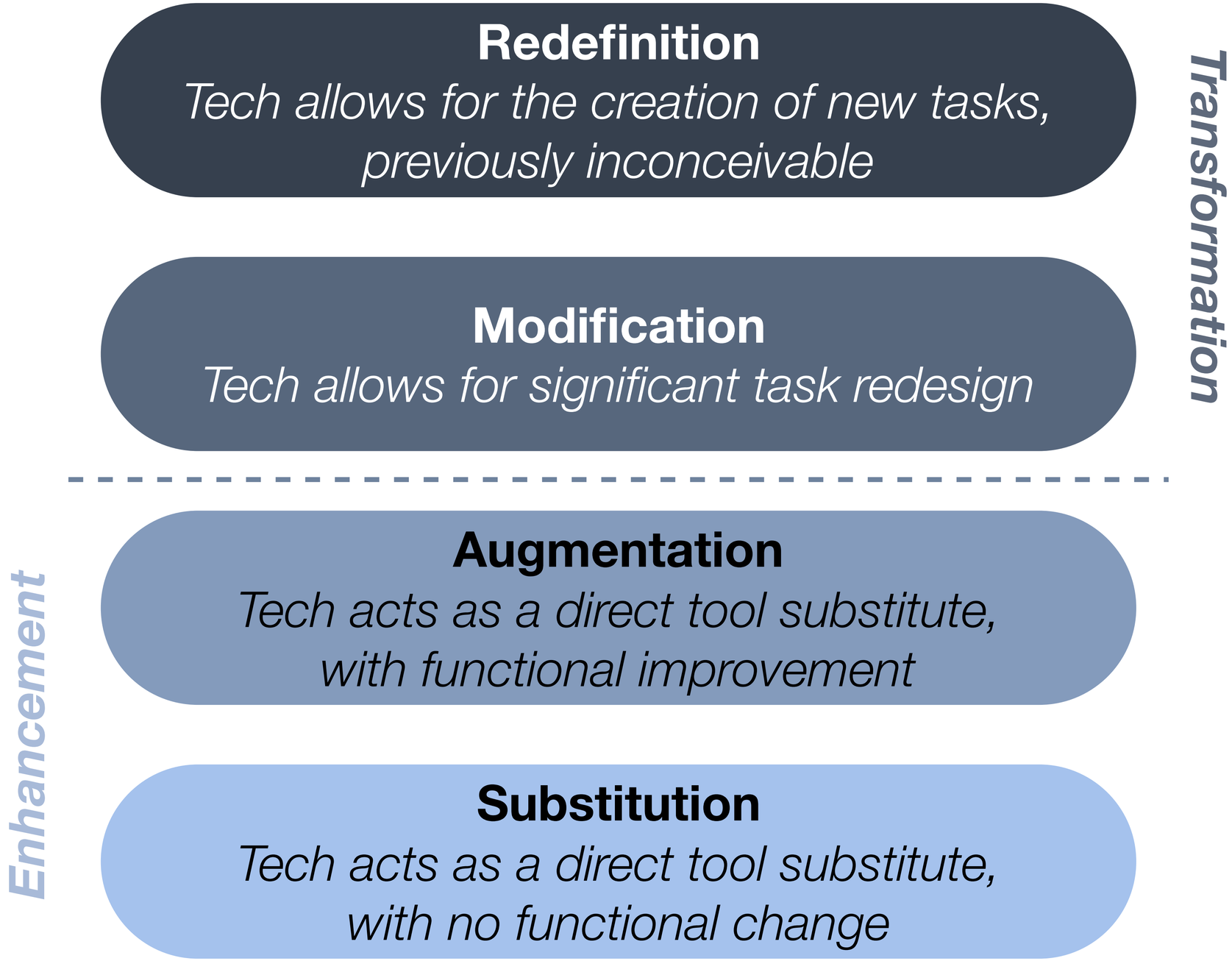
Designing STEM Learning:
A SAMR Hands-On Approach

Ruben R. Puentedura, Ph.D.

1. Frameworks



Ruben R. Puentedura, *As We May Teach: Educational Technology, From Theory Into Practice*. (2009)

Social	Mobility	Visualization	Storytelling	Gaming
200,000 years	70,000 years	40,000 years	17,000 years	8,000 years

Ruben R. Puentedura, “Technology In Education: The First 200,000 Years” *The NMC Perspective Series: Ideas that Matter*. NMC Summer Conference, 2012.

Social

Bookmarks

RSS Feeds

Discussions

Microblogging

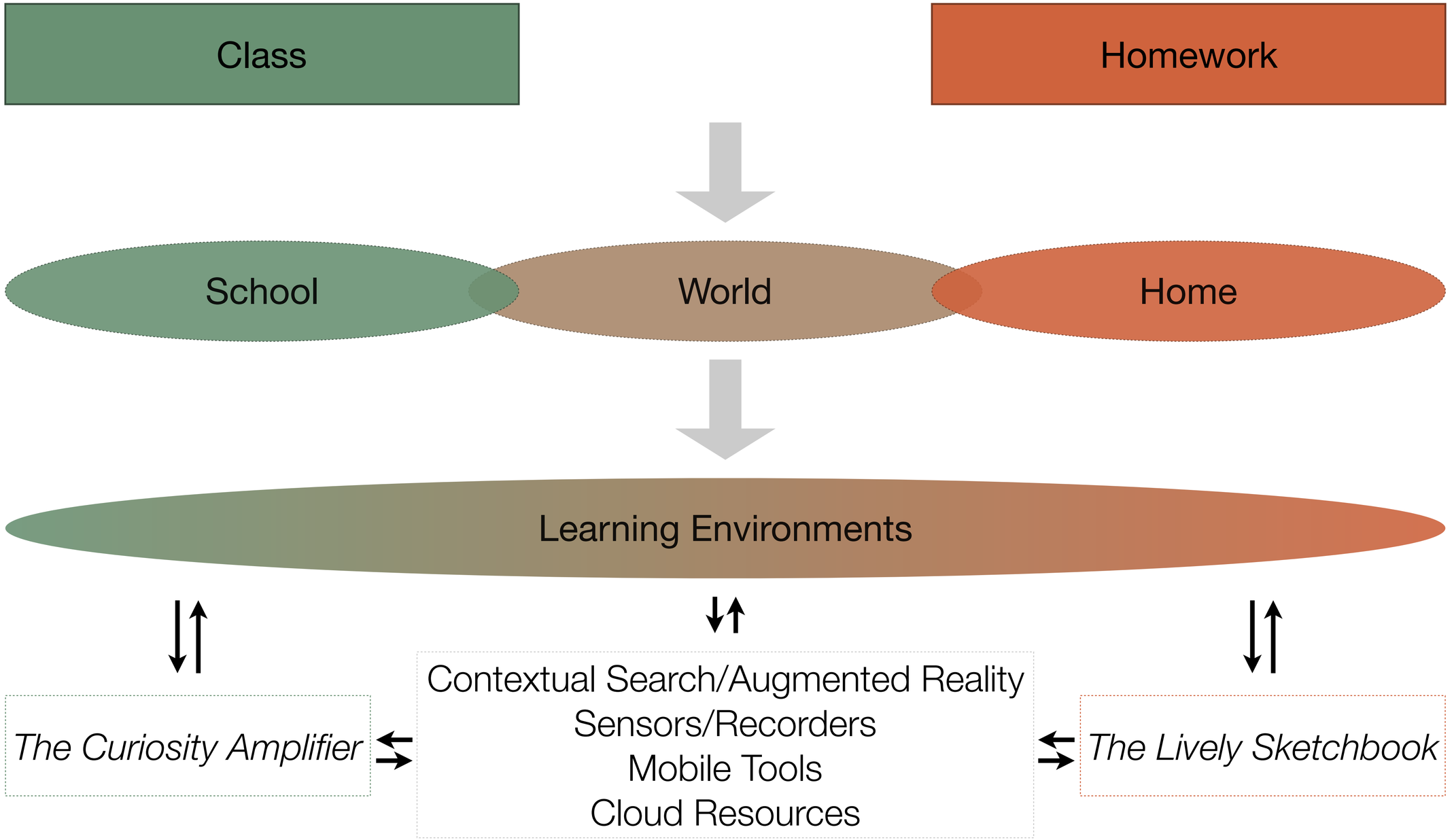
Blogging

Wikis

Telepresence

File Sharing

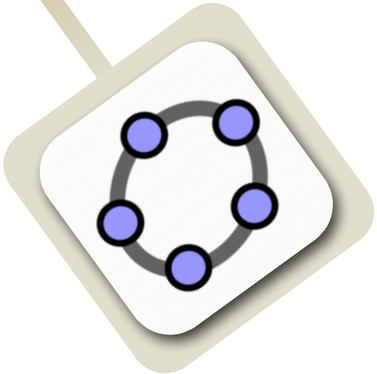
Mobility



John Seely Brown. “A New Culture of Learning”. *NMC Summer Conference, Closing Keynote*. (2010)

Ruben R. Puentedura, “The Lively Sketchbook”. *Hippasus Blog*. (2010)

Visualization



Storytelling

Narrative sources;
Narrative constraints

Pictorial vocabulary;
Narrative transitions;
Text/image integration

CDS Seven Elements;
Montage structures

Narrative structures;
Narrative flows

Ludic elements

Image Assembly → Sequential Art → Moving Image → Interactive Media → Interactive Fiction

TIME

PLACE

Infinite Canvas

CONNECTION

SOCIAL

Formal Definition of **Game** (Salen & Zimmerman)

"A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome."

Katie Salen and Eric Zimmerman. *Rules of Play: Game Design Fundamentals*. The MIT Press, 2003.

The EdTech Quintet – Associated Practices	
Social	Communication, Collaboration, Sharing
Mobility	Anytime, Anyplace Learning and Creation
Visualization	Making Abstract Concepts Tangible
Storytelling	Knowledge Integration and Transmission
Gaming	Feedback Loops and Formative Assessment

The Value of Shared Practices

- Augmented Note Taking and Annotation
- Visualization Methods:
  - 5 Primary Domains: Space, Time, Networks, Text, Number
- Simple Blogging
- Simple Digital Storytelling Video
- Flipped Classroom:
  - Materials Creation
  - Peer Discussion/Instruction Methods
- Simple Interactive Fiction
- LMS Practices

Redefinition

Tech allows for the creation of new tasks, previously inconceivable

Modification

Tech allows for significant task redesign

Augmentation

Tech acts as a direct tool substitute, with functional improvement

Substitution

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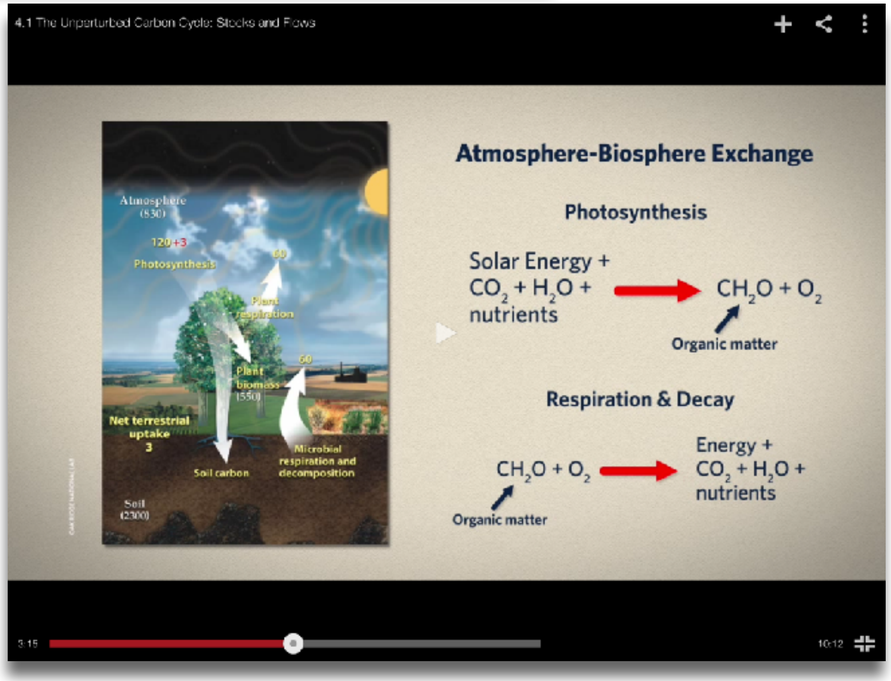

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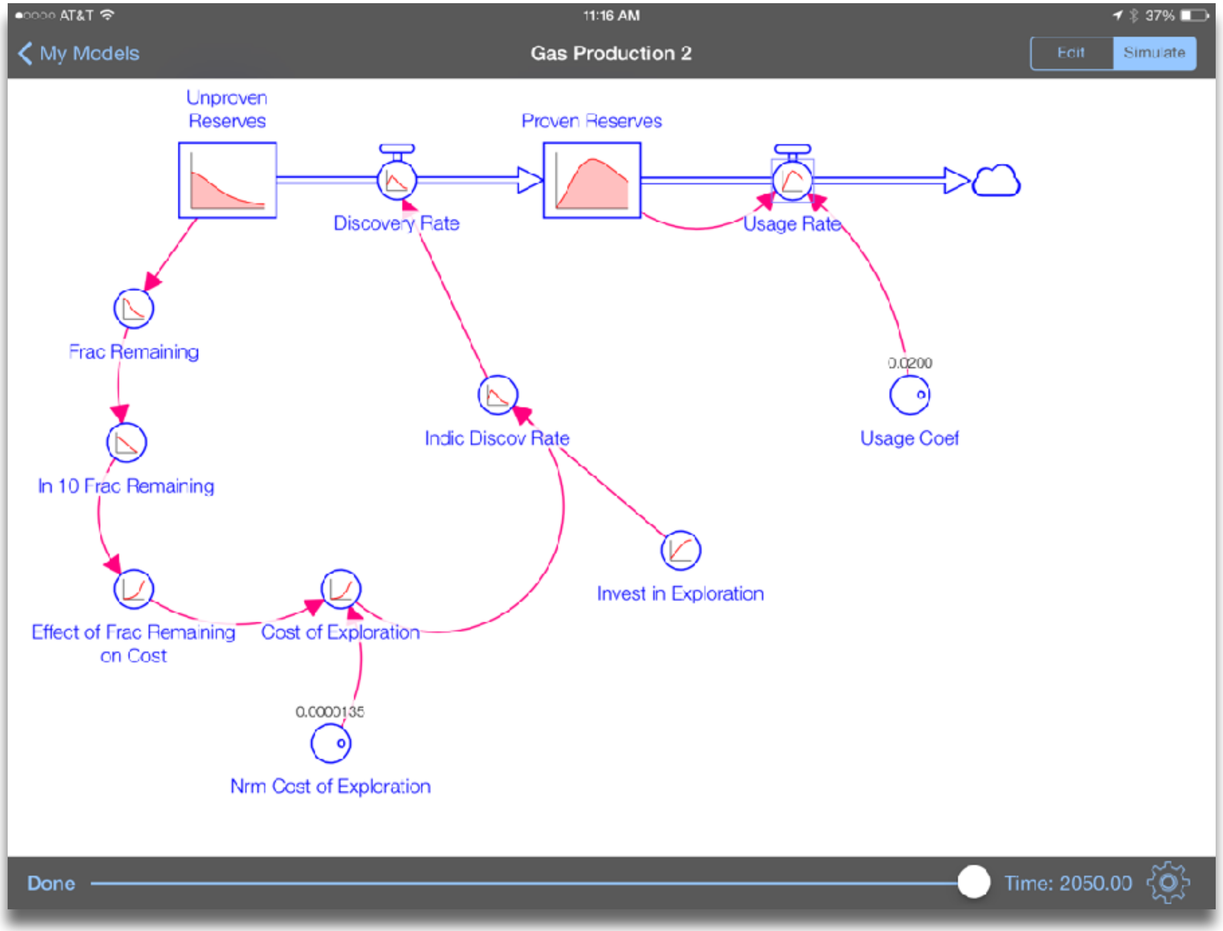

Diego Lieban & Zsolt Lavicza, “Geometric modelling inspired by Da Vinci: shaping and adding movement using technology and physical resources”. *10th Congress of European Research in Mathematics Education*. (2017)

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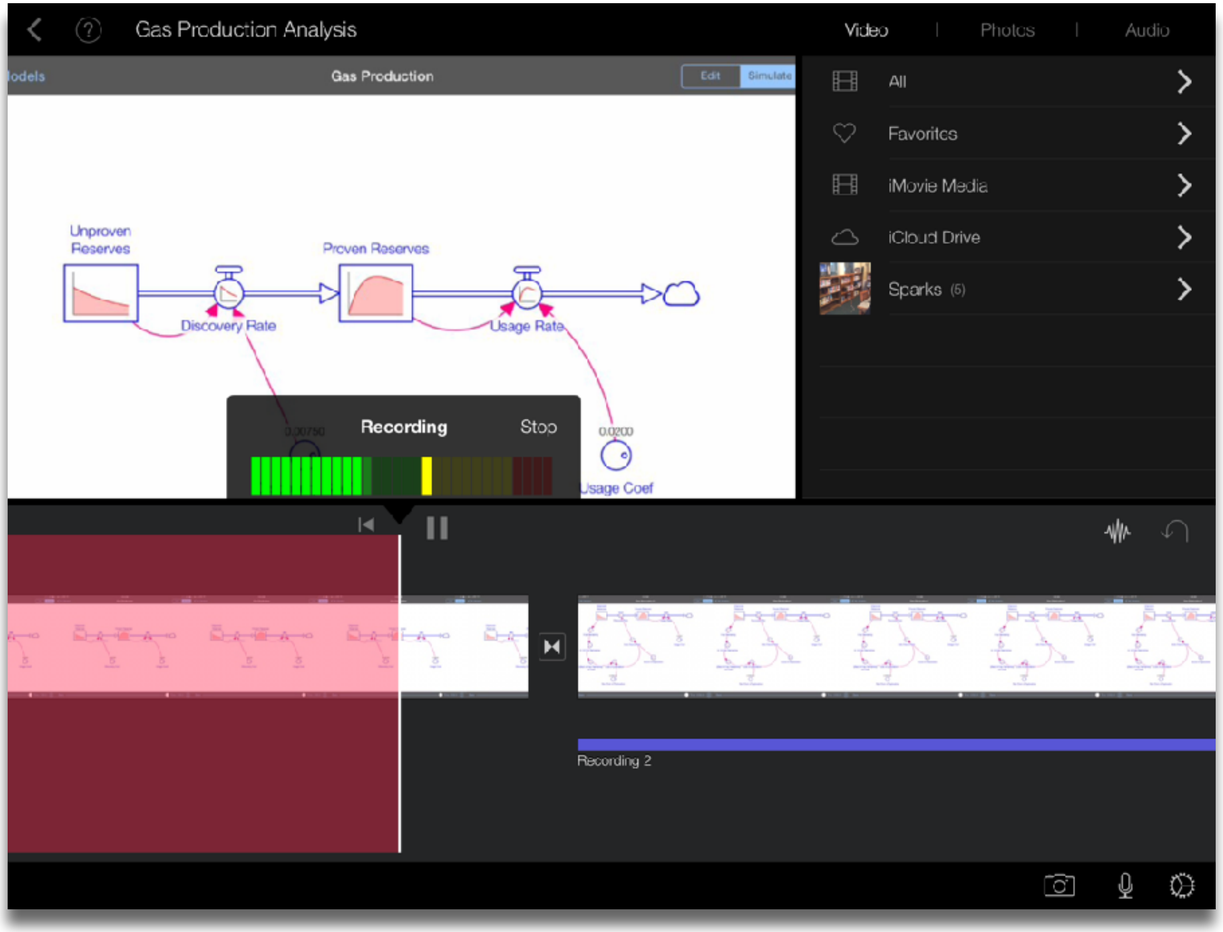

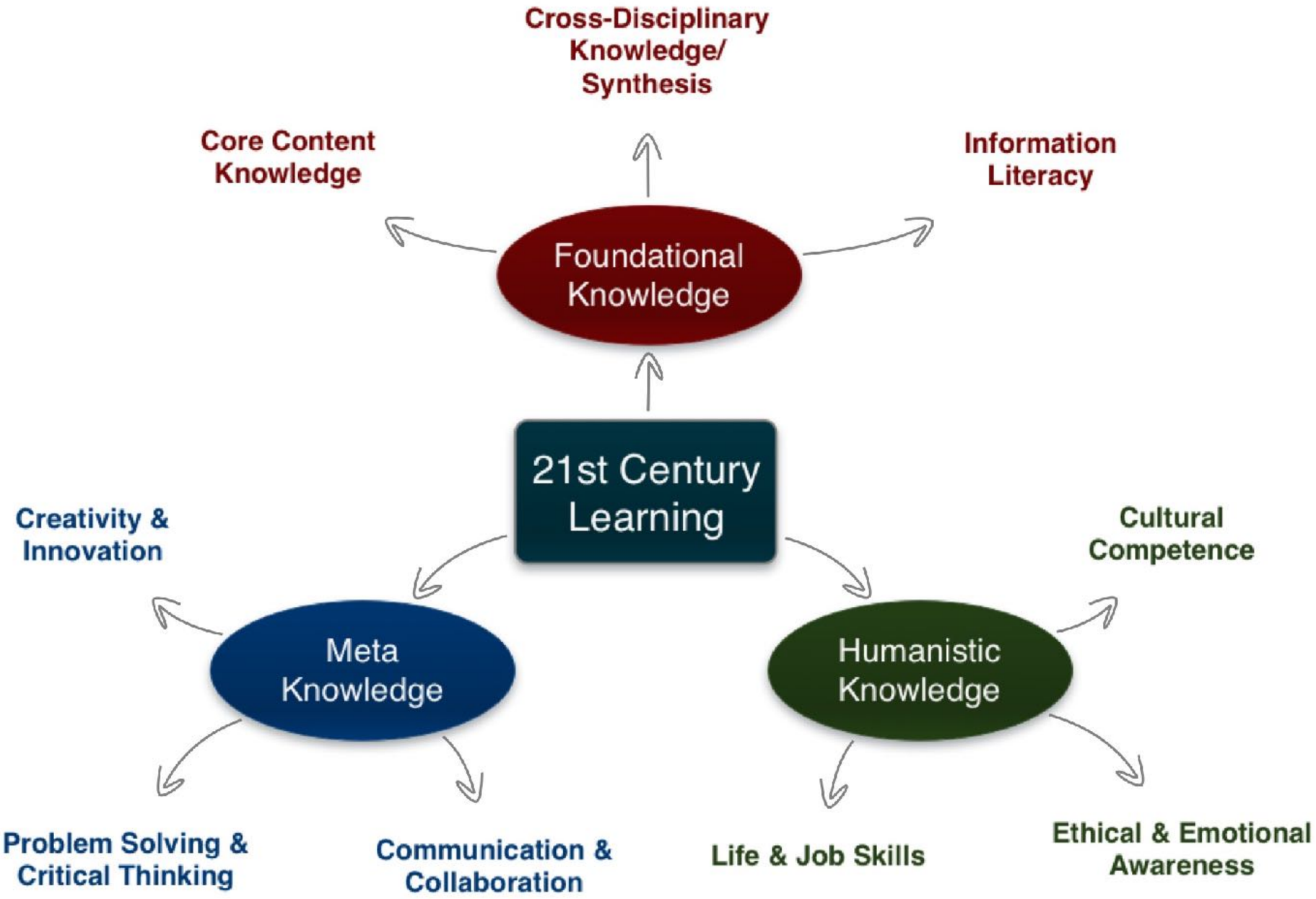

Kristen Kereluik, Punya Mishra, Chris Fahnoe, and Laura Terry, "What Knowledge Is of Most Worth: Teacher Knowledge for 21st Century Learning". *Journal of Digital Learning in Teacher Education (29)* 4 (2013)

Competency / Concept	Model	Apply Quantitative Reasoning	Engage in Argument from Evidence	Engage in Scientific Inquiry and Experimental Design	Analyze and Evaluate Data	Appreciate and Apply the Interdisciplinary Nature of Science
Evolution						
Information Flow						
Structure and Function						
Pathways and Transformations of Matter and Energy						
Systems						

Dimensions of Computational Thinking

Computational Concepts	Computational Practices	Computational Perspectives
Sequences	Being Incremental and Iterative	Expressing
Loops	Testing and Debugging	Connecting
Events	Reusing and Remixing	Questioning
Parallelism	Abstracting and Modularizing	
Conditionals		
Operators		
Data		

Brennan, Karen, and Mitchel Resnick. "New frameworks for studying and assessing the development of computational thinking." *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada*. 2012.

Computational Thinking in Math and Science

Data Practices	Modeling & Simulation Practices	Computational Problem Solving Practices	System Thinking Practices
Collecting Data	Using Computational Models to Understand a Concept	Preparing Problems for Computational Solutions	Investigating a Complex System as a Whole
Creating Data	Using Computational Models to Find and Test Solutions	Programming	Understanding the Relationships within a System
Manipulating Data	Assessing Computational Models	Choosing Effective Computational Tools	Thinking in Levels
Analyzing Data	Designing Computational Models	Assessing Different Approaches/ Solutions to a Problem	Communicating Information about a System
Visualizing Data	Constructing Computational Models	Developing Modular Computational Solutions	Defining Systems and Managing Complexity
		Creating Computational Abstractions	
		Troubleshooting and Debugging	

Weintrop, David, et al. "Defining computational thinking for mathematics and science classrooms." *Journal of Science Education and Technology* 25.1 (2016): 127-147.

Defining a STEM Framework Using SAMR/ETQ: Three Questions

1. What are the ways of knowing in science, math, and technology?
   - Use SAMR/ETQ to frame and support epistemologically robust experiences.

2. What can a child do now that they could not do without a modern approach to STEM?
   - Use SAMR/ETQ to design A- to R-level experiences that allow children to do what they otherwise could not.

3. What are the key sense-making narratives that select and define linkages between the components of STEM and their respective narratives?
   - Use SAMR/ETQ to clarify STEM narratives, and to scaffold and define integration processes.

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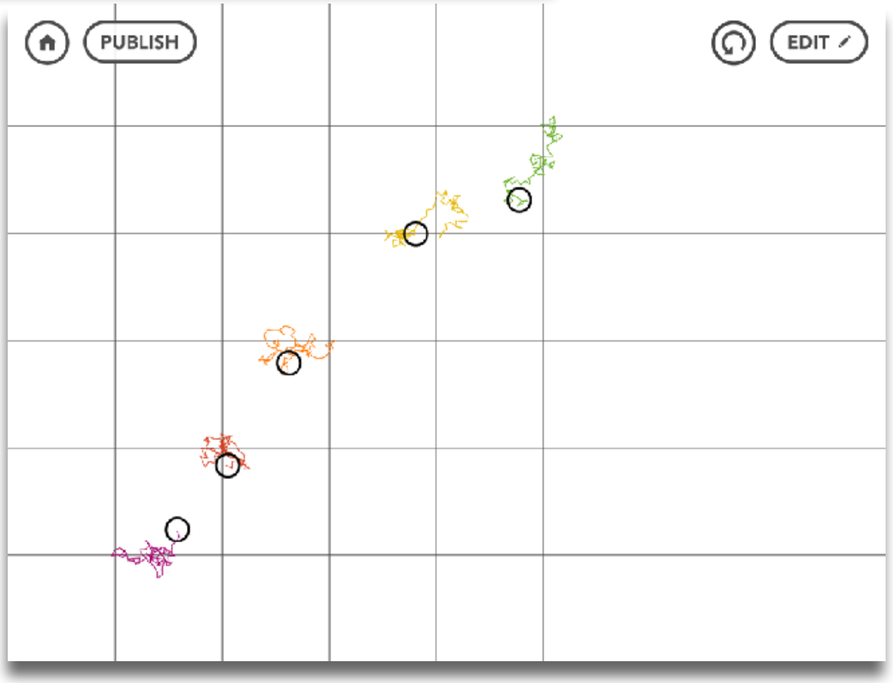

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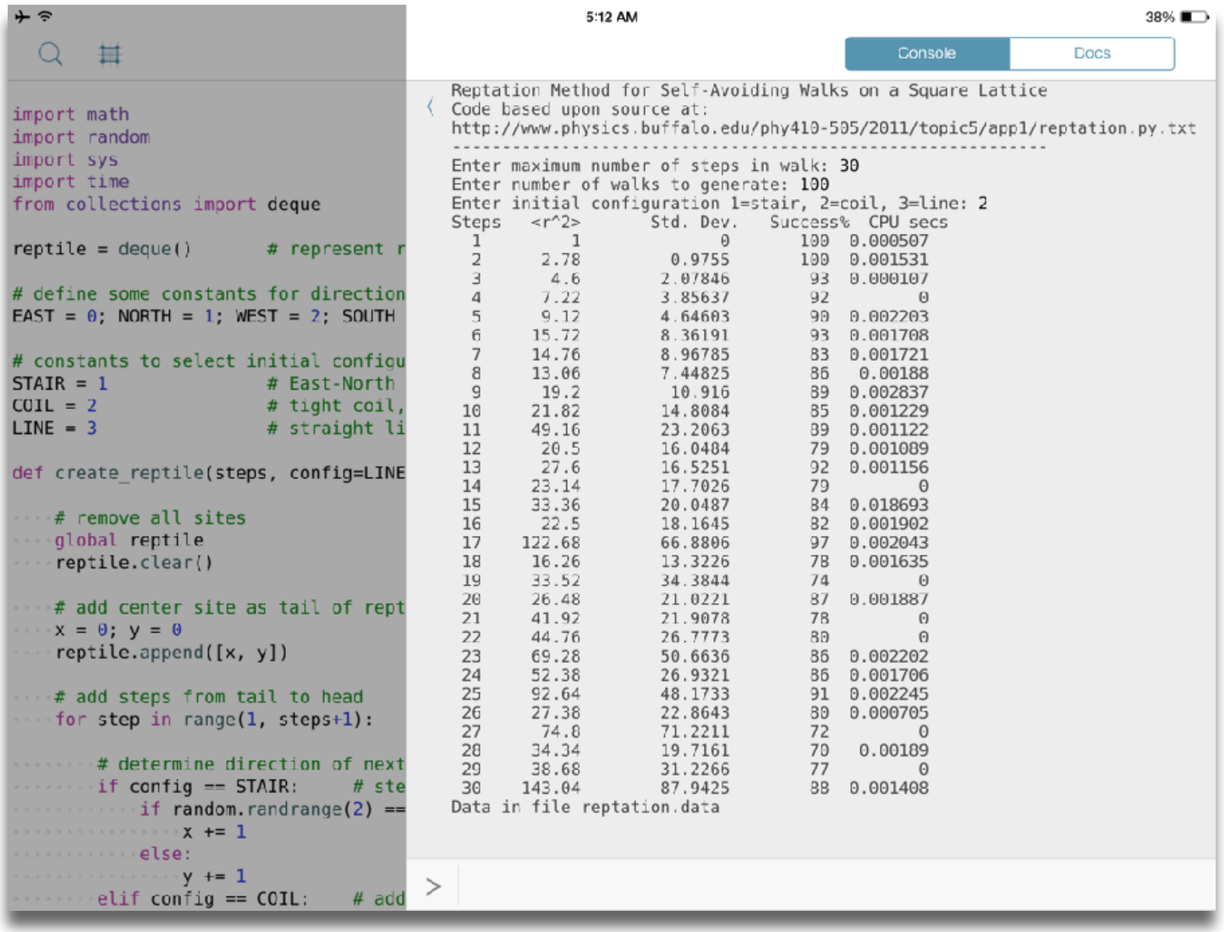

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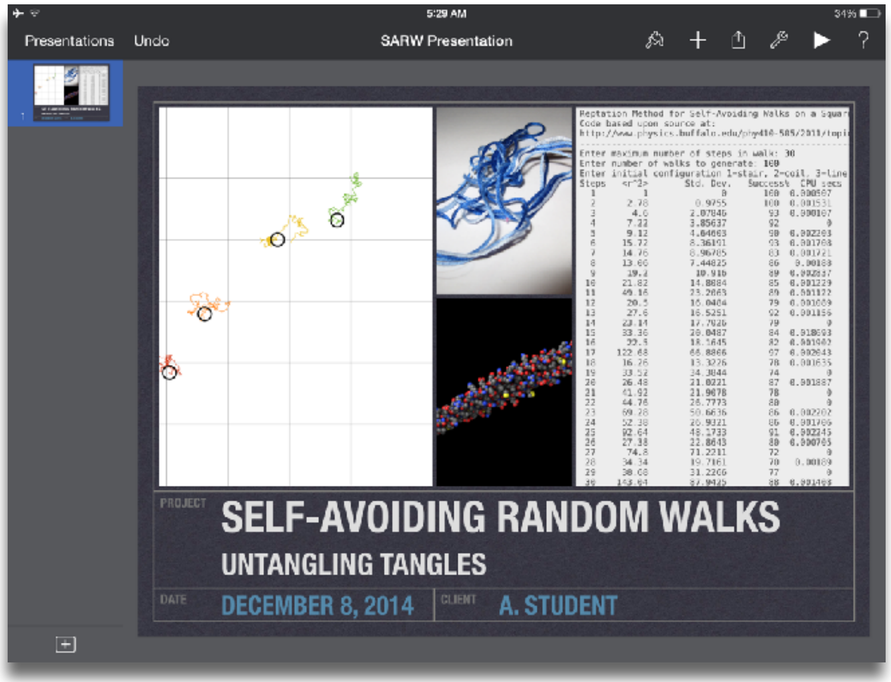
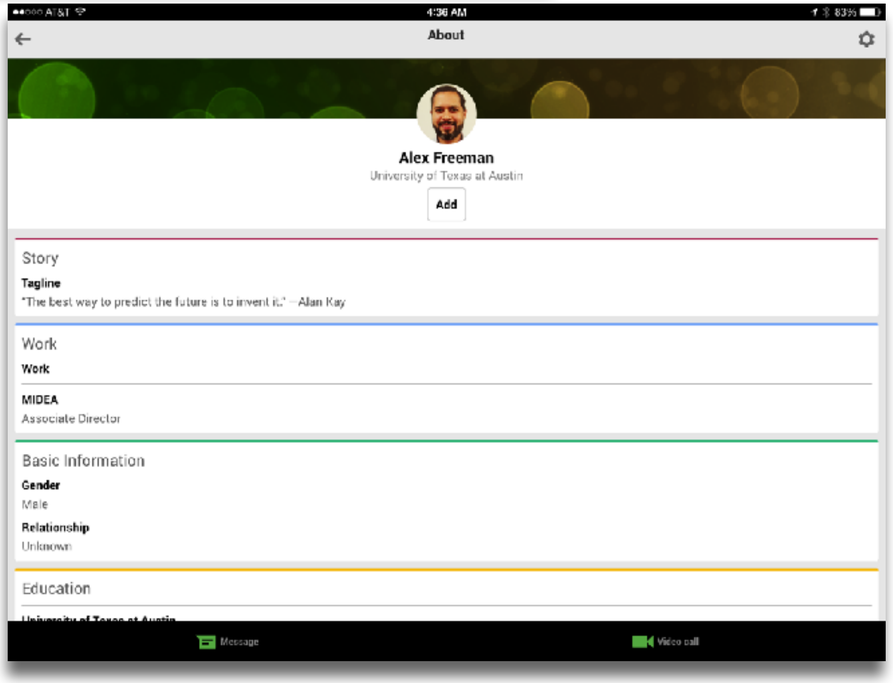
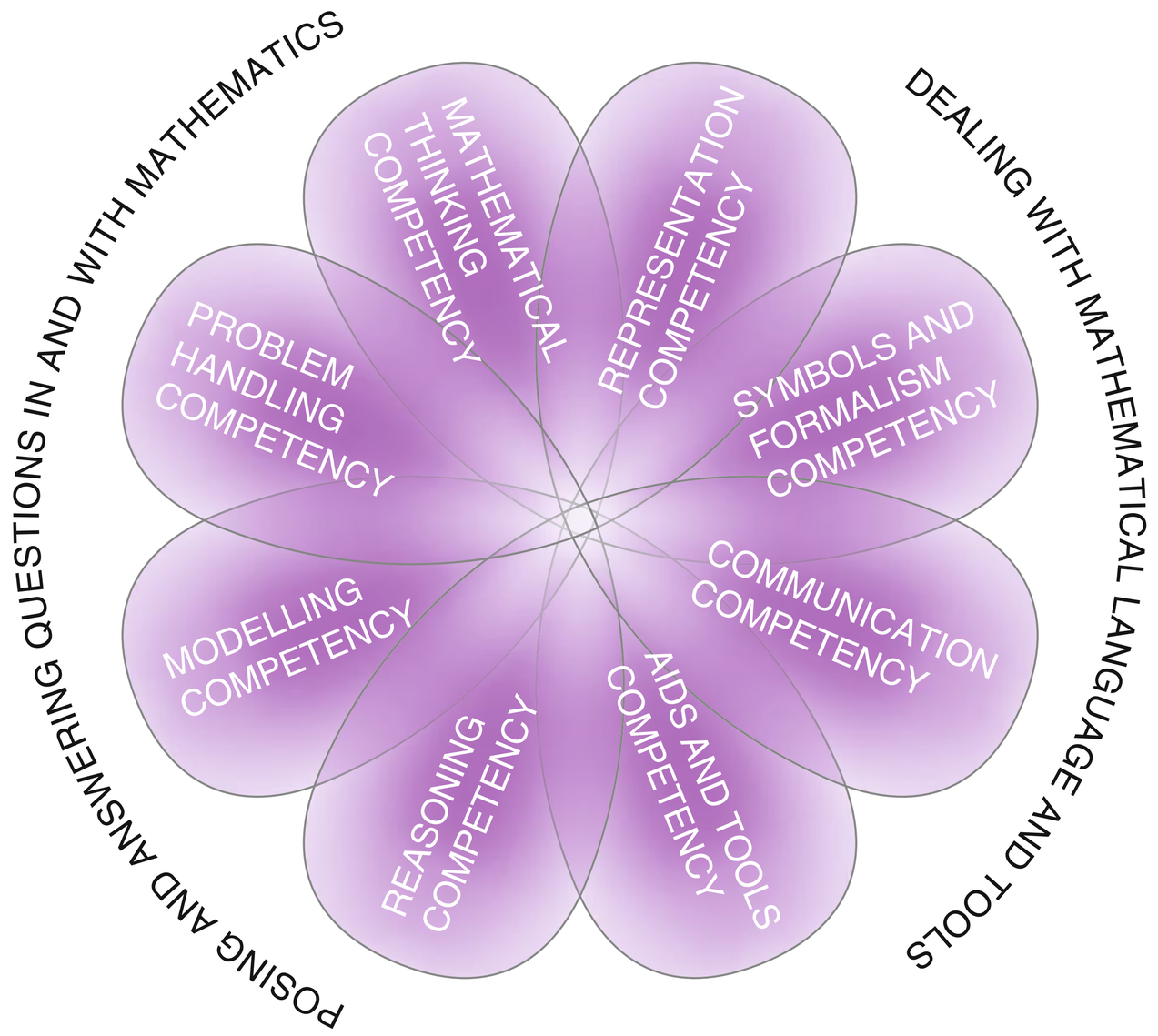
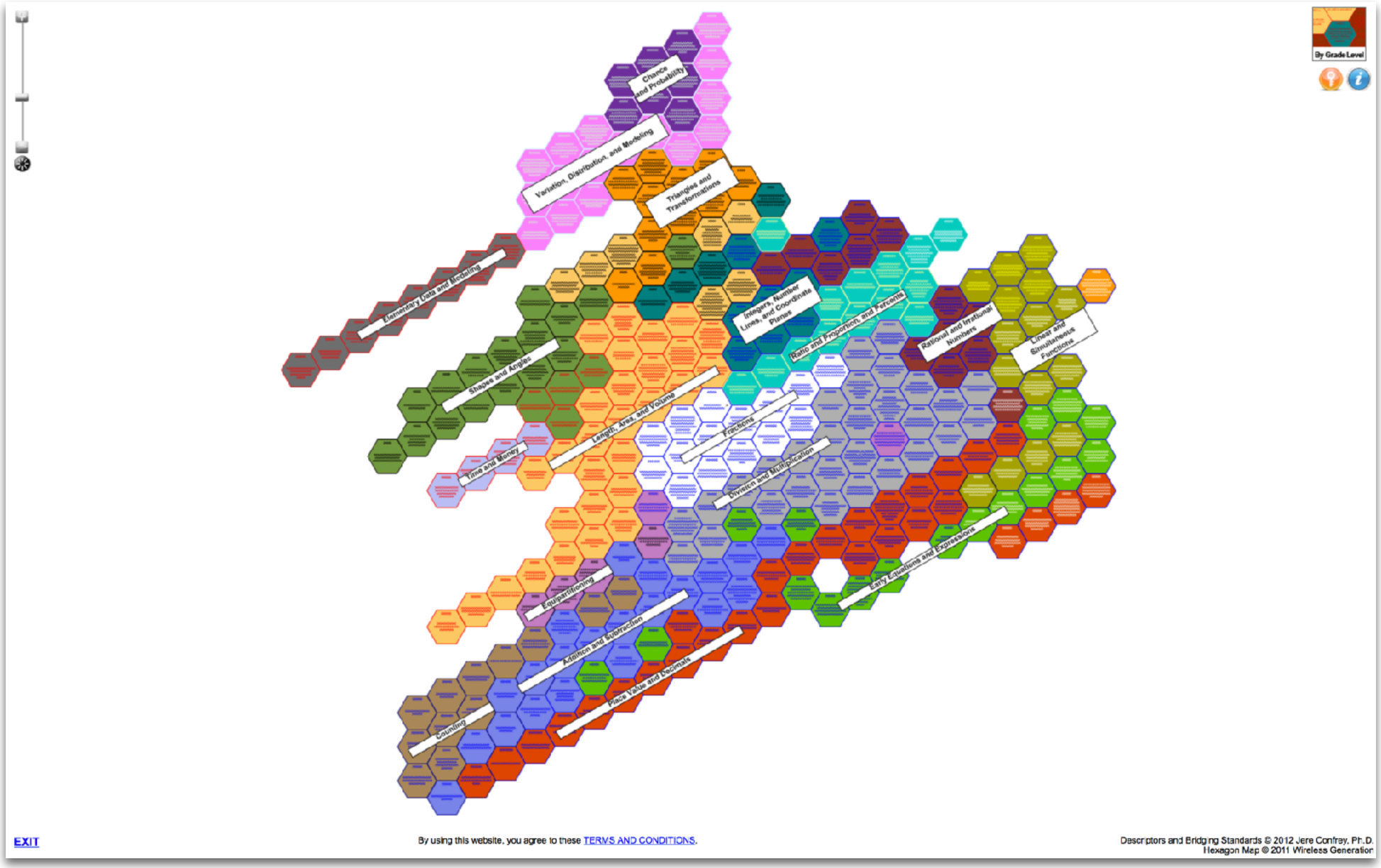




2. Mathematics



Niss, Mogens, and Tomas Højgaard. "Competencies and mathematical learning." *Ideas and inspiration for the development of mathematics teaching and learning in Denmark* (2011).


By Grade Level
Chance and Probability
Variation, Distribution, and Modeling
Triangles and Transformations
Elementary Data and Modeling
Integers, Number Lines, and Coordinate Planes
Ratio and Proportion and Percents
Rational and Irrational Numbers
Linear and Simultaneous Functions
Shapes and Angles
Length, Area, and Volume
Fractions
Time and Money
Division and Multiplication
Equipartitioning
Early Expressions and Equations
Addition and Subtraction
Place Value and Decimals
Counting
EXIT
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Thinking Like a Mathematician

- **To get started:**
    1. Play with examples.
    2. Break it down – take small bites.
    3. Change the problem:
        - If we weaken assumptions (e.g. drop assumptions), then we get a generalization.
        - If we strengthen assumptions, then we get a specialization.
- **To get to a higher level:**
    1. Reverse the question – construct your own examples.
    2. Ask ‘What happens if...?’
    3. Reflect and see the web of ideas.

Houston, Kevin. *How to think like a mathematician: A companion to undergraduate mathematics.* Cambridge University Press, 2009.

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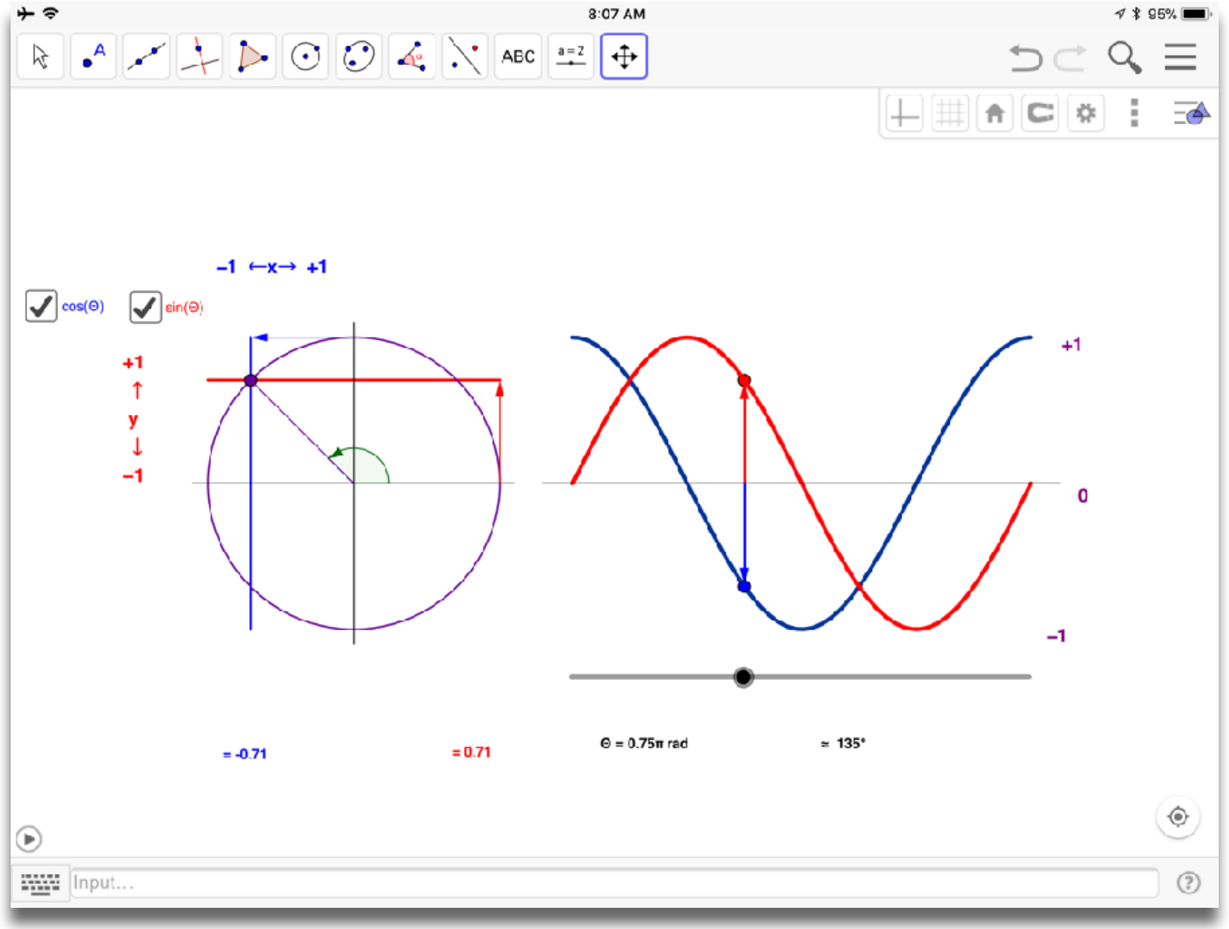

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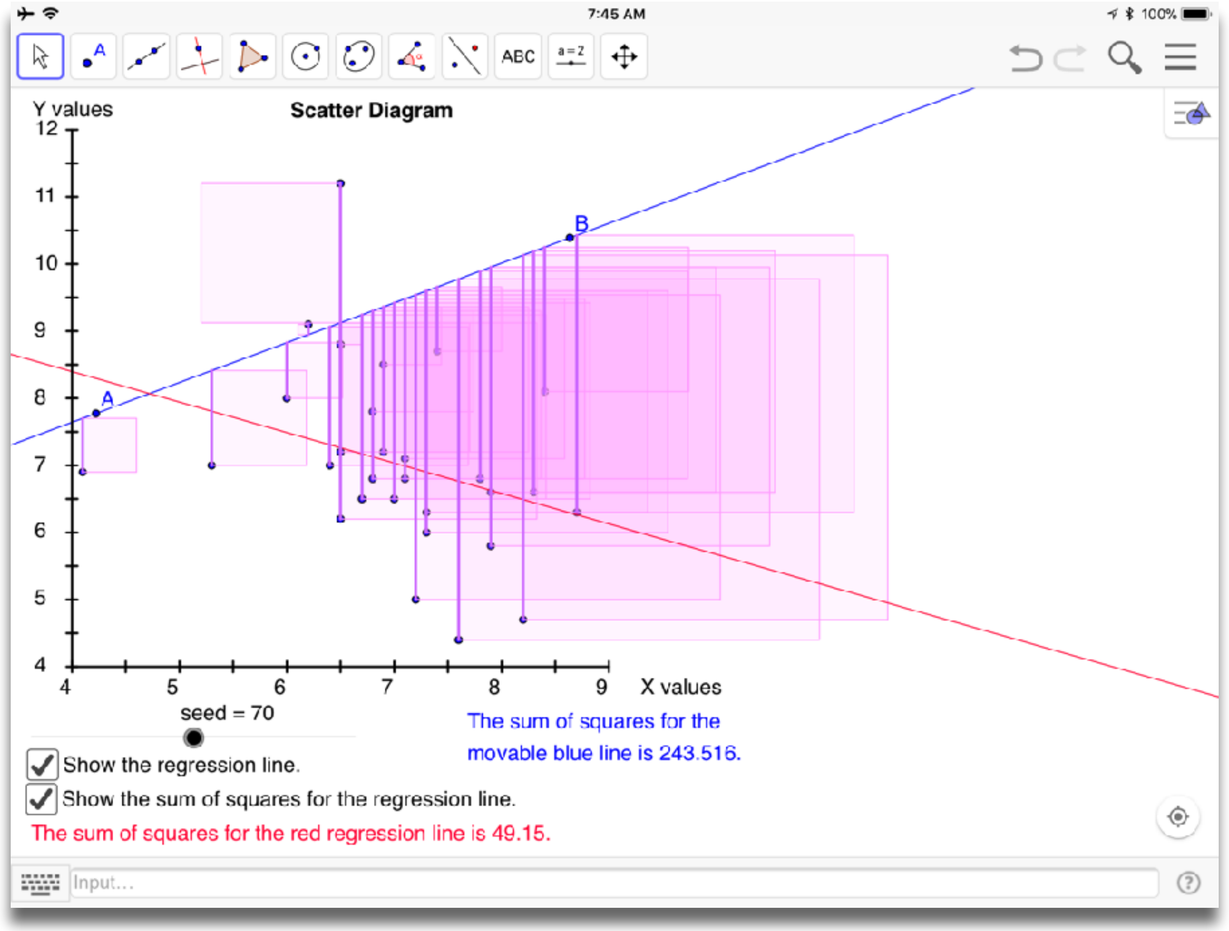

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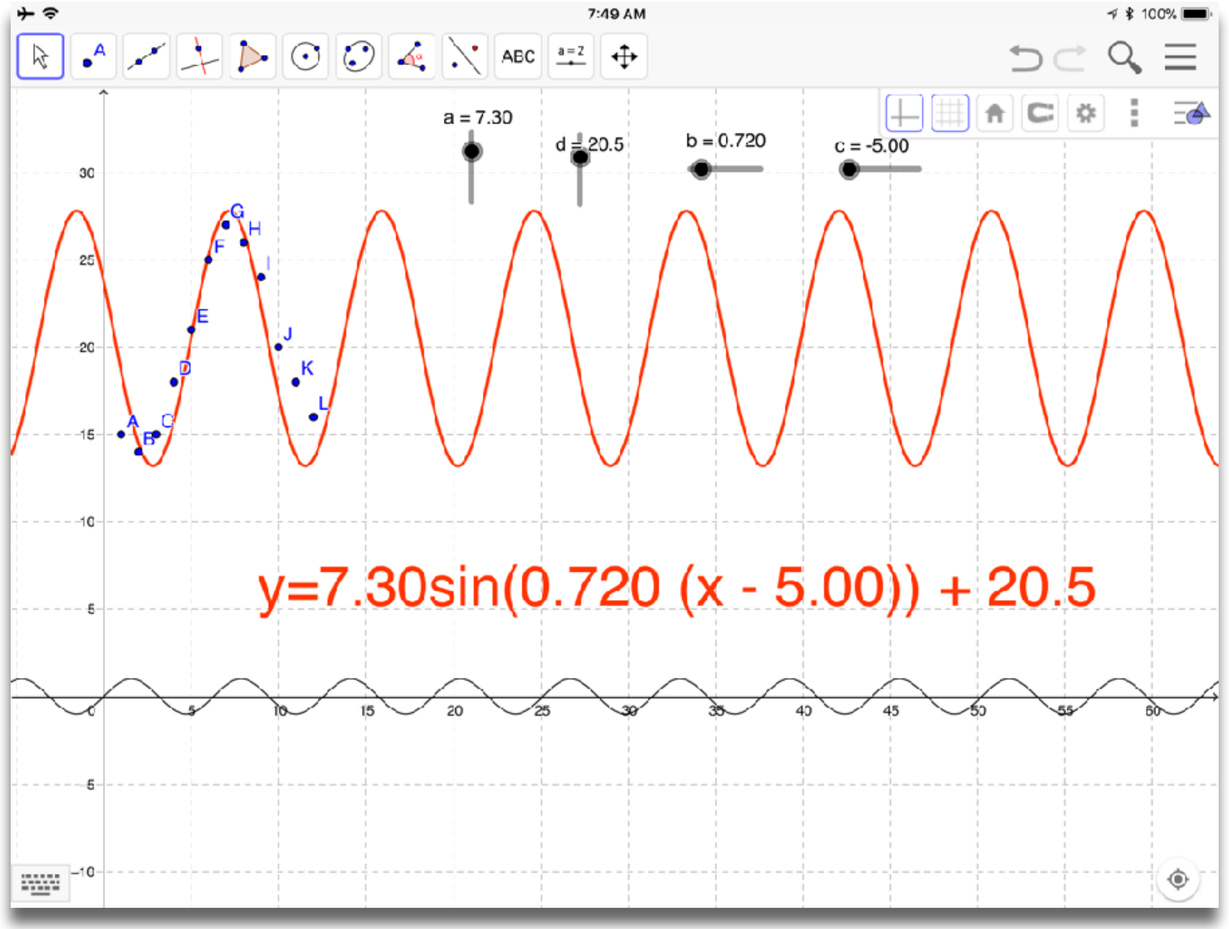

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3. Science

Two Useful Concepts from the Philosophy of Science

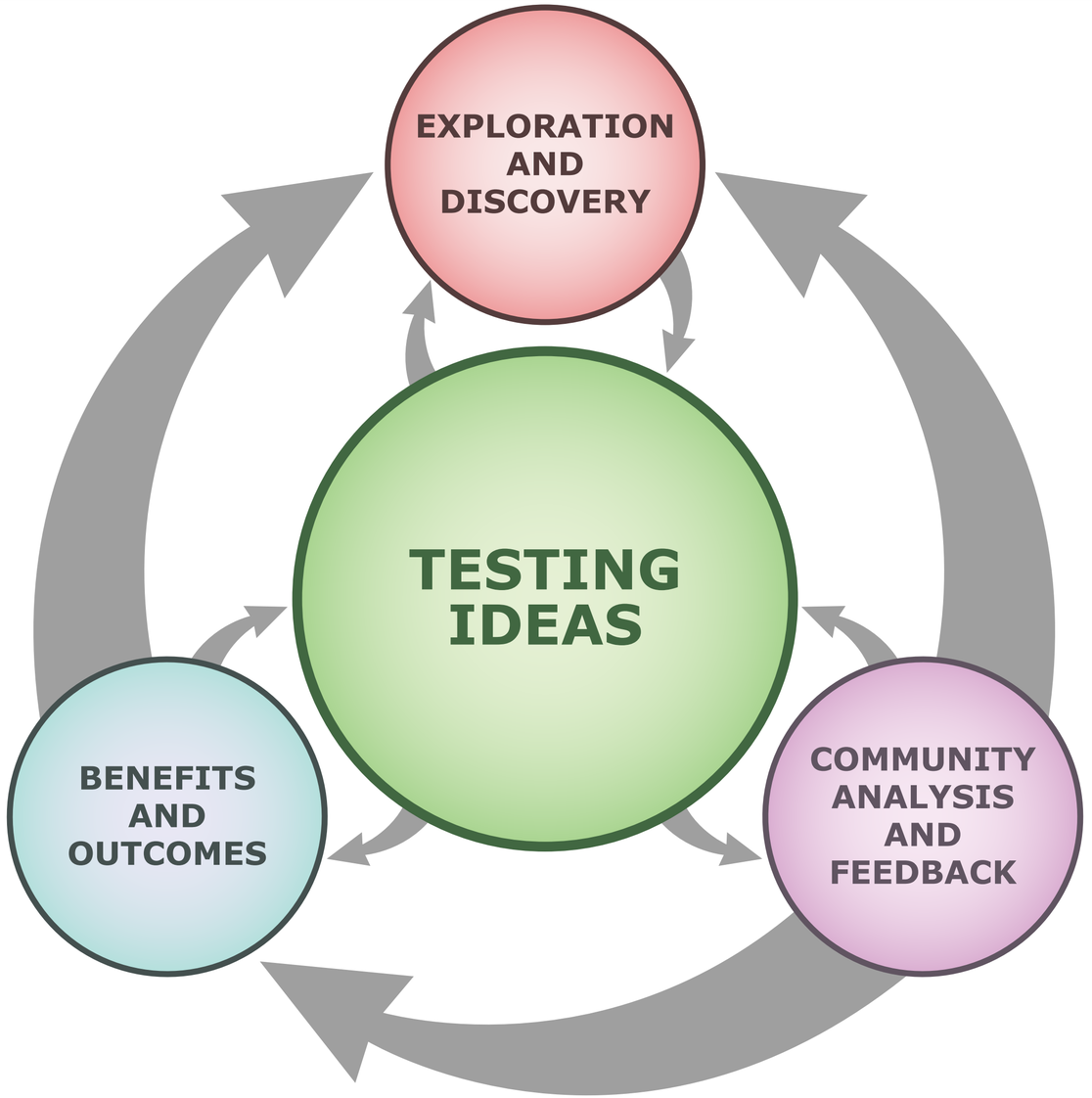
- Limiting Case (Einstein, 1917)
- Falsifiability (Popper, 1934)

Einstein, A. *Relativity: The Special and the General Theory - Authorized translation by RW Lawson from the fifth German edition.* London, Methuen (1920).

Popper, Karl. *The Logic of Scientific Discovery*. Hutchinson & Co. (1959).

	K	1st	2nd	3rd	4th	5th	MS	HS
Physical Sciences			Structure and Properties of Matter			Structure and Properties of Matter	Structure and Properties of Matter	Structure and Properties of Matter
							Chemical Reactions	Chemical Reactions
	Forces and Interactions: Pushes and Pulls			Forces and Interactions			Forces and Interactions	Forces and Interactions
					Energy		Energy	Energy
		Waves: Light and Sound			Waves		Waves and Electromagnetic Radiation	Waves and Electromagnetic Radiation
Life Sciences		Structure, Function, and Information Processing			Structure, Function, and Information Processing		Structure, Function, and Information Processing	Structure and Function
						Matter and Energy in Organisms and Ecosystems	Matter and Energy in Organisms and Ecosystems	Matter and Energy in Organisms and Ecosystems
	Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment		Interdependent Relationships in Ecosystems	Interdependent Relationships in Ecosystems: Environmental Impacts on Organisms			Interdependent Relationships in Ecosystems	Interdependent Relationships in Ecosystems
				Inheritance and Variation of Traits: Life Cycles and Traits			Growth, Development, and Reproduction of Organisms	Inheritance and Variation of Traits
							Natural Selection and Adaptations	Natural Selection and Evolution
Earth and Space Sciences		Space Systems: Patterns and Cycles				Space Systems: Stars and the Solar System	Space Systems	Space Systems
							History of Earth	History of Earth
			Earth's Systems: Processes that Shape the Earth		Earth's Systems: Processes that Shape the Earth	Earth's Systems	Earth's Systems	Earth's Systems
	Weather and Climate			Weather and Climate			Weather and Climate	Weather and Climate
							Human Impacts	Human Sustainability

Understanding Science: How Science Works



Understanding Science. 2017. University of California Museum of Paleontology. 3 January 2017 <http://www.understandingscience.org>

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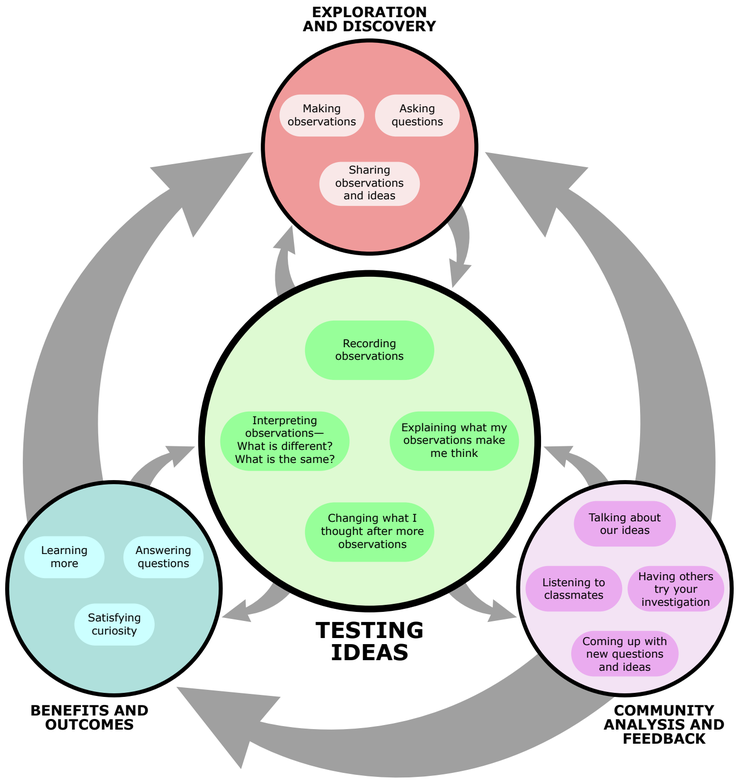
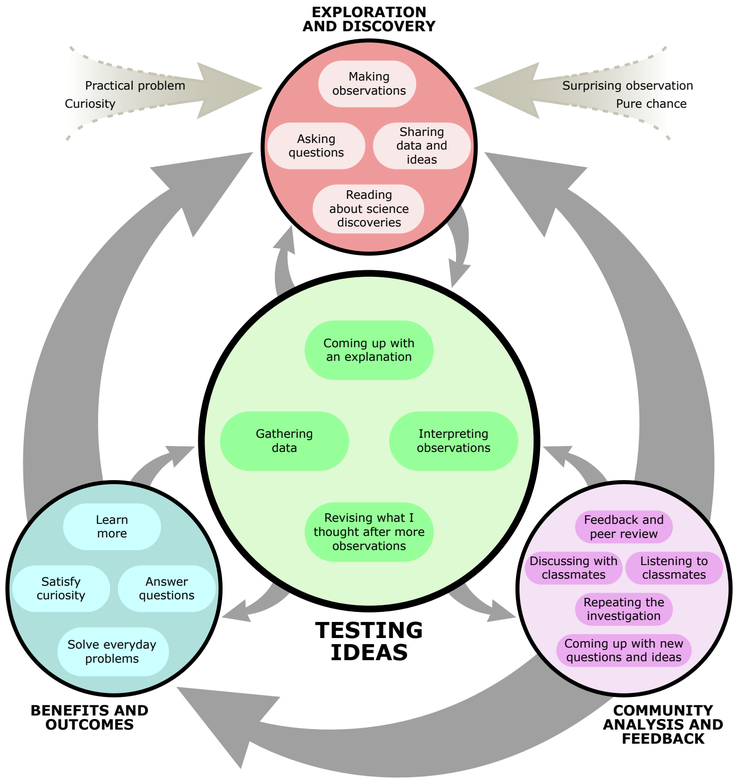
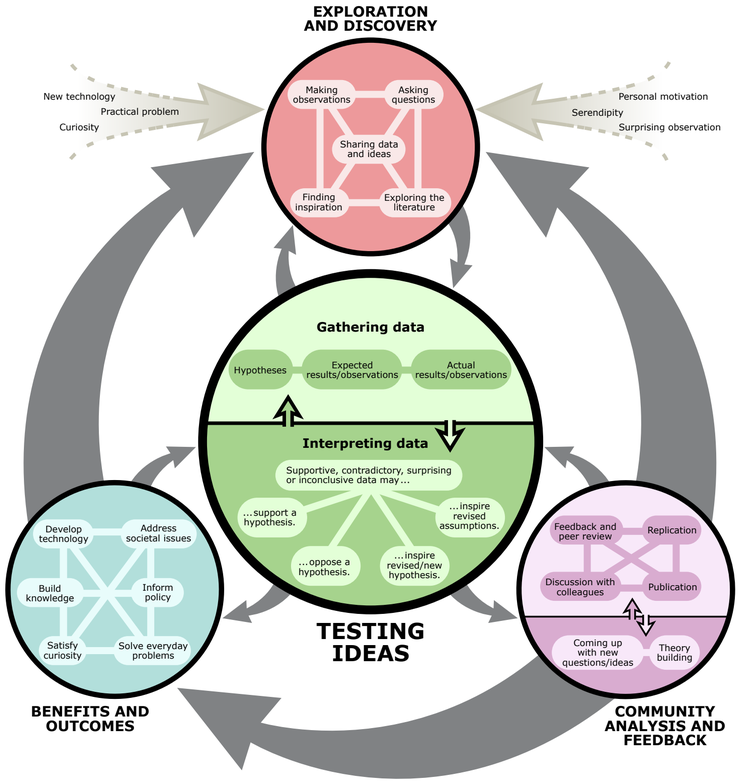


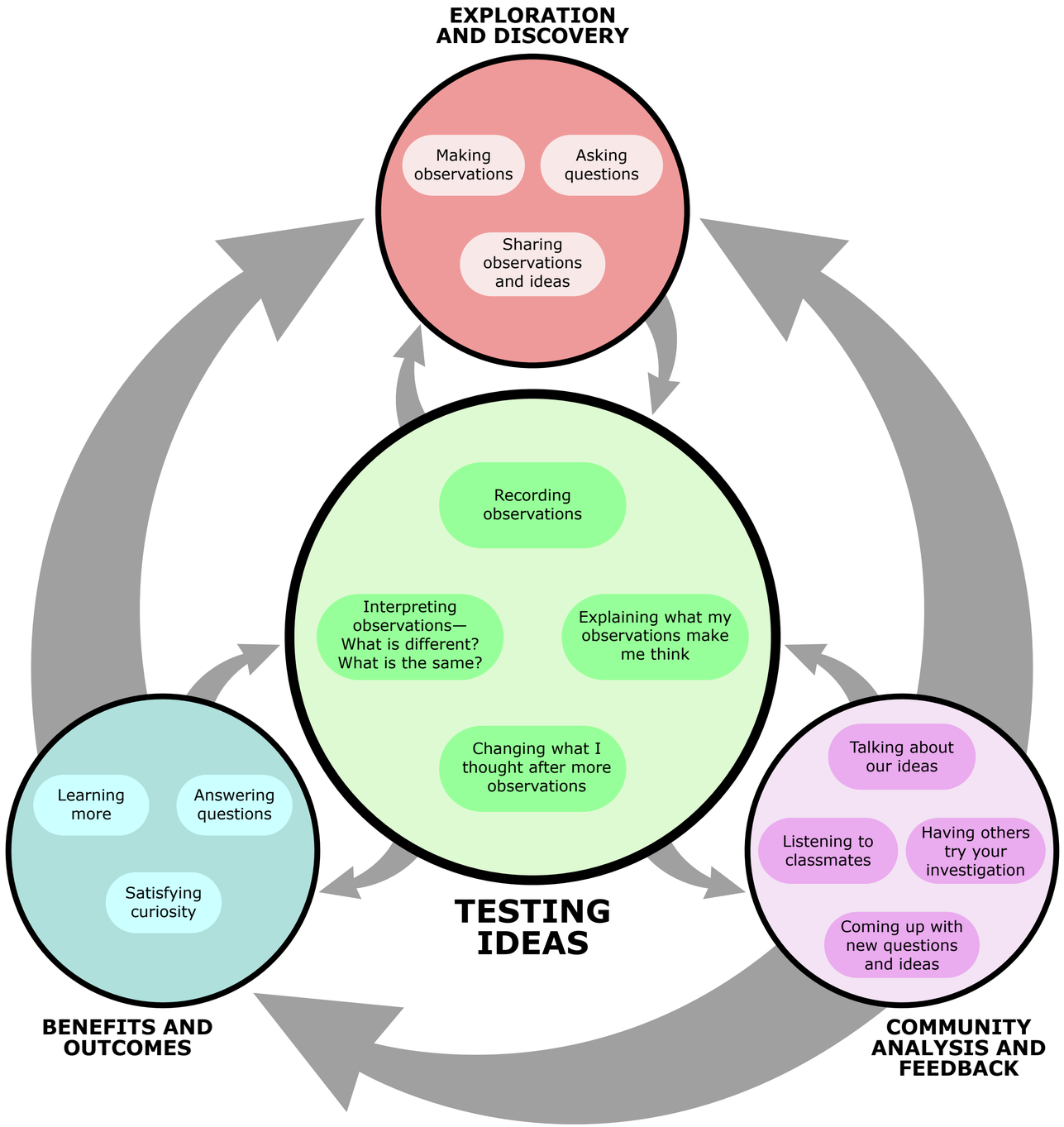
K–2

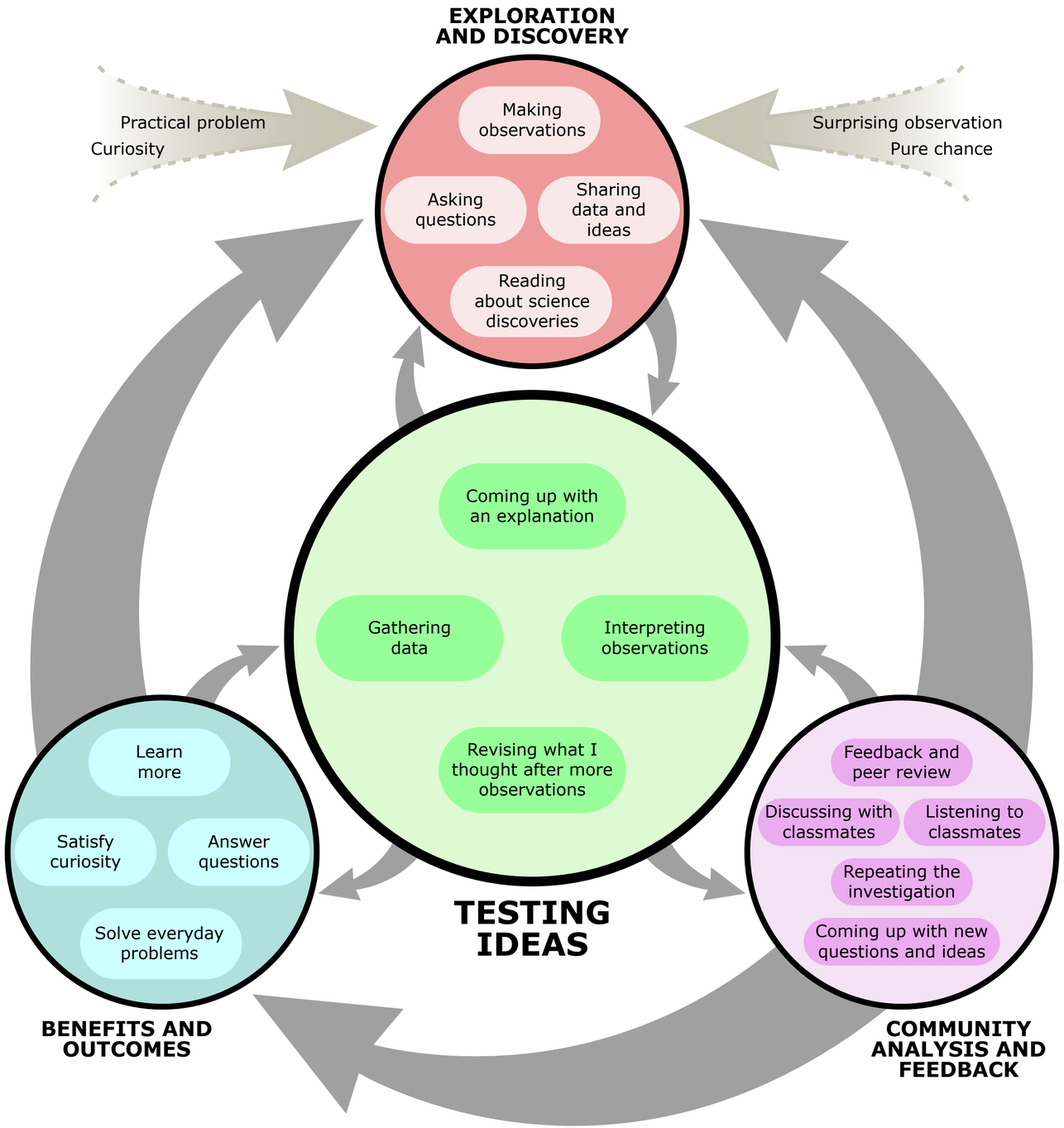


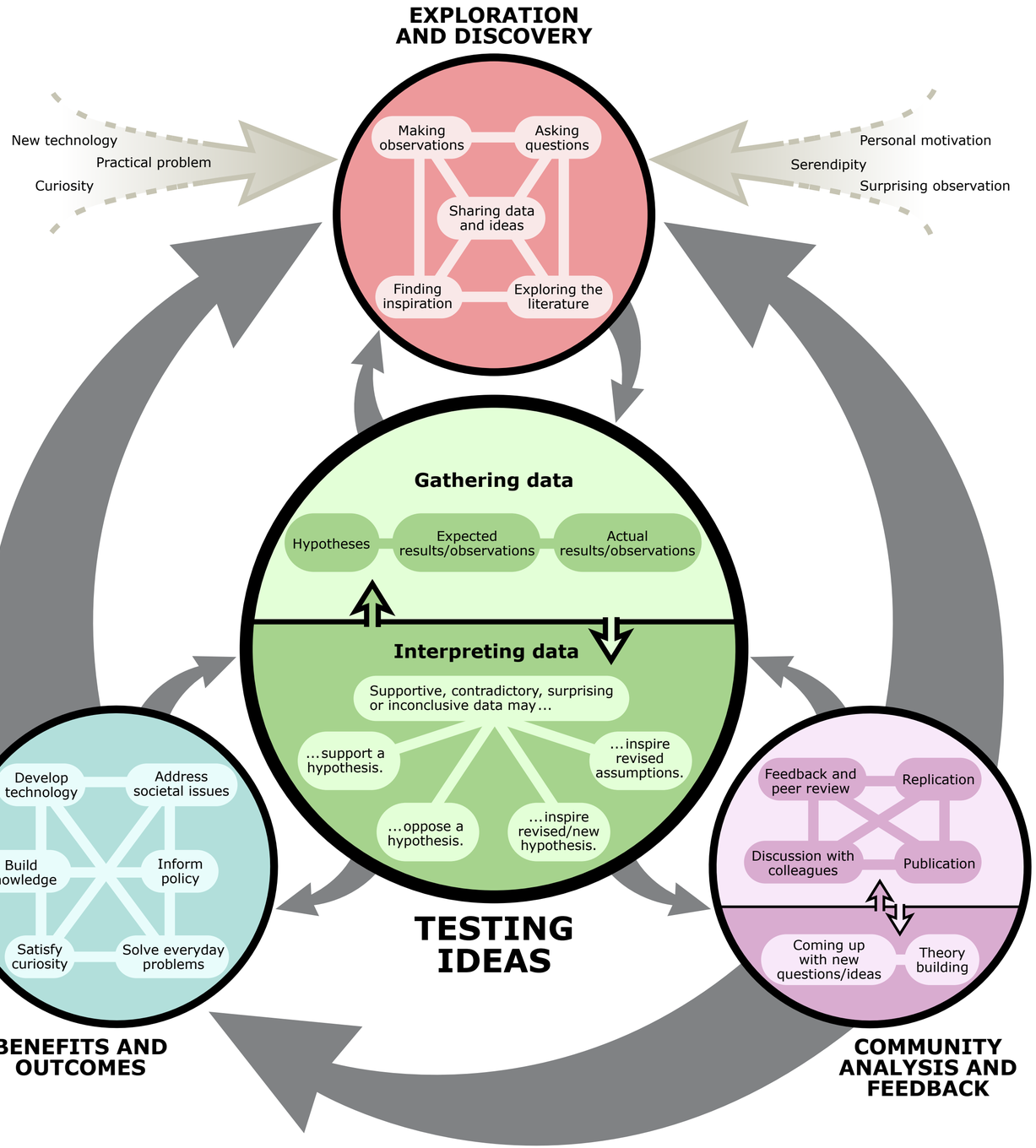
3–5



6–16


EXPLORATION AND DISCOVERY
Making observations
Asking questions
Sharing observations and ideas
Recording observations
Interpreting observations— What is different? What is the same?
Explaining what my observations make me think
Changing what I thought after more observations
TESTING IDEAS
Learning more
Answering questions
Satisfying curiosity
BENEFITS AND OUTCOMES
Talking about our ideas
Listening to classmates
Having others try your investigation
Coming up with new questions and ideas
COMMUNITY ANALYSIS AND FEEDBACK


EXPLORATION AND DISCOVERY
Practical problem
Curiosity
Surprising observation
Pure chance
Making observations
Asking questions
Sharing data and ideas
Reading about science discoveries
Coming up with an explanation
Gathering data
Interpreting observations
Revising what I thought after more observations
TESTING IDEAS
Learn more
Satisfy curiosity
Answer questions
Solve everyday problems
BENEFITS AND OUTCOMES
Feedback and peer review
Discussing with classmates
Listening to classmates
Repeating the investigation
Coming up with new questions and ideas
COMMUNITY ANALYSIS AND FEEDBACK


EXPLORATION AND DISCOVERY
New technology
Practical problem
Curiosity
Personal motivation
Serendipity
Surprising observation
Making observations
Asking questions
Sharing data and ideas
Finding inspiration
Exploring the literature
Gathering data
Hypotheses
Expected results/observations
Actual results/observations
Interpreting data
Supportive, contradictory, surprising or inconclusive data may…
…support a hypothesis.
…inspire revised assumptions.
…oppose a hypothesis.
…inspire revised/new hypothesis.
TESTING IDEAS
Develop technology
Address societal issues
Build knowledge
Inform policy
Satisfy curiosity
Solve everyday problems
BENEFITS AND OUTCOMES
Feedback and peer review
Replication
Discussion with colleagues
Publication
Coming up with new questions/ideas
Theory building
COMMUNITY ANALYSIS AND FEEDBACK

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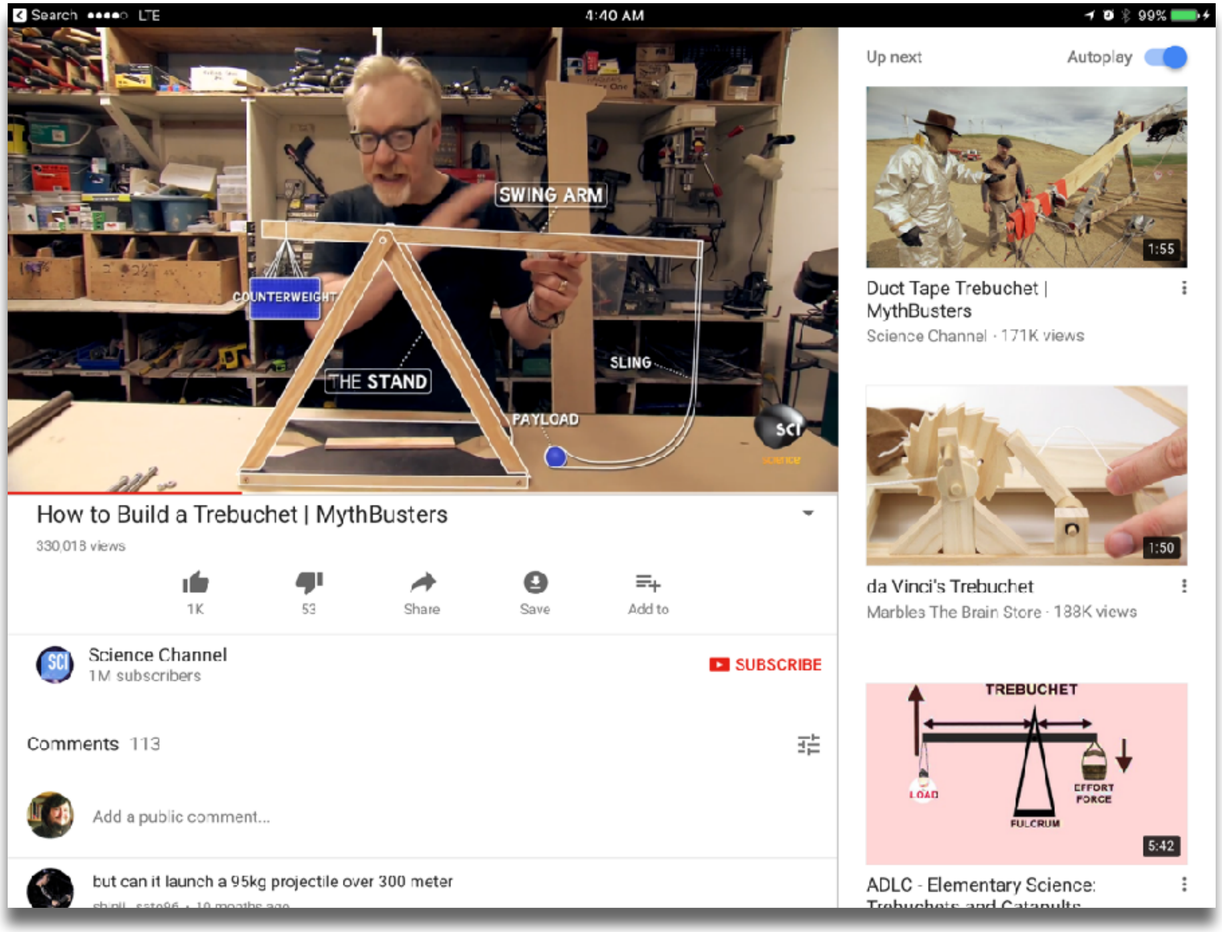

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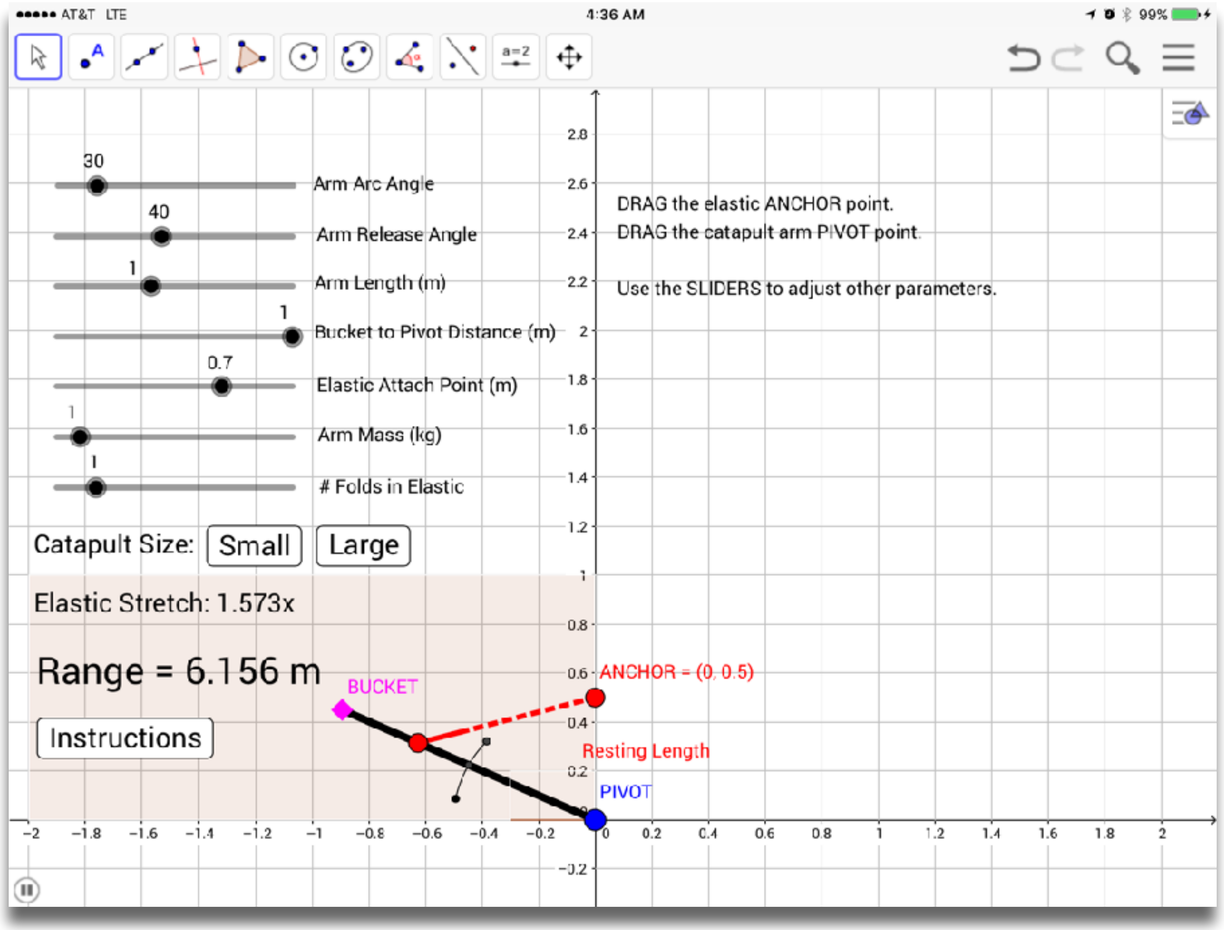

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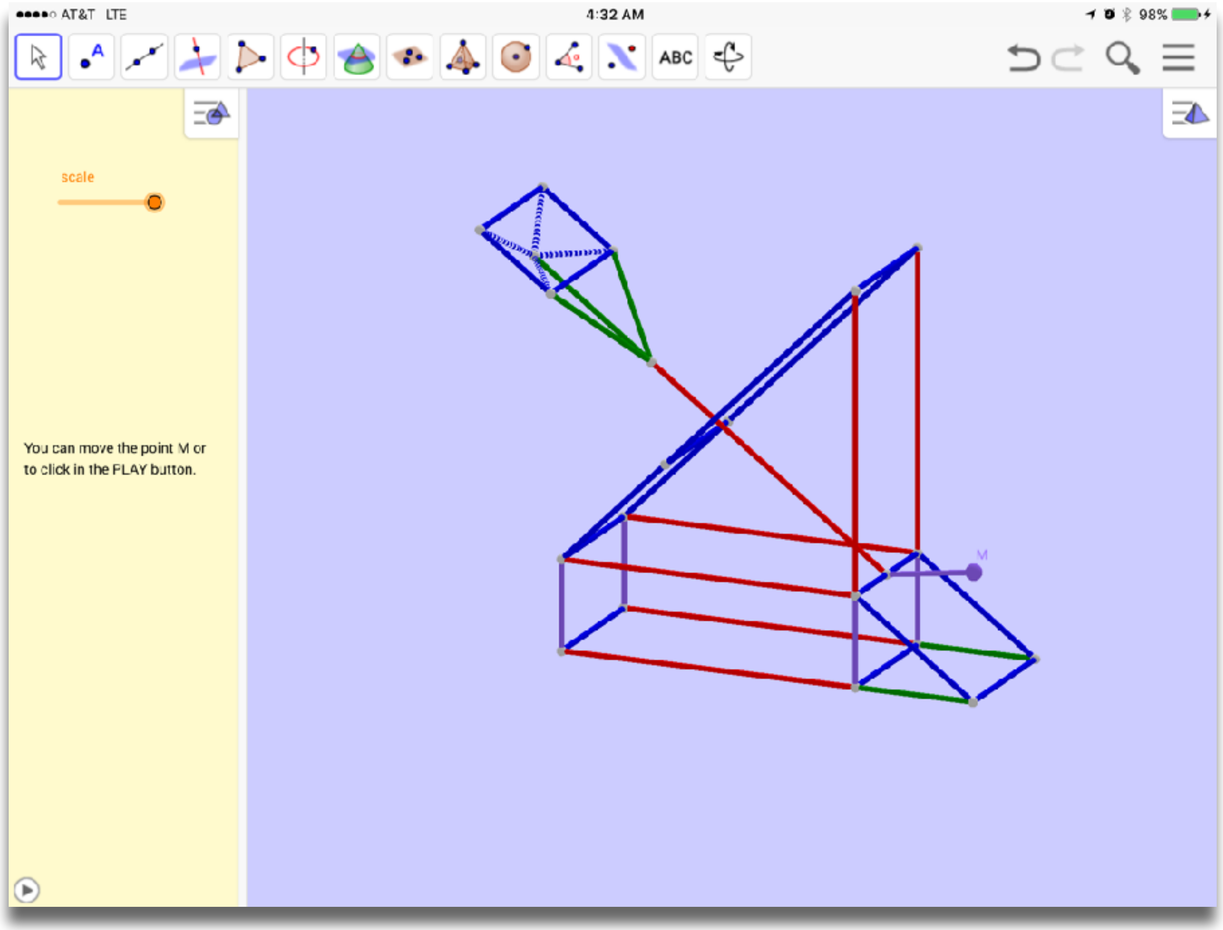

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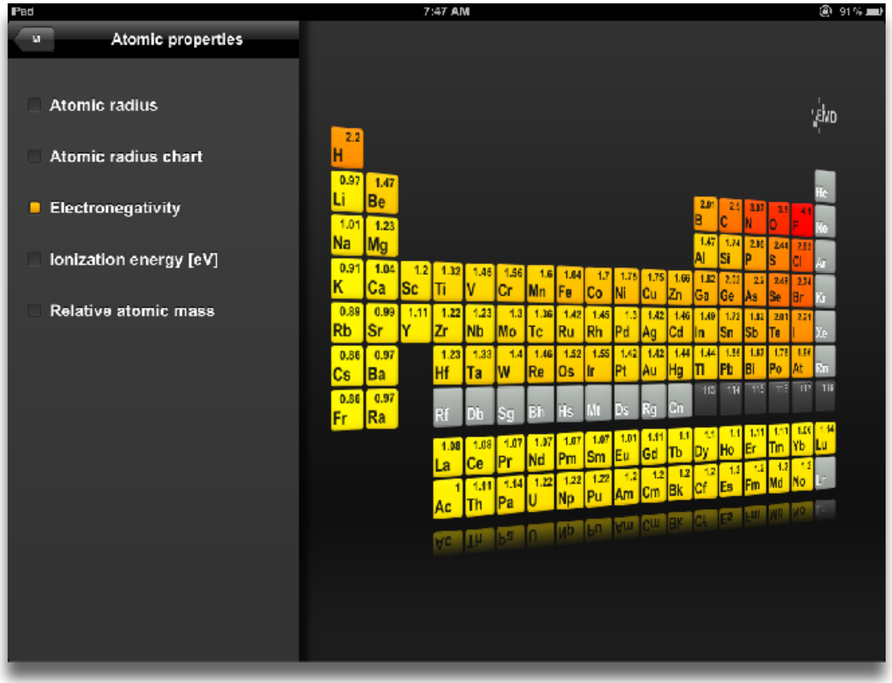

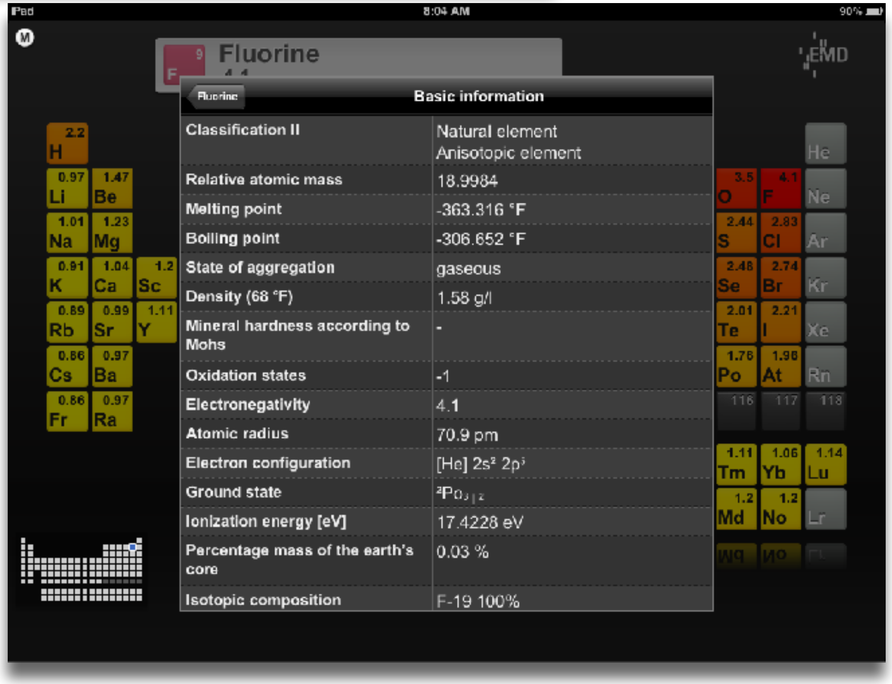

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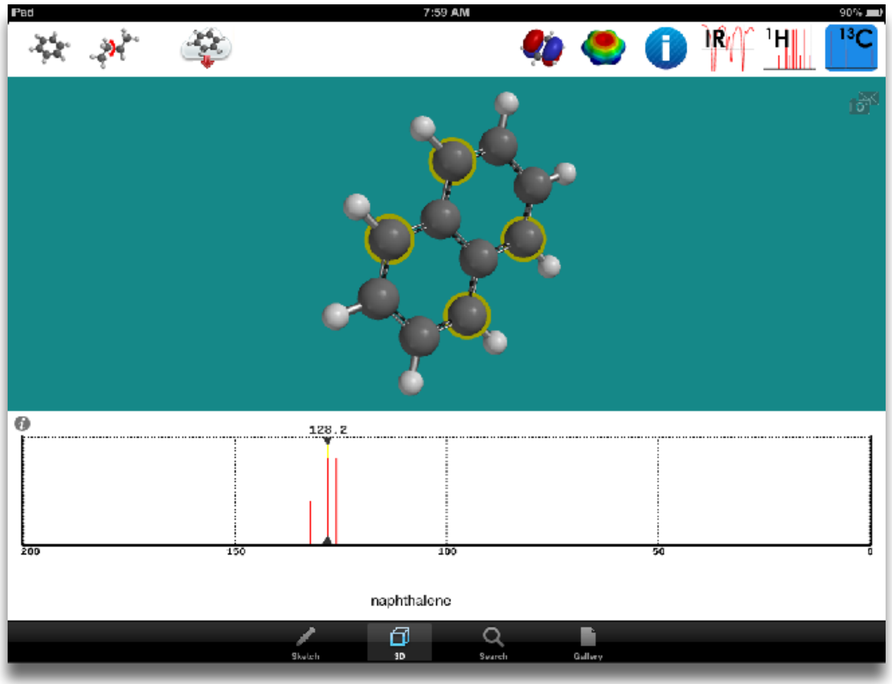

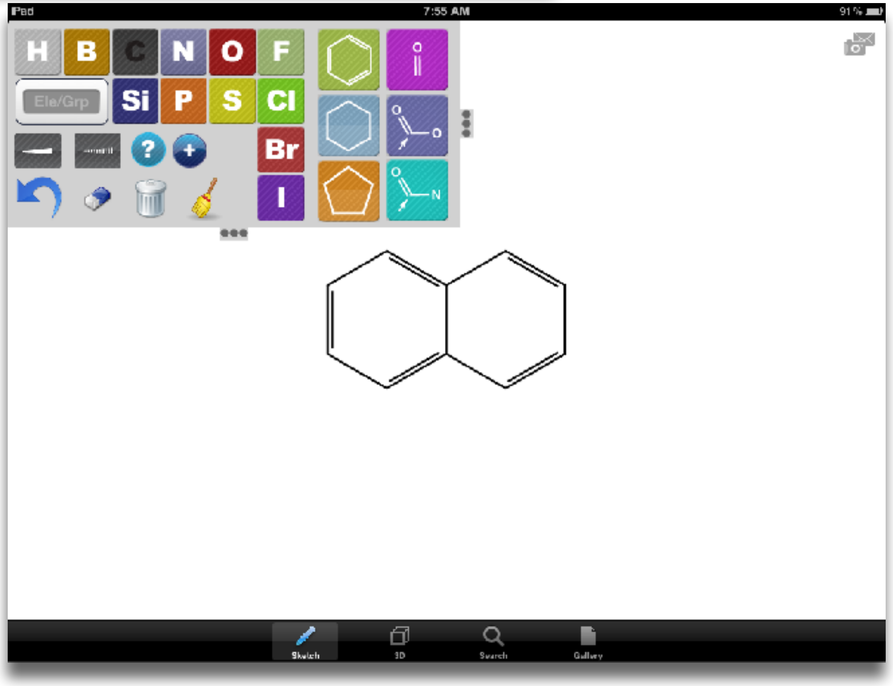

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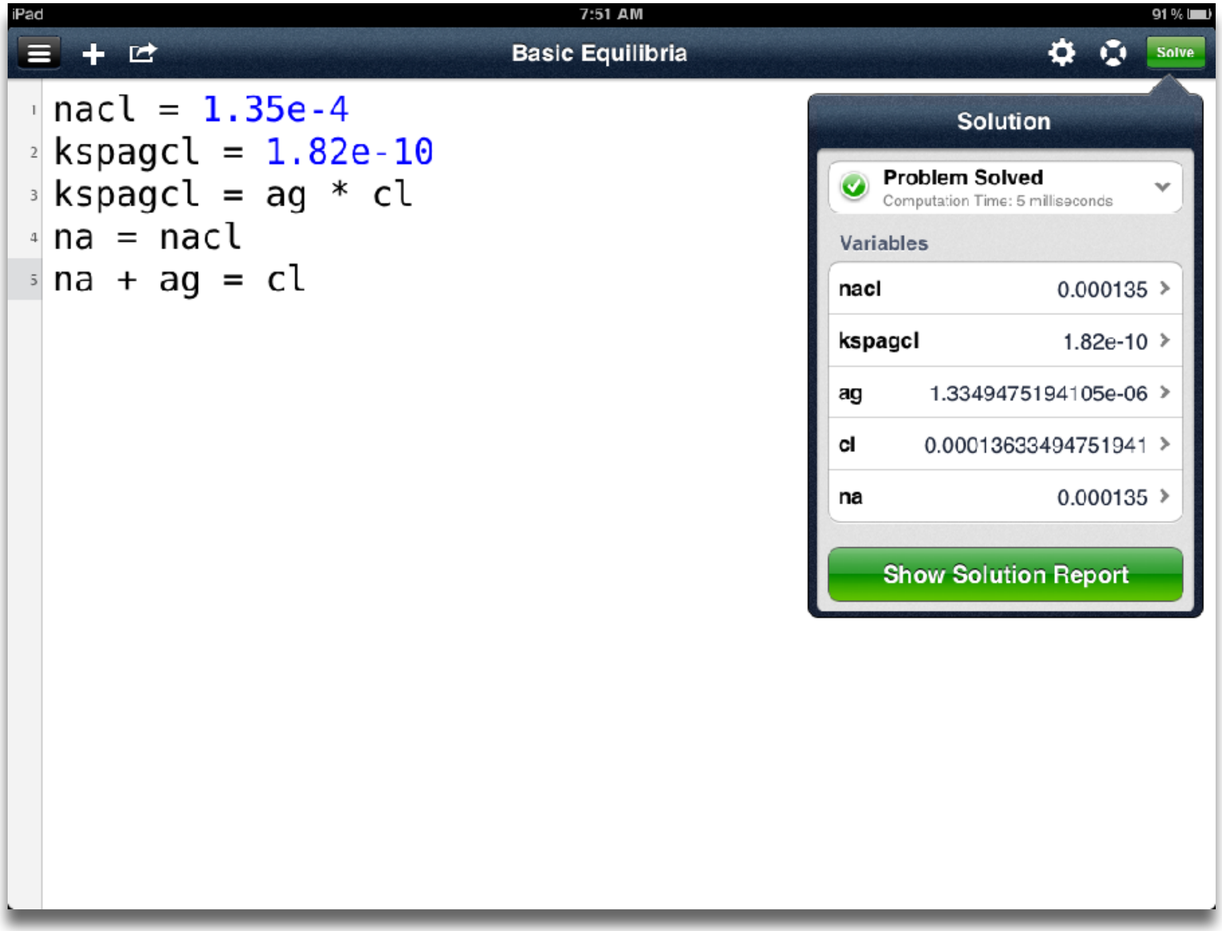

Diego Lieban & Zsolt Lavicza, “Geometric modelling inspired by Da Vinci: shaping and adding movement using technology and physical resources”. *10th Congress of European Research in Mathematics Education*. (2017)

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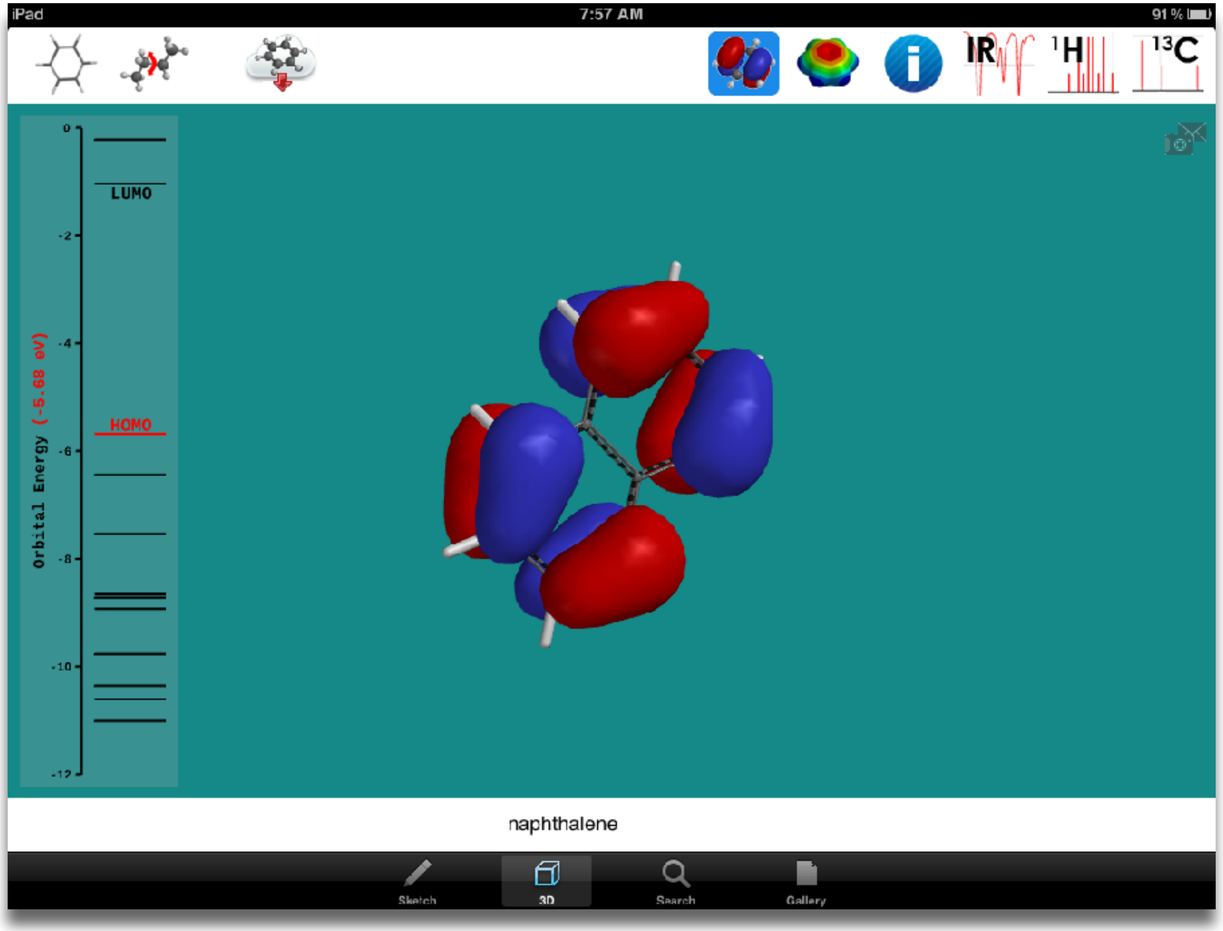


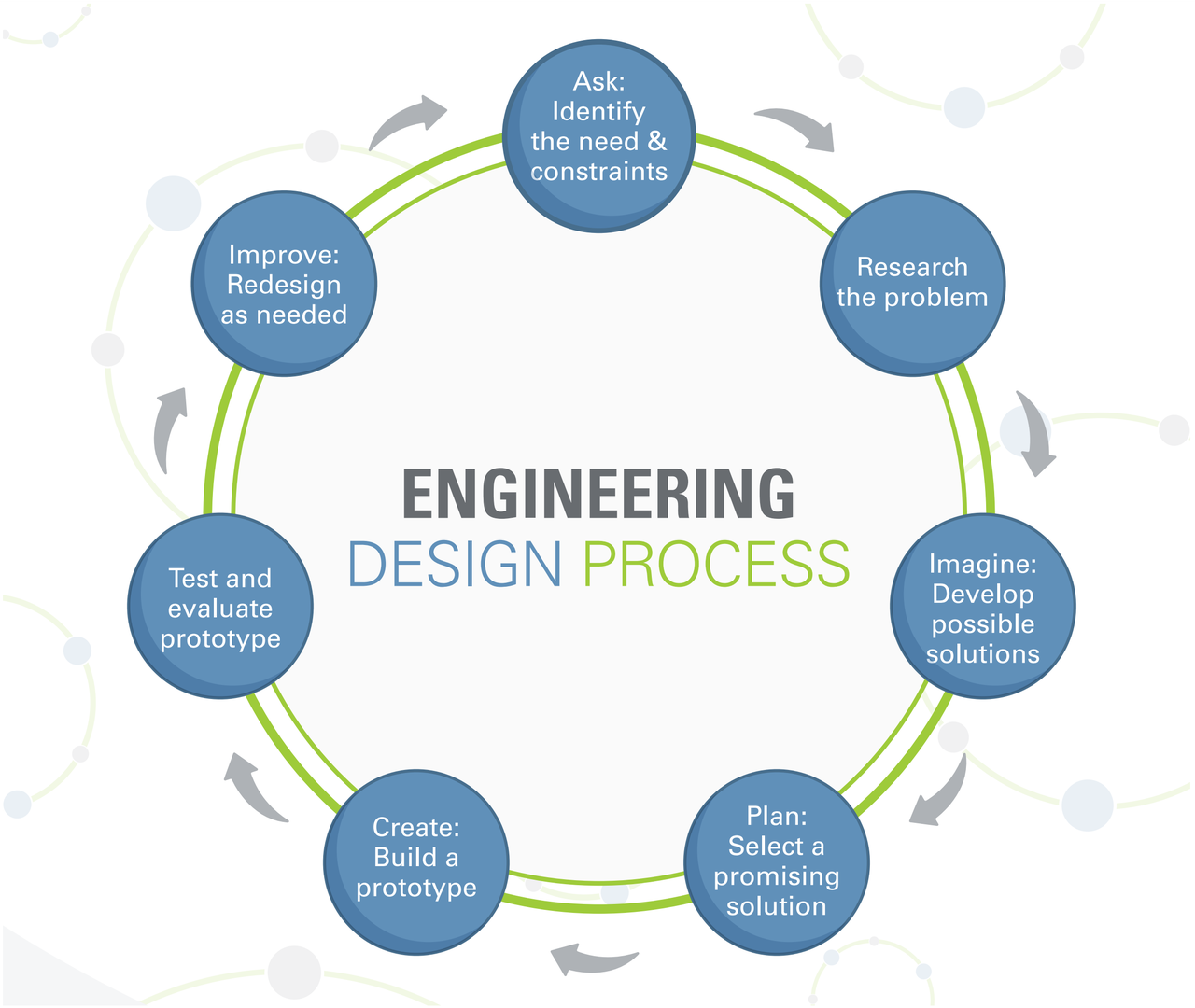
4. Engineering

ITEA Standards for Technological Literacy

1. **The Nature of Technology:**
   - The characteristics and scope of technology
   - The core concepts of technology
   - The relationships among technologies and the connections between technology and other fields
2. **Technology and Society:**
   - The cultural, social, economic, and political effects of technology
   - The effects of technology on the environment
   - The role of society in the development and use of technology
   - The influence of technology on history
3. **Design:**
   - The attributes of design
   - Engineering design
   - The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving
4. **Abilities for a Technological World**
   - Apply the design process
   - Use and maintain technological products and systems
   - Assess the impact of products and systems
5. **The Designed World**
   - Medical technologies
   - Agricultural and related biotechnologies
   - Energy and power technologies
   - Information and communication technologies
   - Transportation technologies
   - Manufacturing technologies
   - Construction technologies

Technology for All Americans Project, and International Technology Education Association. *Standards for technological literacy: Content for the study of technology, Third Edition*. International Technology Education Association, 2000. - https://www.iteea.org/Publications/StandardsOverview.aspx

The Engineering Design Process



TeachEngineeering, *Engineering Design Process* – https://www.teachengineering.org/k12engineering/designprocess

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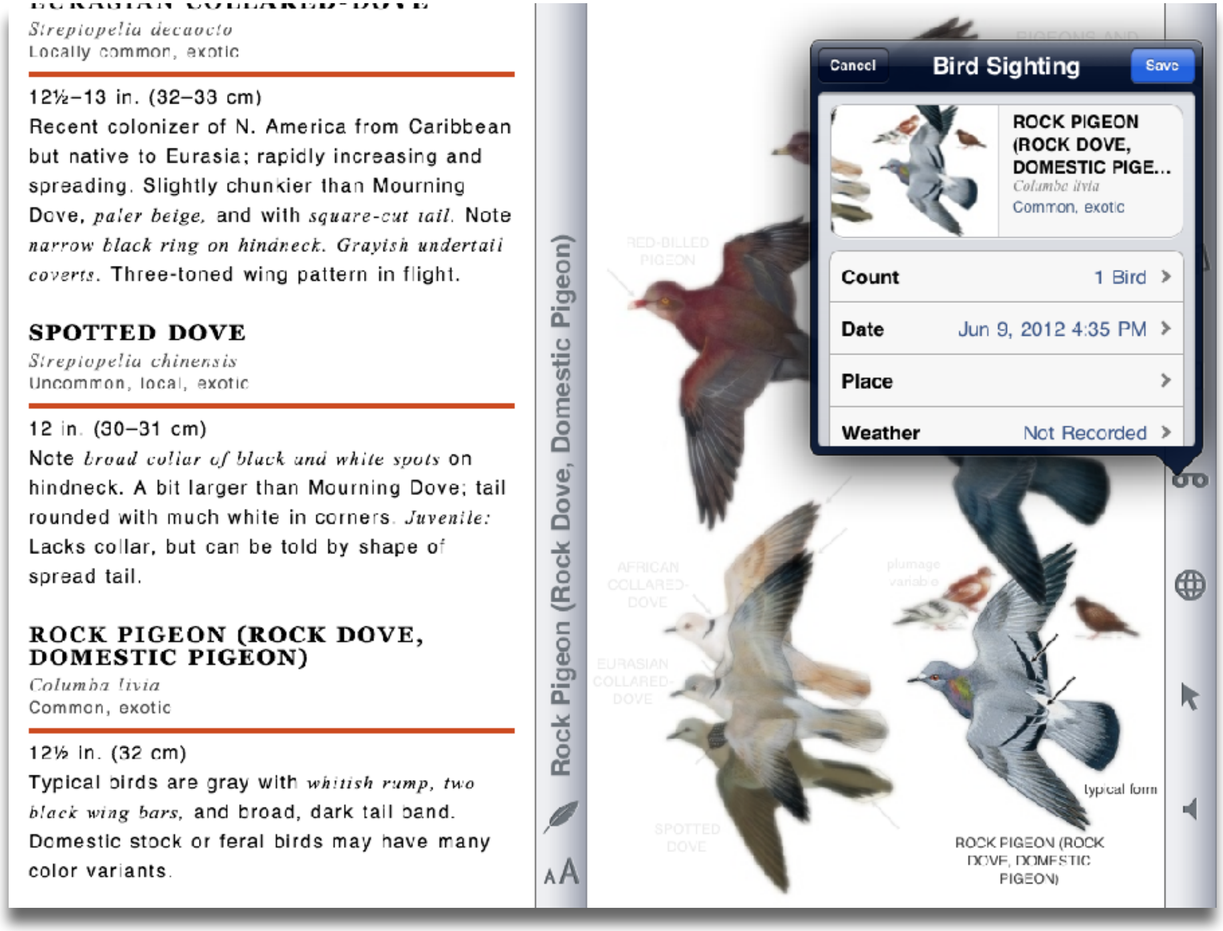

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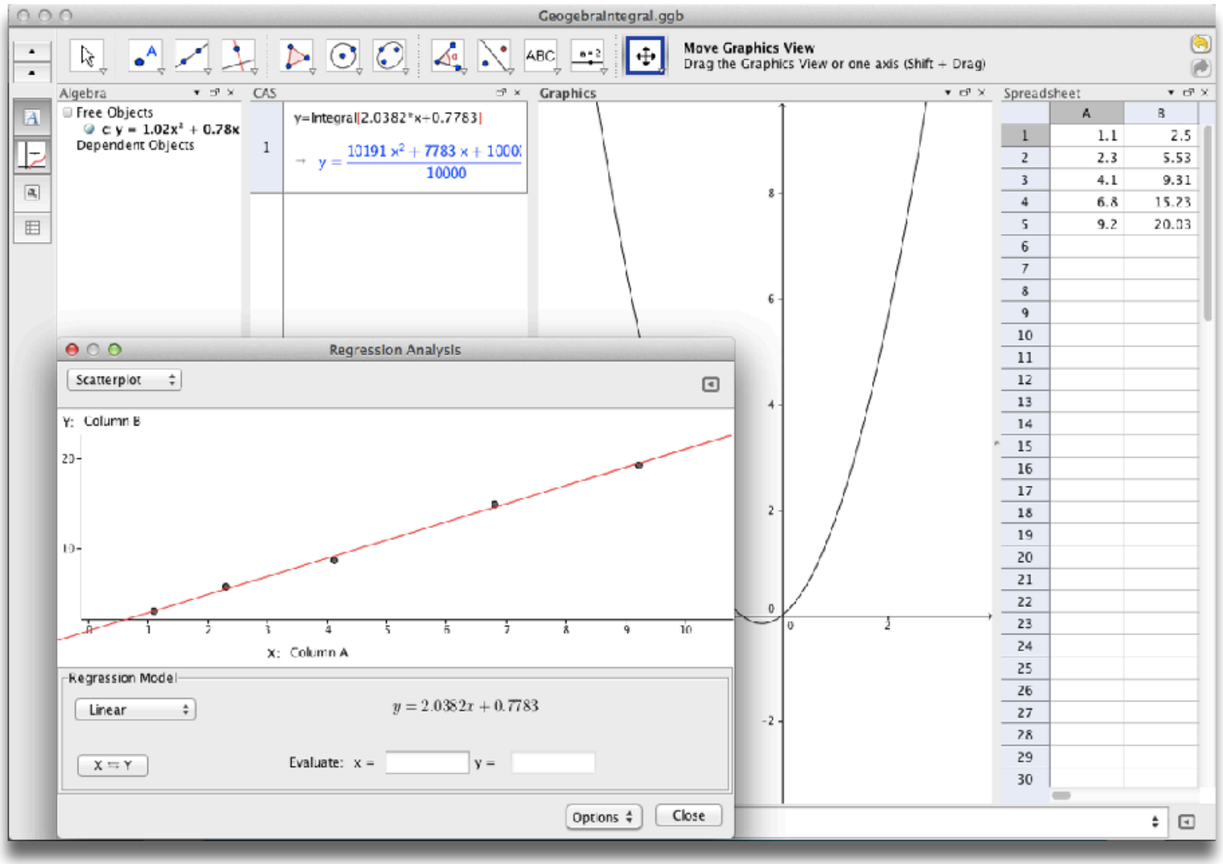

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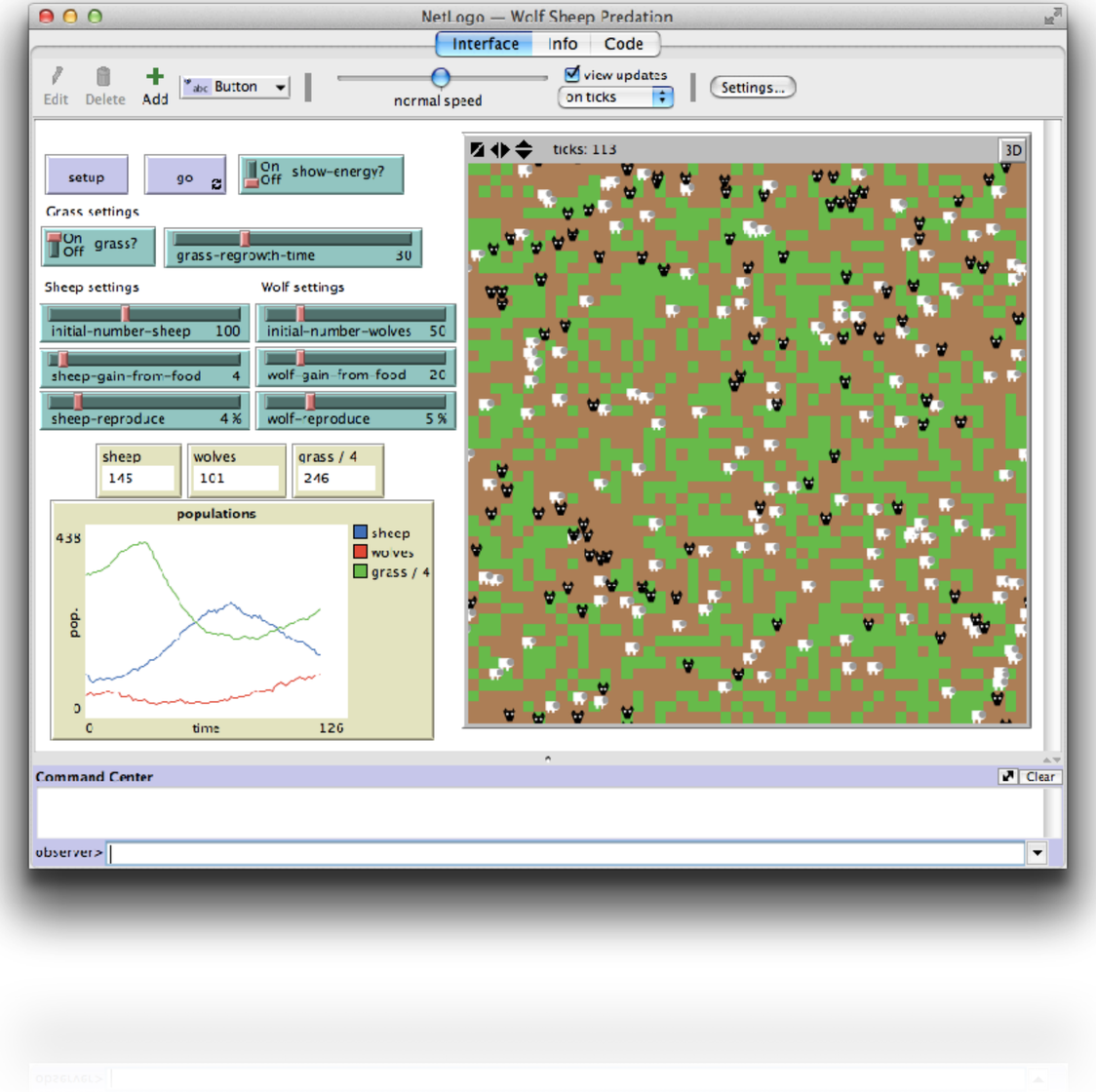

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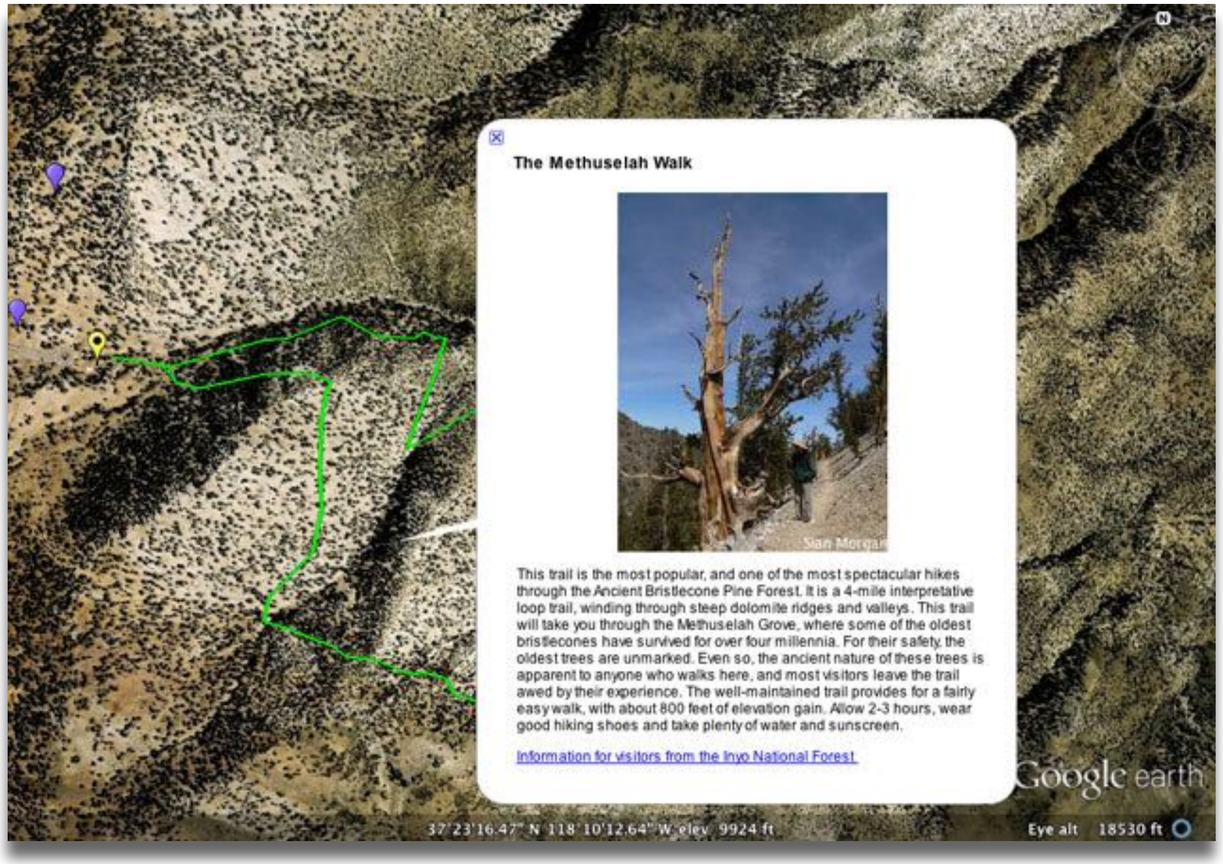
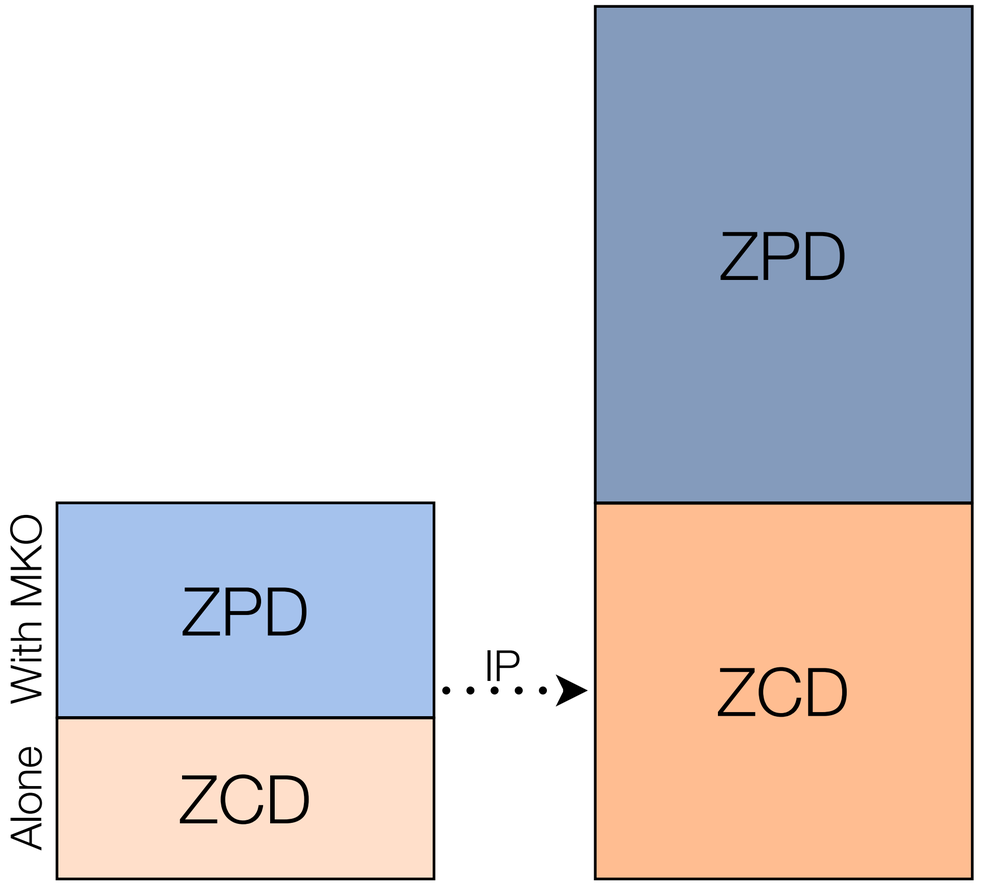
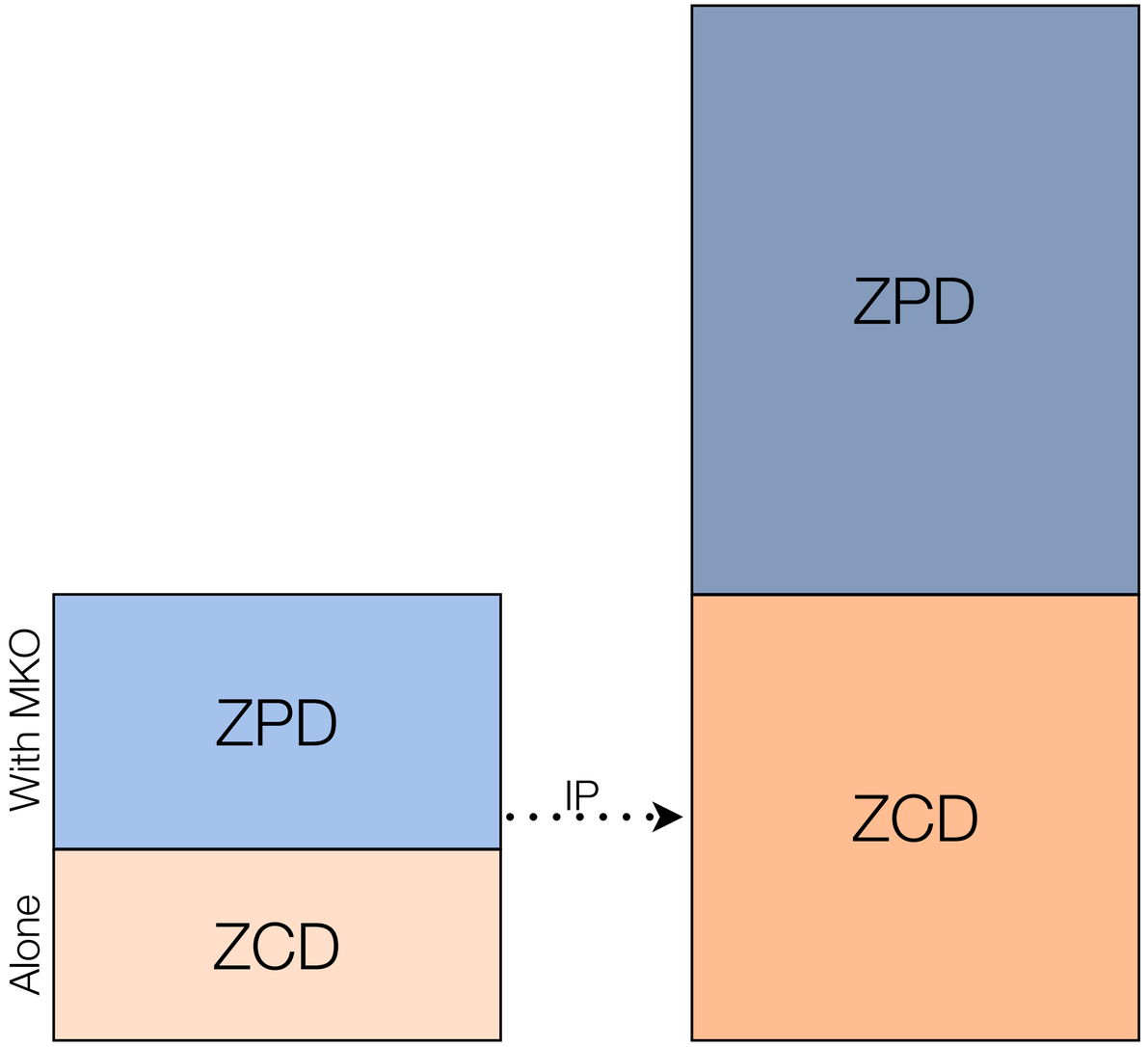


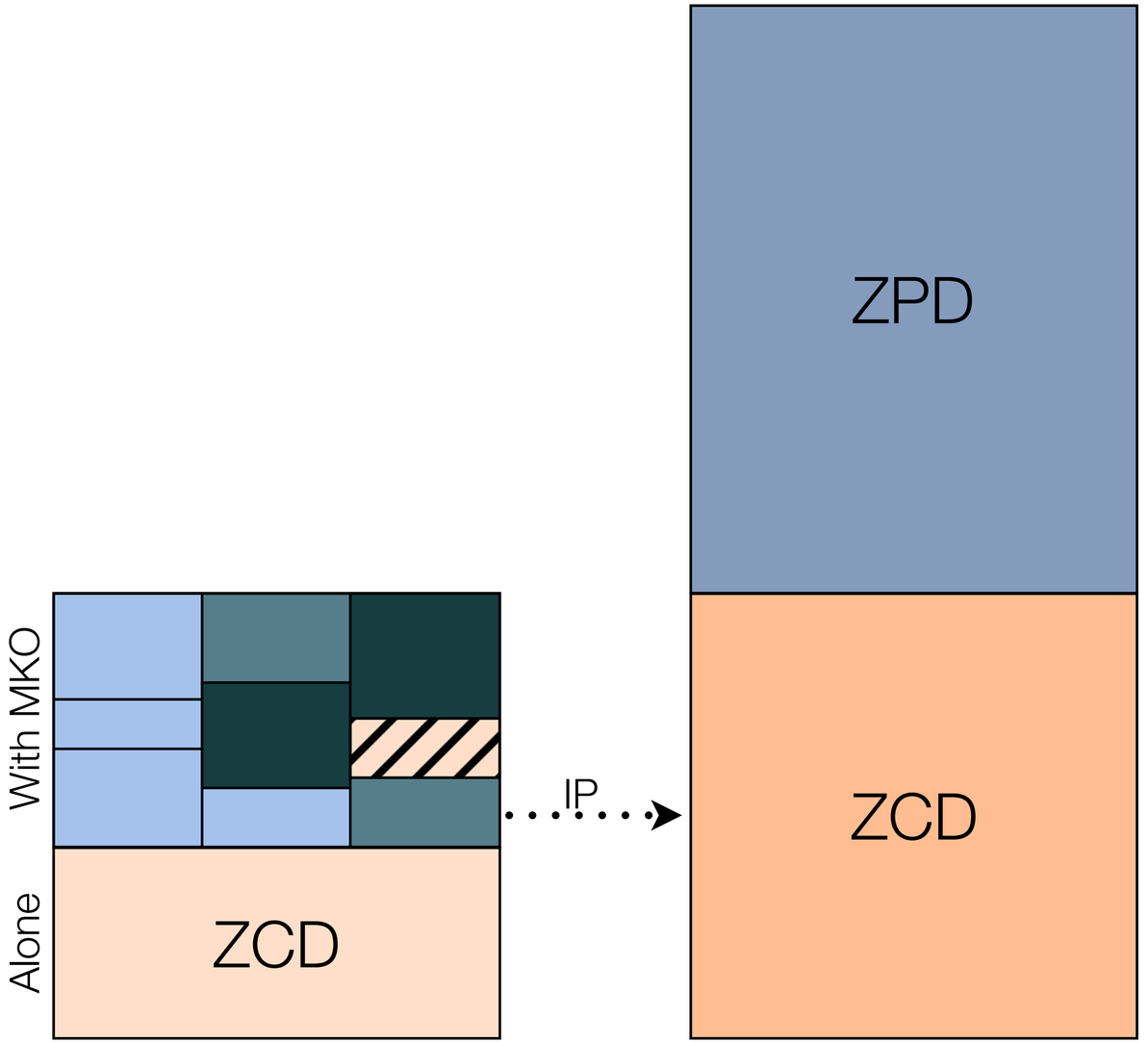
5. The Road to STEAM



- Zone of Proximal Development (ZPD):
  - Region between:
    - what a learner can accomplish independently (the Zone of Current Development, ZCD)
    - what they can accomplish with assistance from a "more knowledgeable other" (MKO)
- *"…what a child can do with assistance today she will be able to do by herself tomorrow."*
- This is an iterative process:
  - The ZCD and ZPD change over time;
  - Independent practice (IP) is required to close the loop.

Lev Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press. (1978)

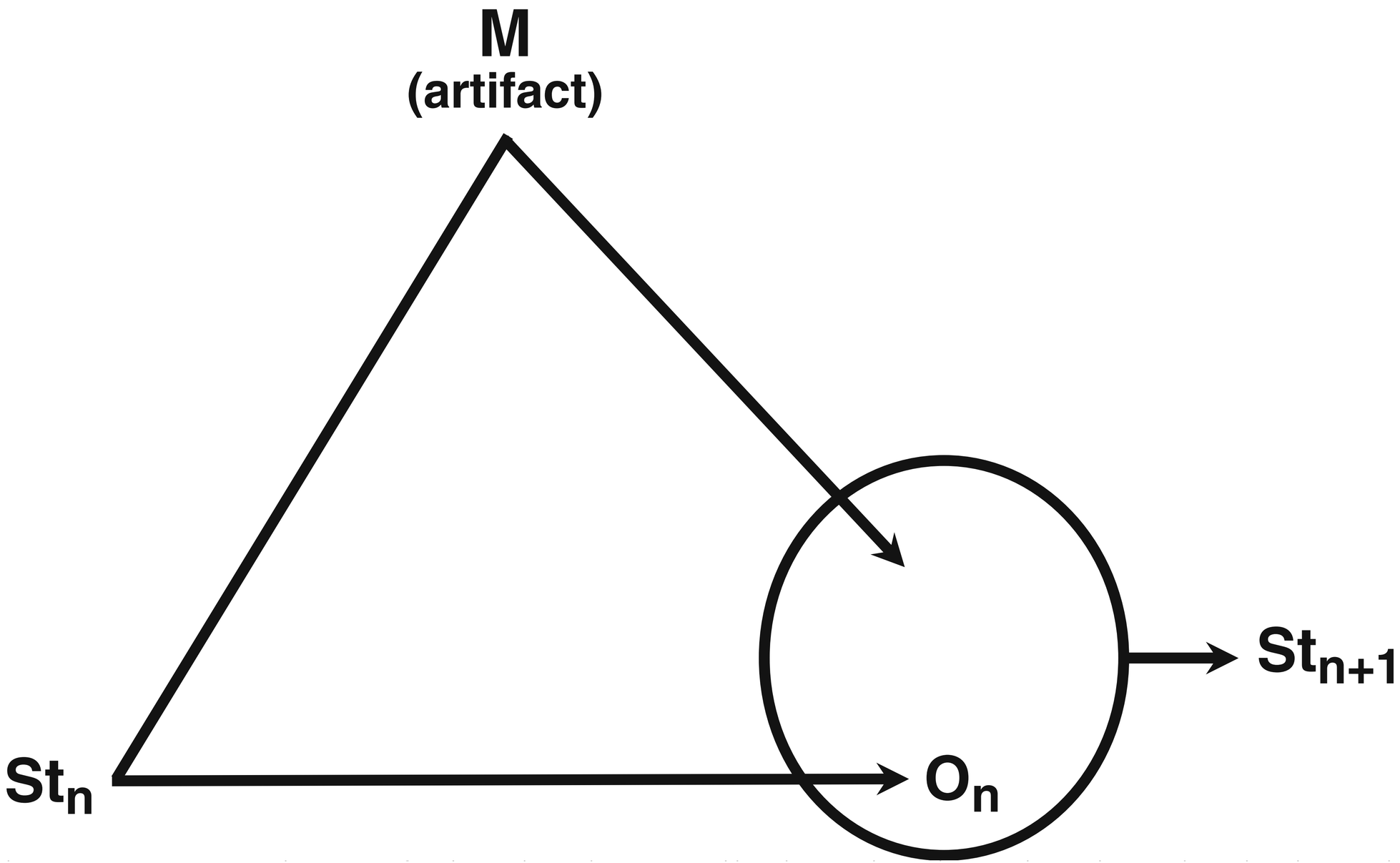

With MKO
ZPD
Alone
ZCD
IP
ZPD
ZCD



Galperin, P.Ia. “Stage by Stage formation as a method of psychological investigation”. *Journal of Russian and East European Psychology, 30*(4), 61-80 (1992)
Van Geert, Paul. "Vygotsky's dynamic systems." *Lev Vygotsky: Critical assessments* 4 (1997): 3-21.
Ann Pendleton-Julian and John Seely Brown. *Pragmatic Imagination: Single from Design Unbound* (2016).

The EdTech Quintet – Associated Practices	
Social	Communication, Collaboration, Sharing
Mobility	Anytime, Anyplace Learning and Creation
Visualization	Making Abstract Concepts Tangible
Storytelling	Knowledge Integration and Transmission
Gaming	Feedback Loops and Formative Assessment

The EdTech Quintet – Associated Practices	
Social	Provides diversity to the ZPD
Mobility	Creates the context for the process
Visualization	Aids in segmenting ZPD, bridging gaps
Storytelling	Aids in the integration of the ZPD
Gaming	Provides frameworks for independent practice



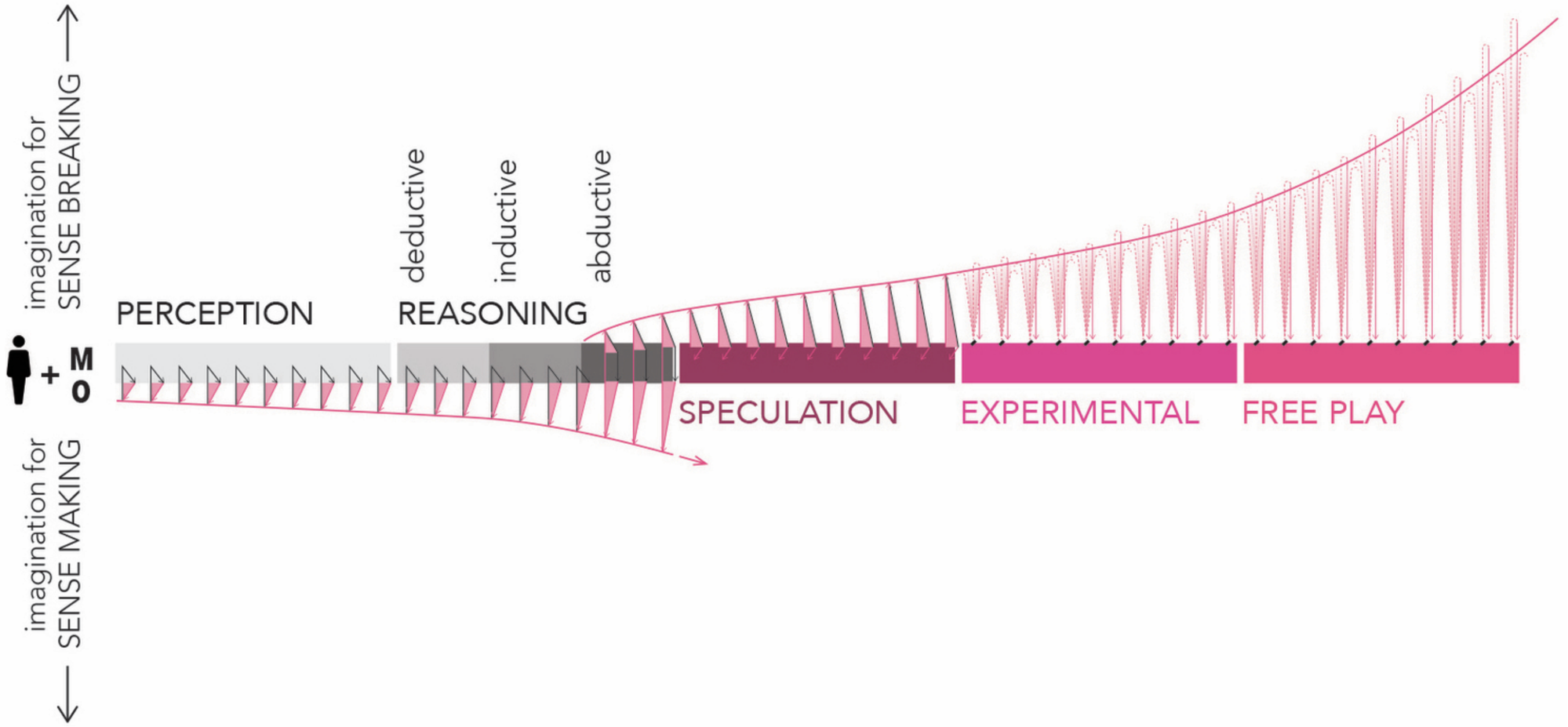
Pelaprat, Etienne, and Michael Cole. ""Minding the gap": Imagination, creativity and human cognition." *Integrative Psychological and Behavioral Science* 45.4 (2011): 397-418.

Ann Pendleton-Jullian & John Seely Brown: The Pragmatic Imagination

- Six Principles:

1. The imagination serves diverse cognitive processes as an entire spectrum of activity.
2. The imagination both resolves and widens the gap between what is unfamiliar and what is known.
3. The Pragmatic Imagination pro-actively imagines the actual in light of meaningful purposeful possibilities.
4. The Pragmatic Imagination sees thought and action as indivisible and reciprocal.
5. The imagination must be instrumentalized to turn ideas into action - the entire spectrum of the imagination.
6. Because the imagination is not under conscious control, we need to understand, find, and design ways to set it in motion and scaffold it for play and purpose.

Ann Pendleton-Jullian & John Seely Brown, *Pragmatic Imagination: Single from Design Unbound*. Blurb (2016)


imagination for
SENSE BREAKING
imagination for
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PERCEPTION
REASONING
deductive
inductive
abductive
SPECULATION
EXPERIMENTAL
FREE PLAY

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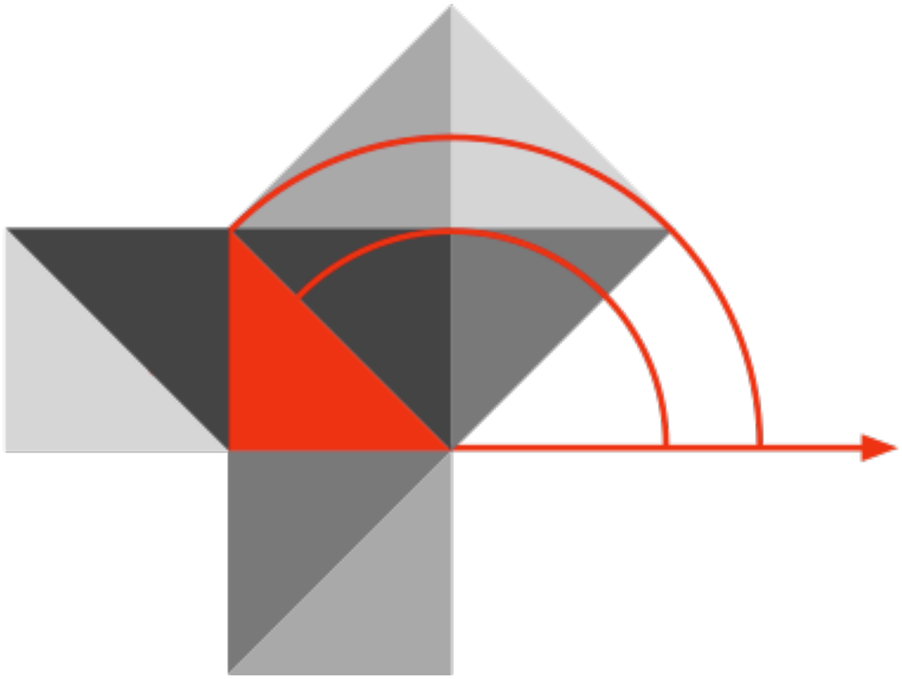

Blog: http://hippasus.com/blog/
Email: rubenrp@hippasus.com
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