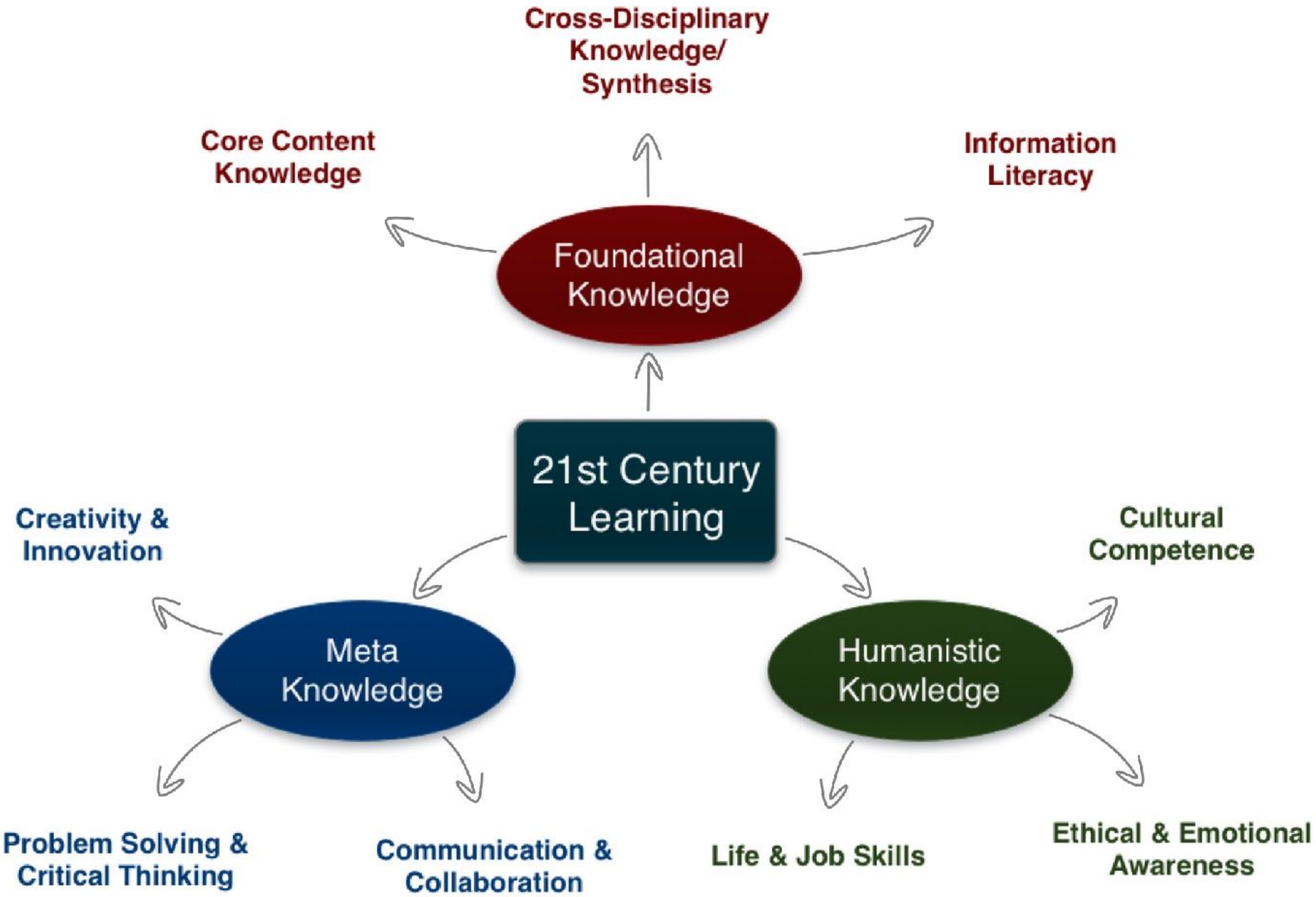
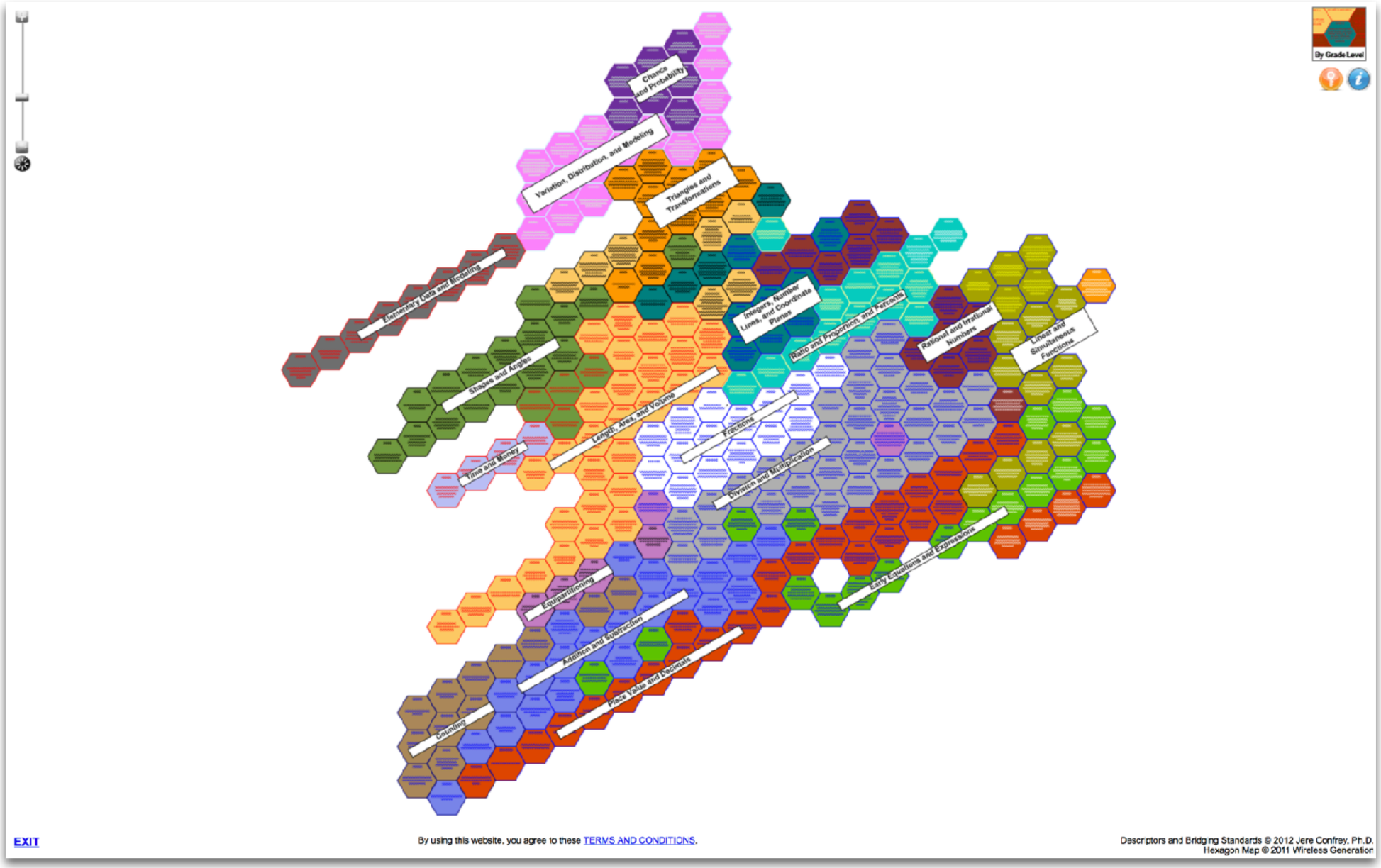
STEM and Learning, in the Context of SAMR and the EdTech Quintet

Ruben R. Puentedura, Ph.D.



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)


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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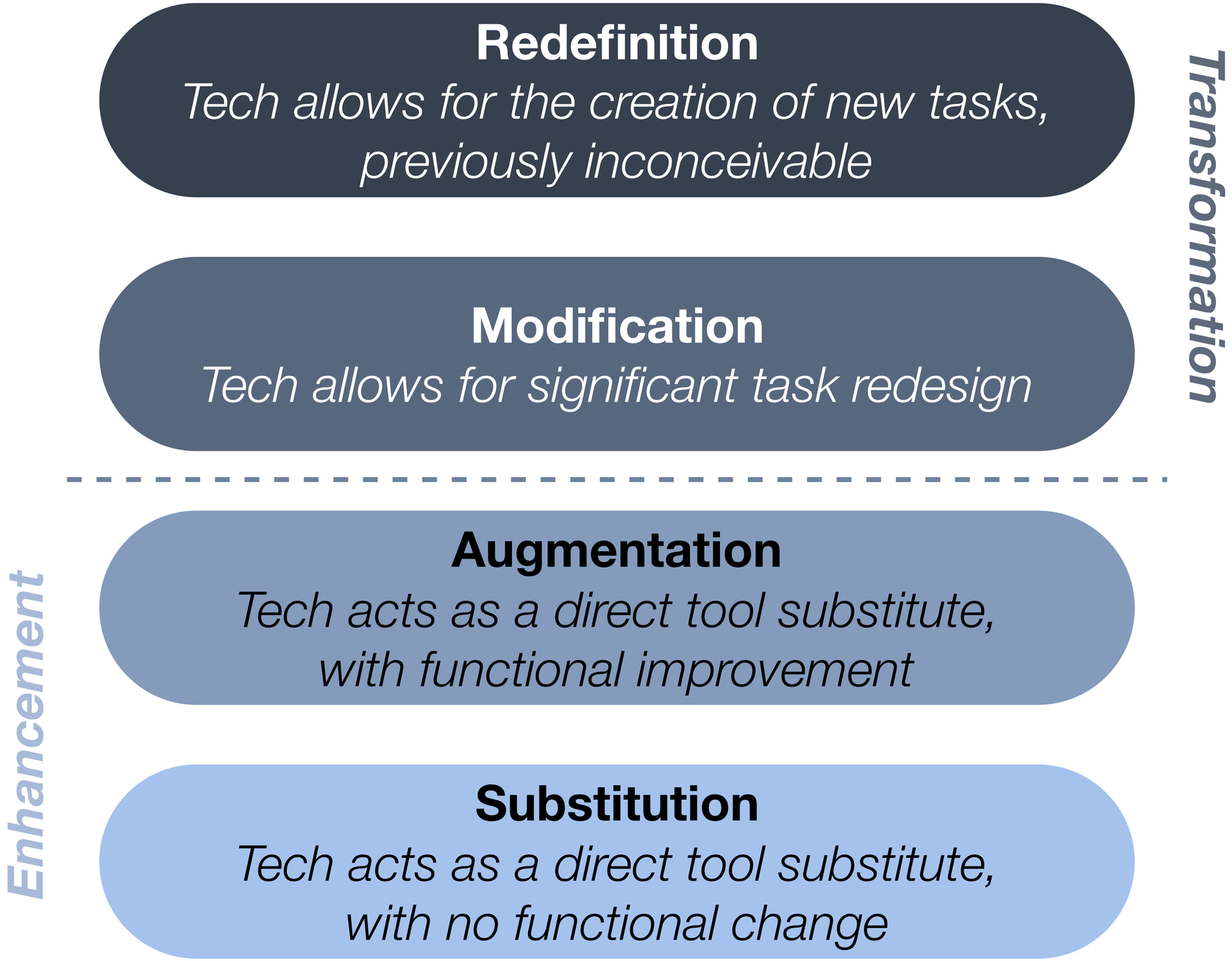
Descriptors and Bridging Standards © 2012 Jere Confrey, Ph.D.
Hexagon Map © 2011 Wireless Generation

	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

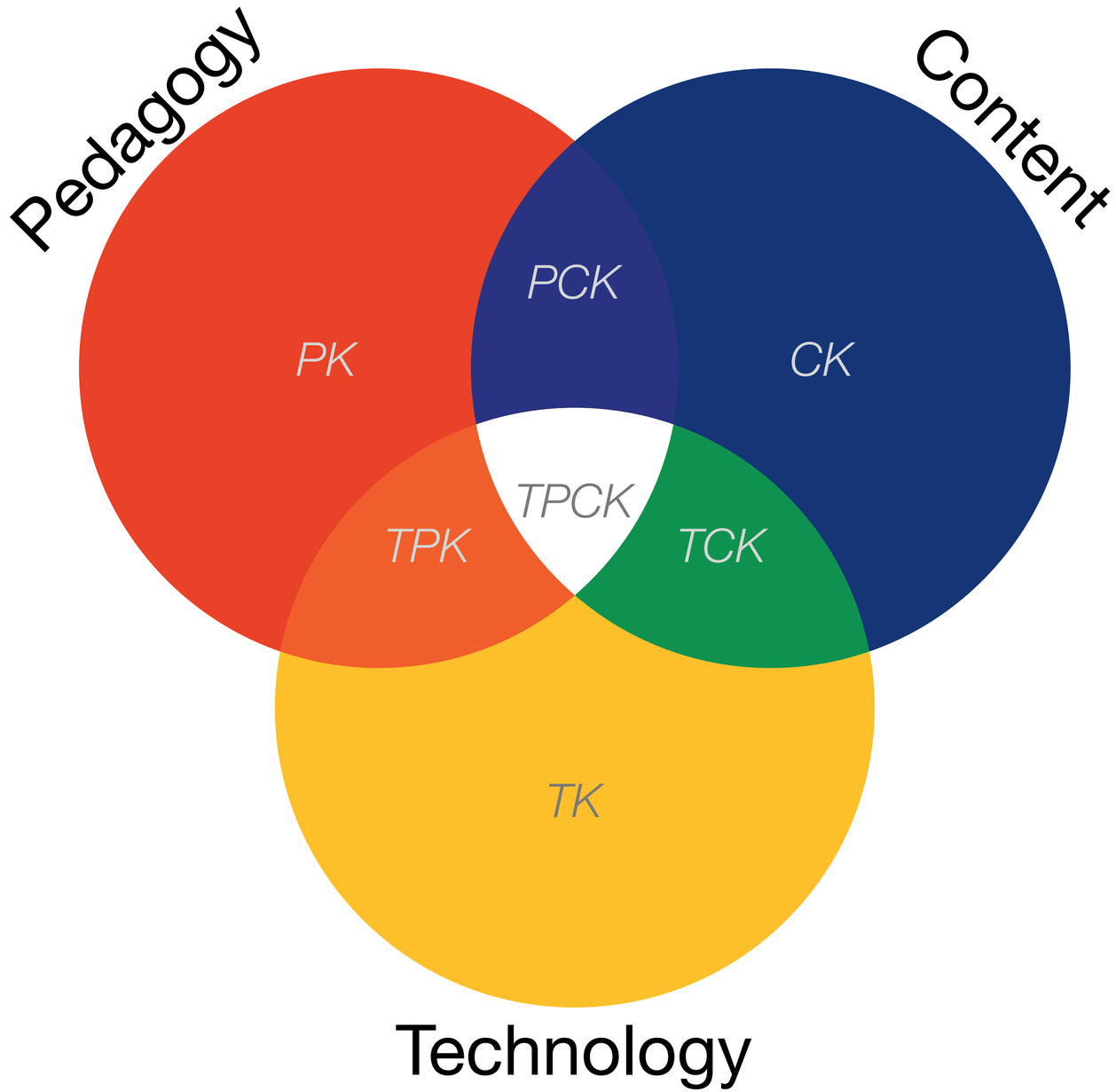
ITEA Standards for Technological Literacy

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



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



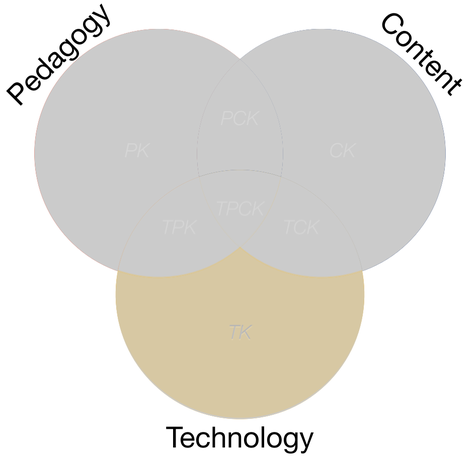
Punya Mishra & Matthew J. Koehler, “Technological pedagogical content knowledge: A framework for teacher knowledge”. *Teachers College Record, 108*(6). (2006)

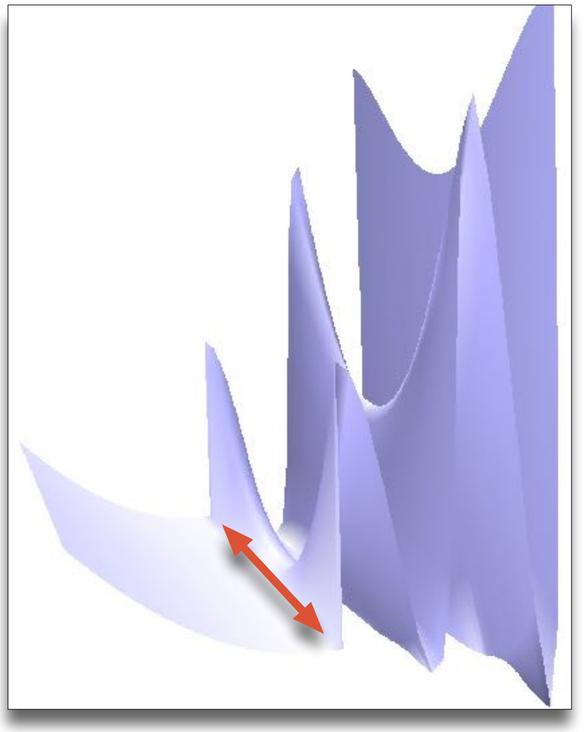
Redefinition
Tech allows for the creation of new tasks, previously inconceivable

Modification
Tech allows for significant task redesign

Augmentation
Tech acts as a direct tool substitute, with functional improvement

Substitution
Tech acts as a direct tool substitute, with no functional change





Direct Use

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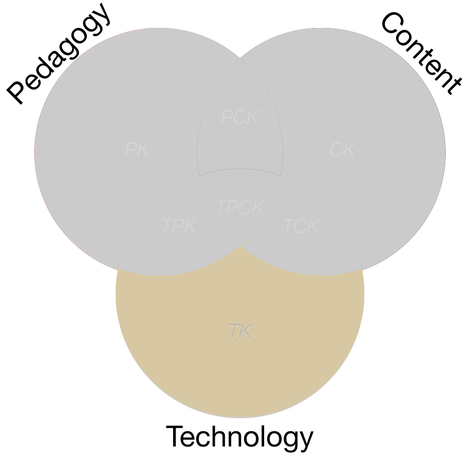

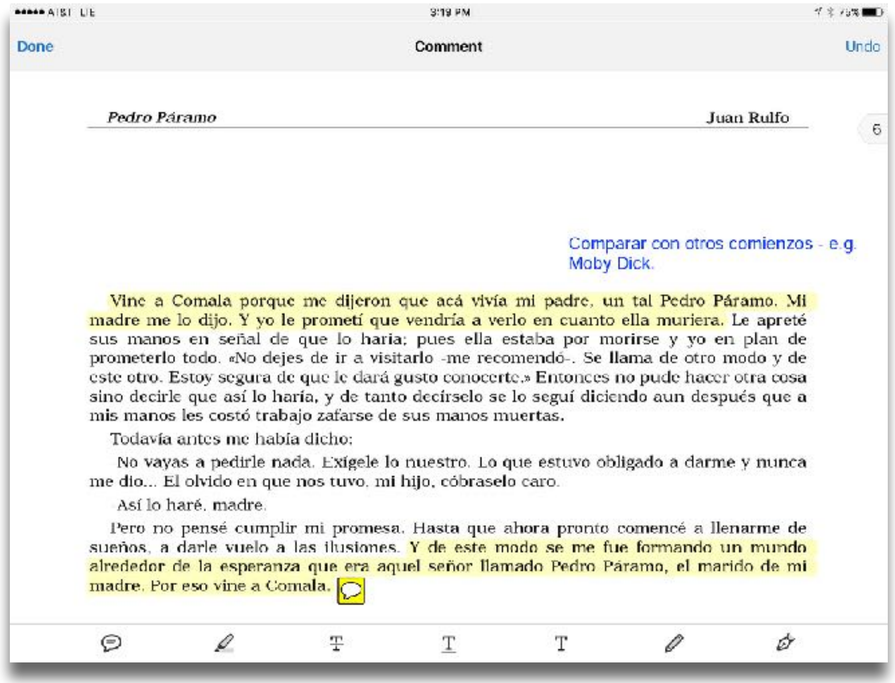

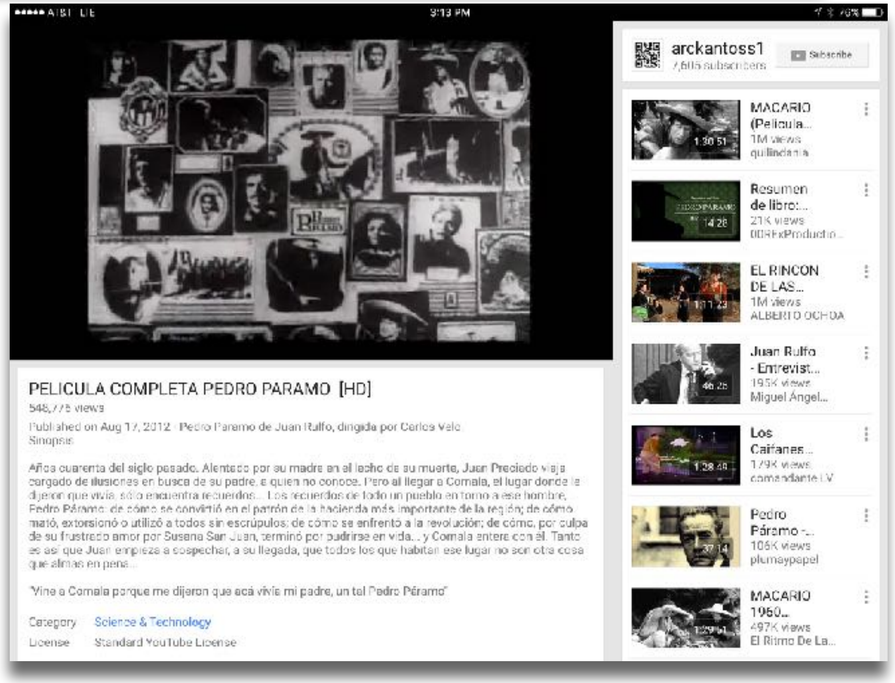

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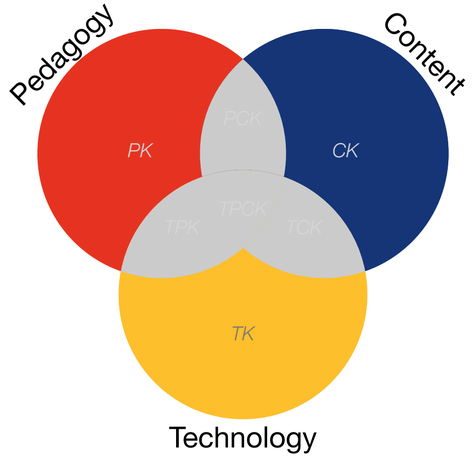

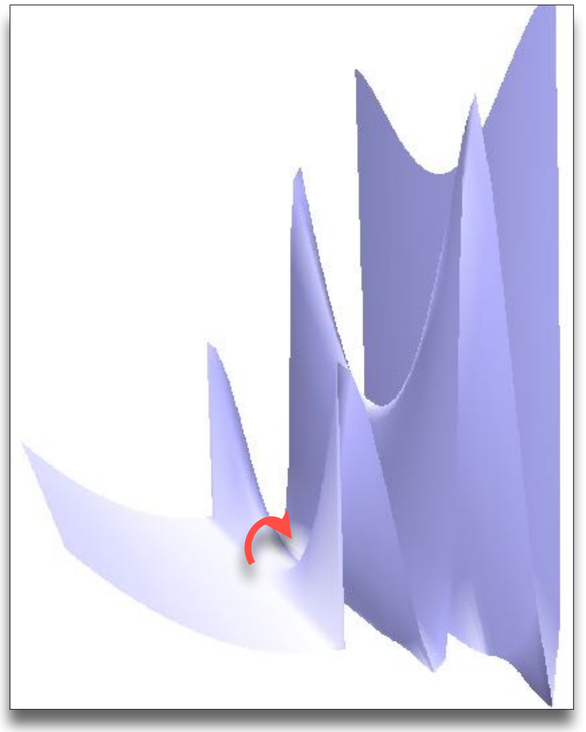

Direct Observation

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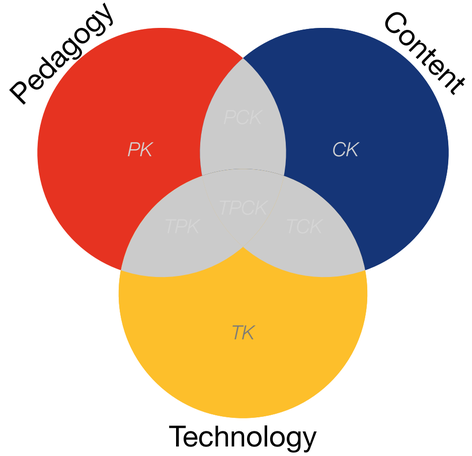

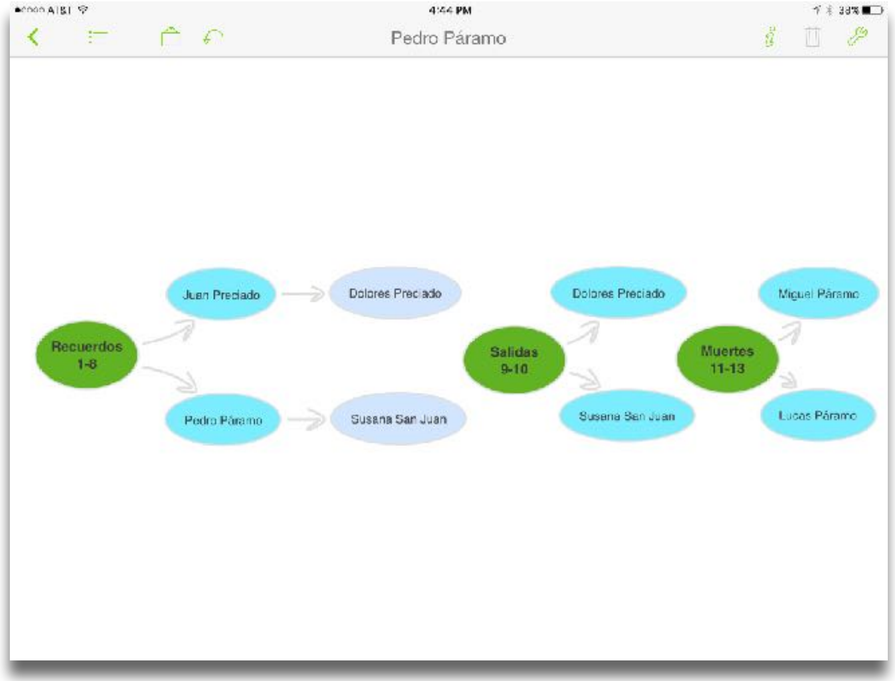

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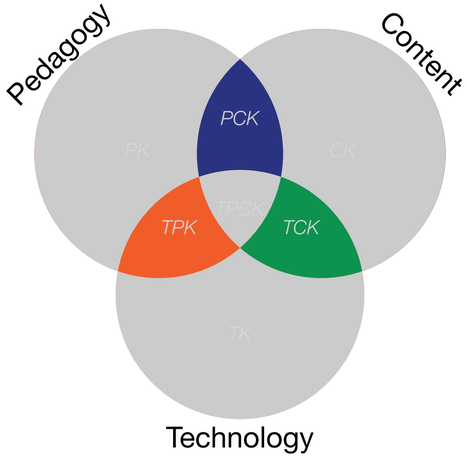

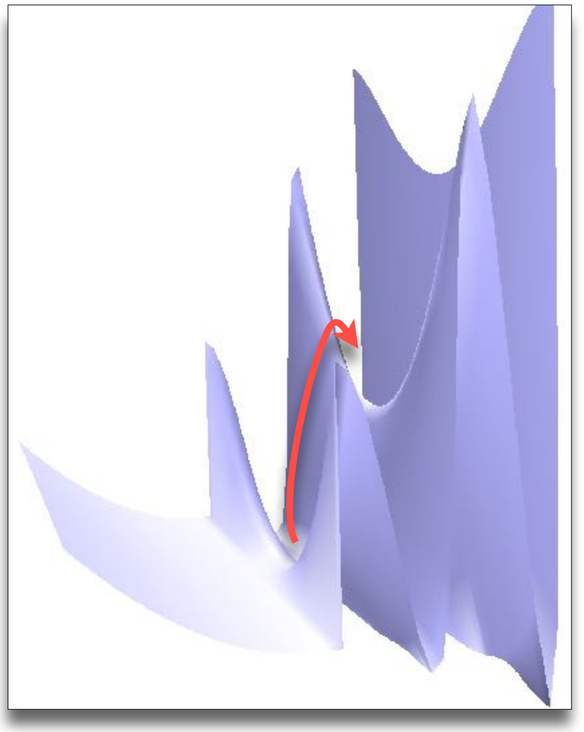

Pattern Recognition

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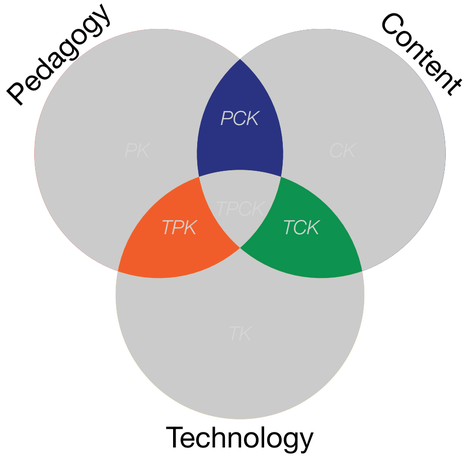

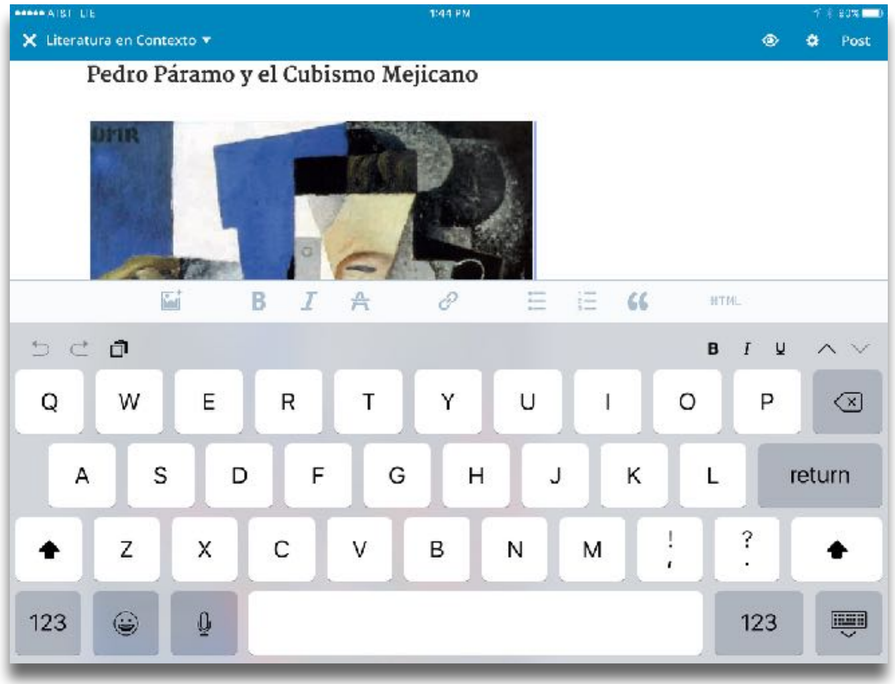

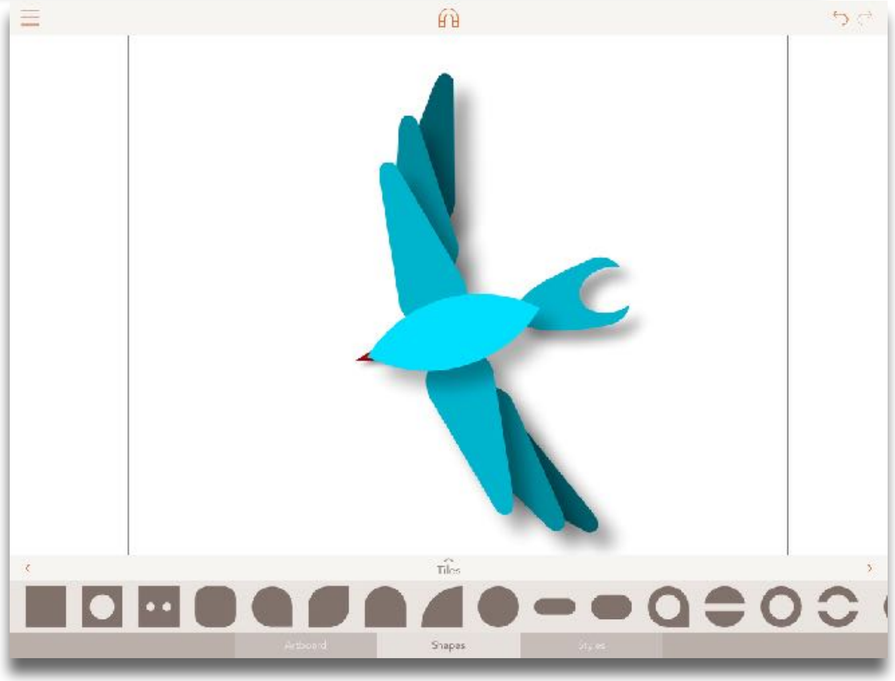

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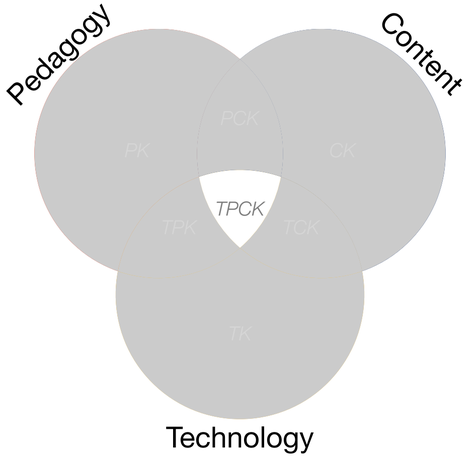

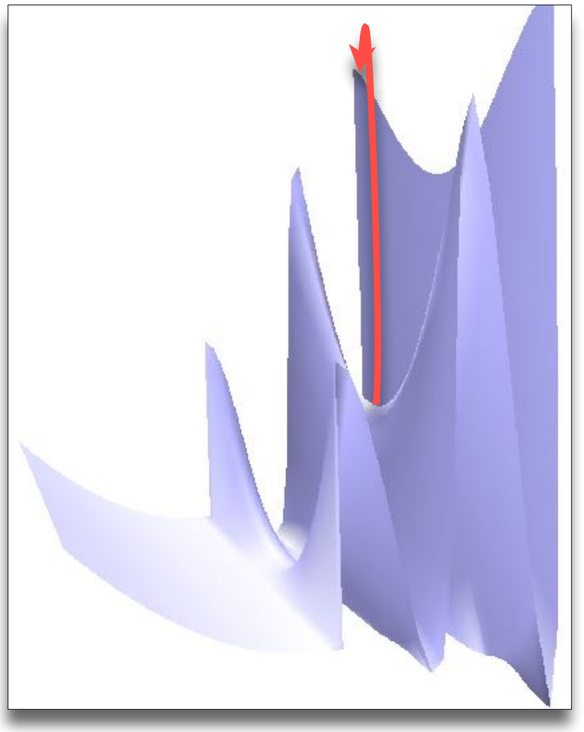

Pattern Synthesis

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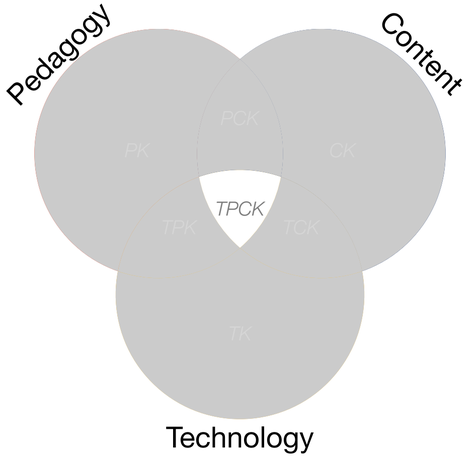
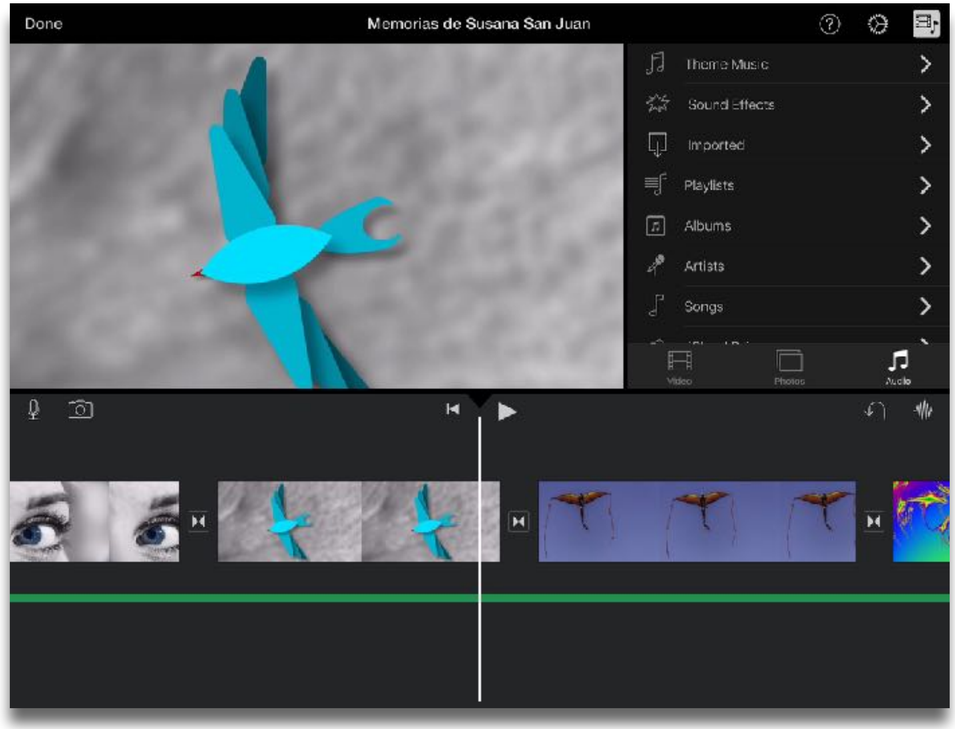




Social	Mobility	Visualization	Storytelling	Gaming
200,000 years	70,000 years	40,000 years	17,000 years	8,000 years

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

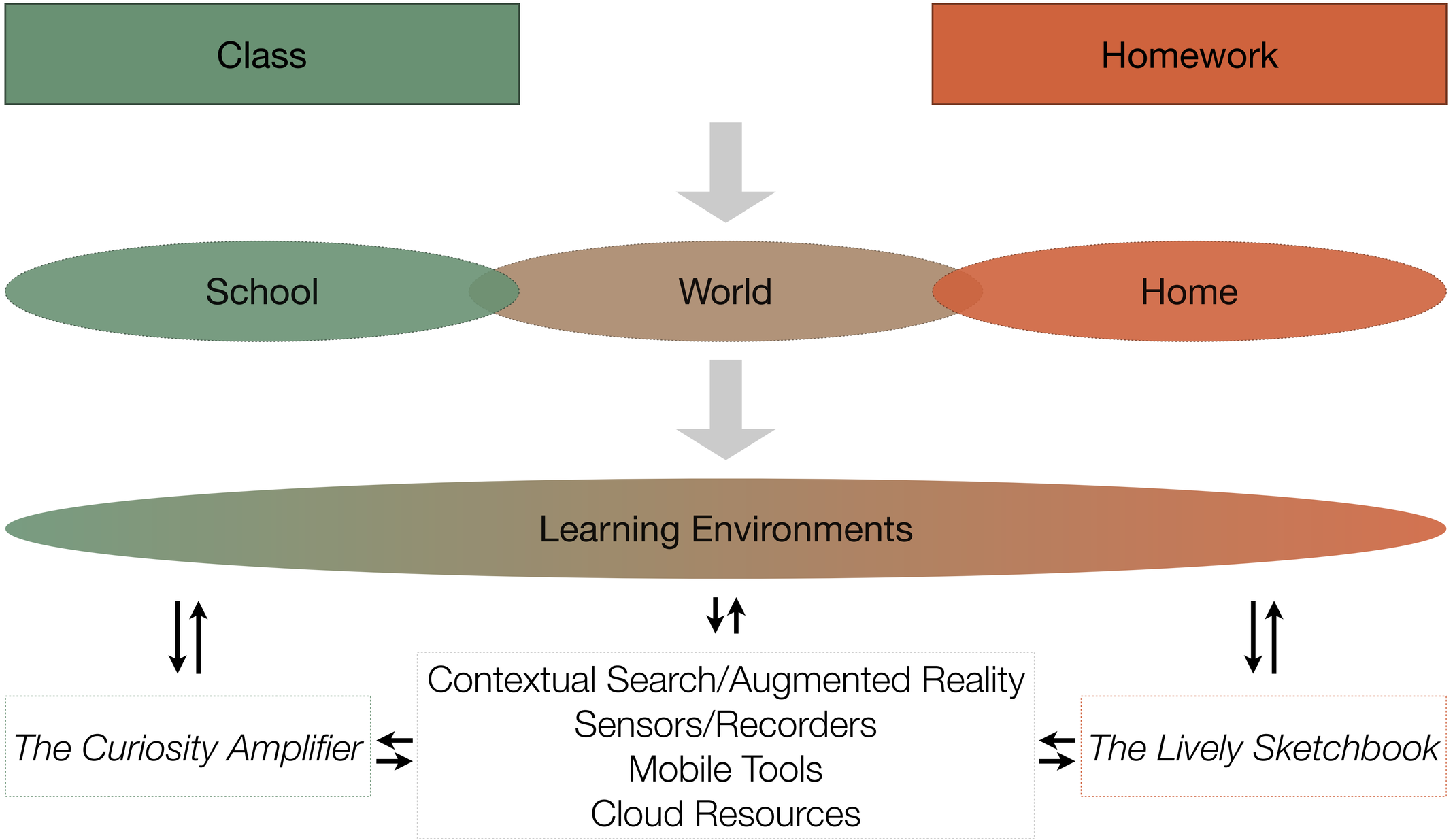
Blogging

Wikis

Telepresence

File Sharing

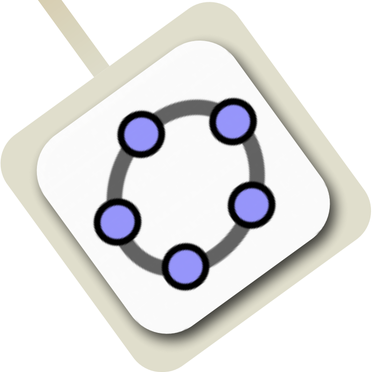
Mobility



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

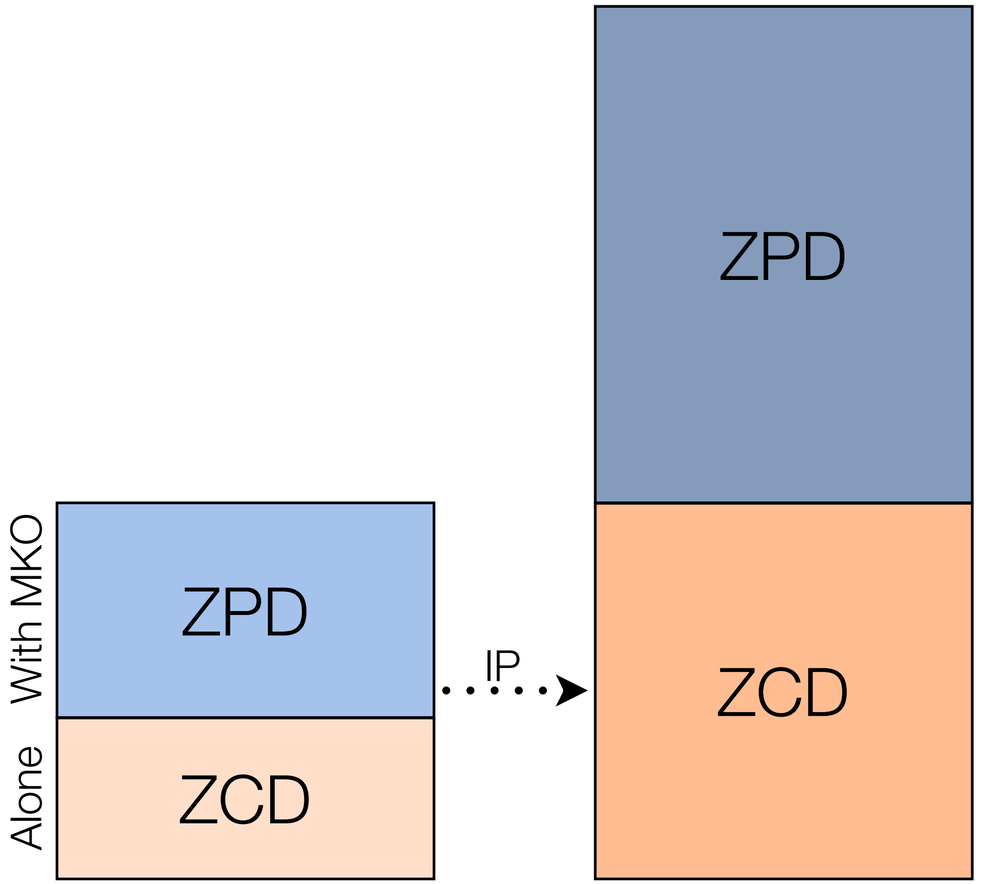
CONNECTION

SOCIAL

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

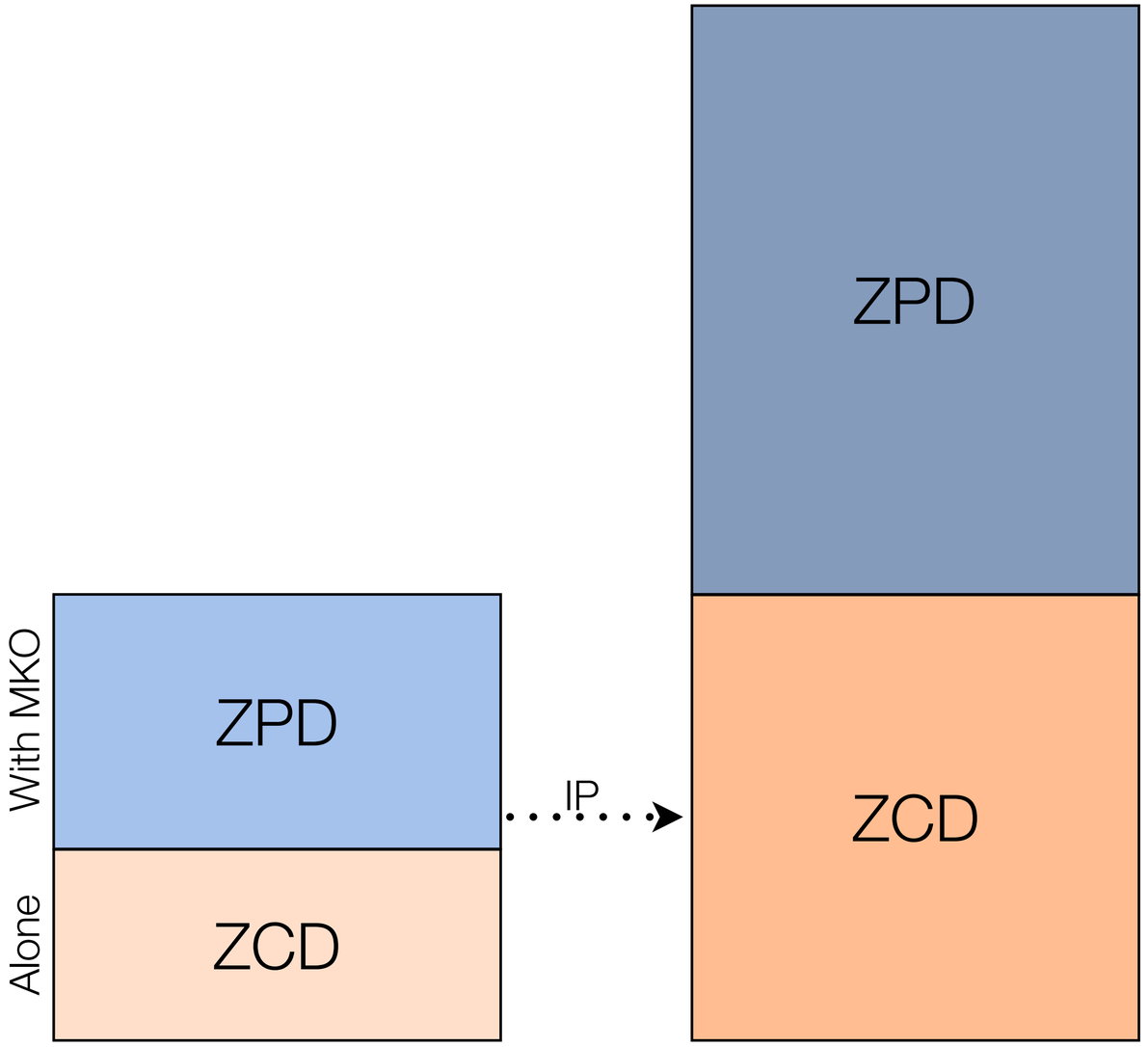
"A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome."

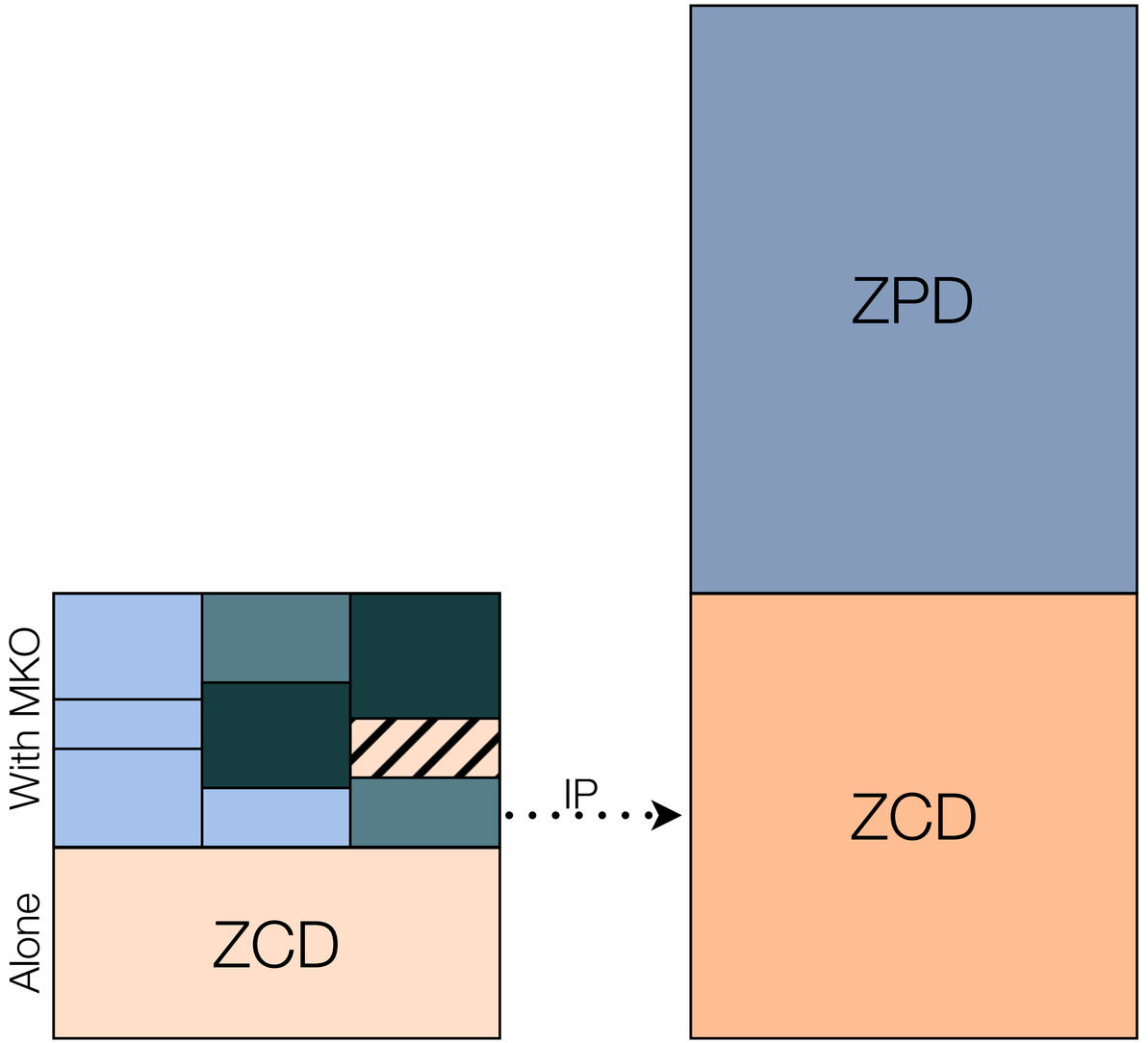
Katie Salen and Eric Zimmerman. *Rules of Play: Game Design Fundamentals*. The MIT Press, 2003.



- 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

Some Core Shared Practices

- Checklists
- Augmented Note Taking Strategies
- Visualization Methods (5 Primary Domains)
- Simple Blogging
- Simple Digital Storytelling Video
- Flipped Classroom – Materials Creation
- Flipped Classroom – Peer Discussion/Instruction Methods
- Simple Interactive Fiction
- LMS Practices

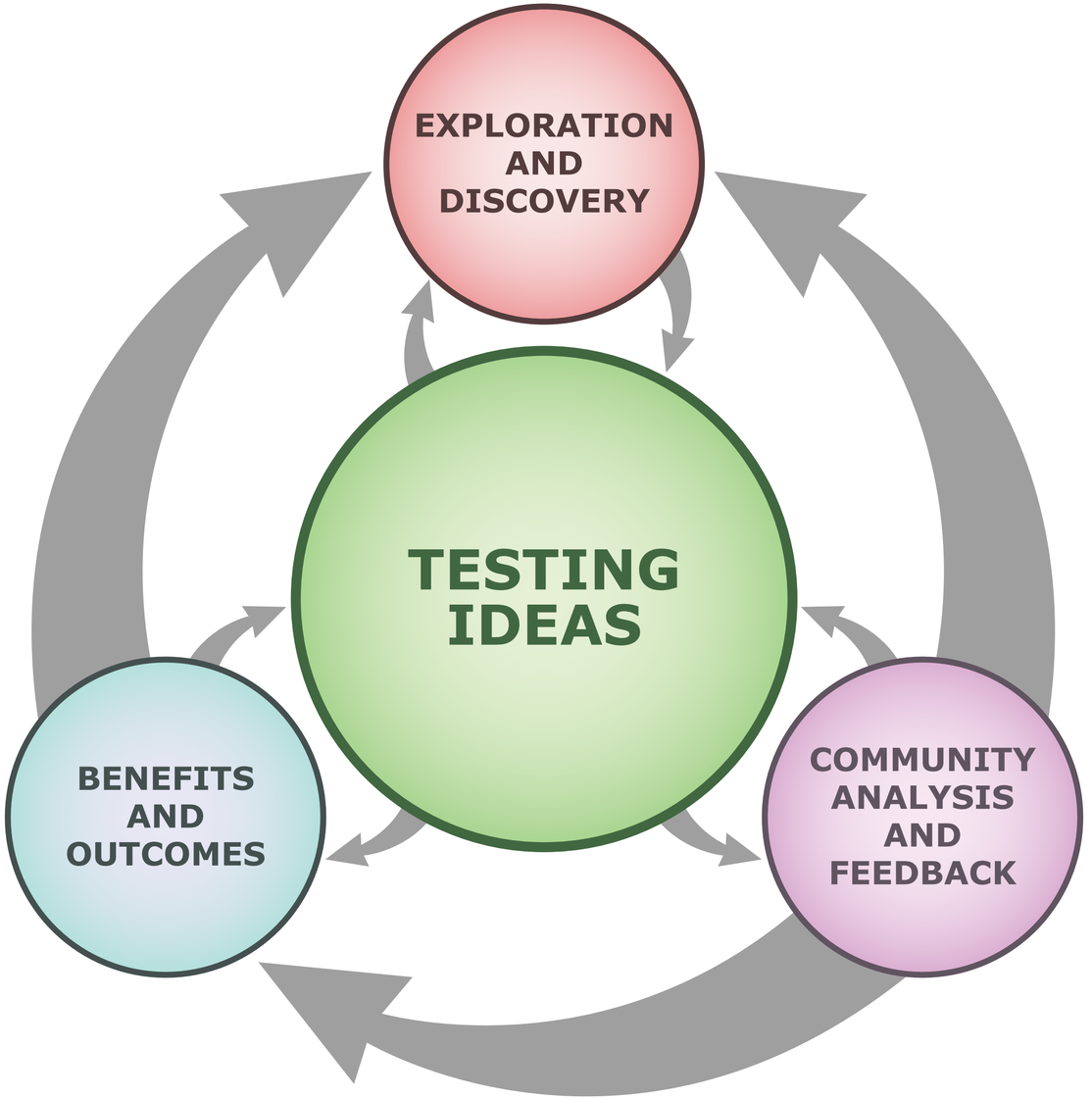
Defining a STEM Framework:
Three Questions

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.

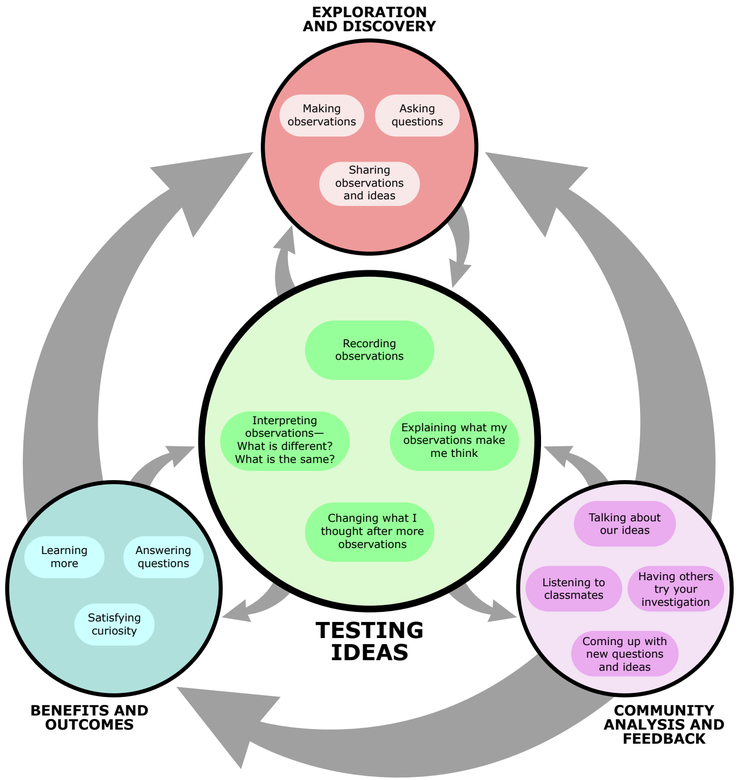
3. What are the key sense-making narratives that select and define linkages between the components of STEM and their respective narratives?
   - Use SAMR/ETQ to clarify STEM narratives, and to scaffold and define integration processes.

Understanding Science: How Science Works

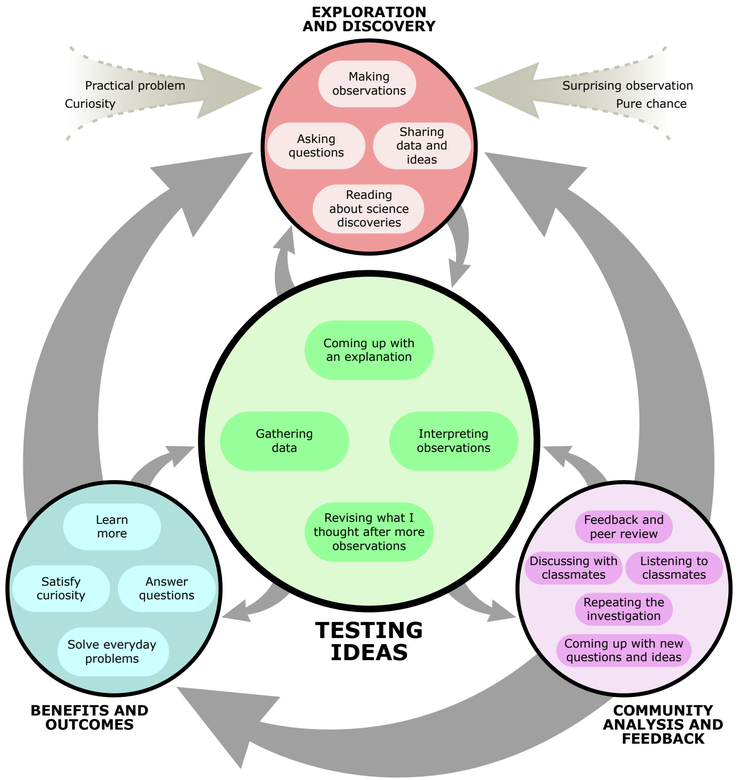


Understanding Science. 2017. University of California Museum of Paleontology. 3 January 2017 <http://www.understandingscience.org>

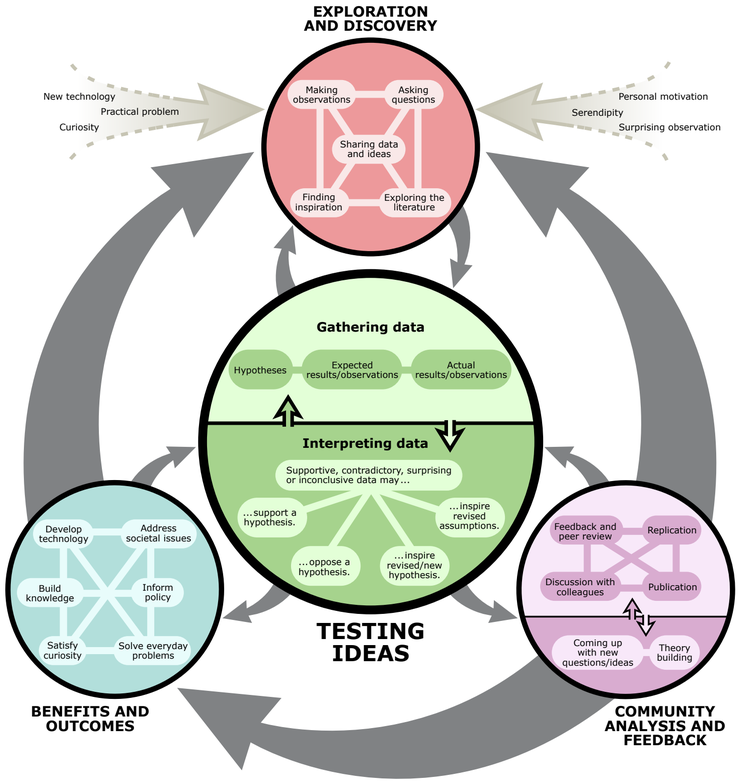
Understanding Science: How Science Works



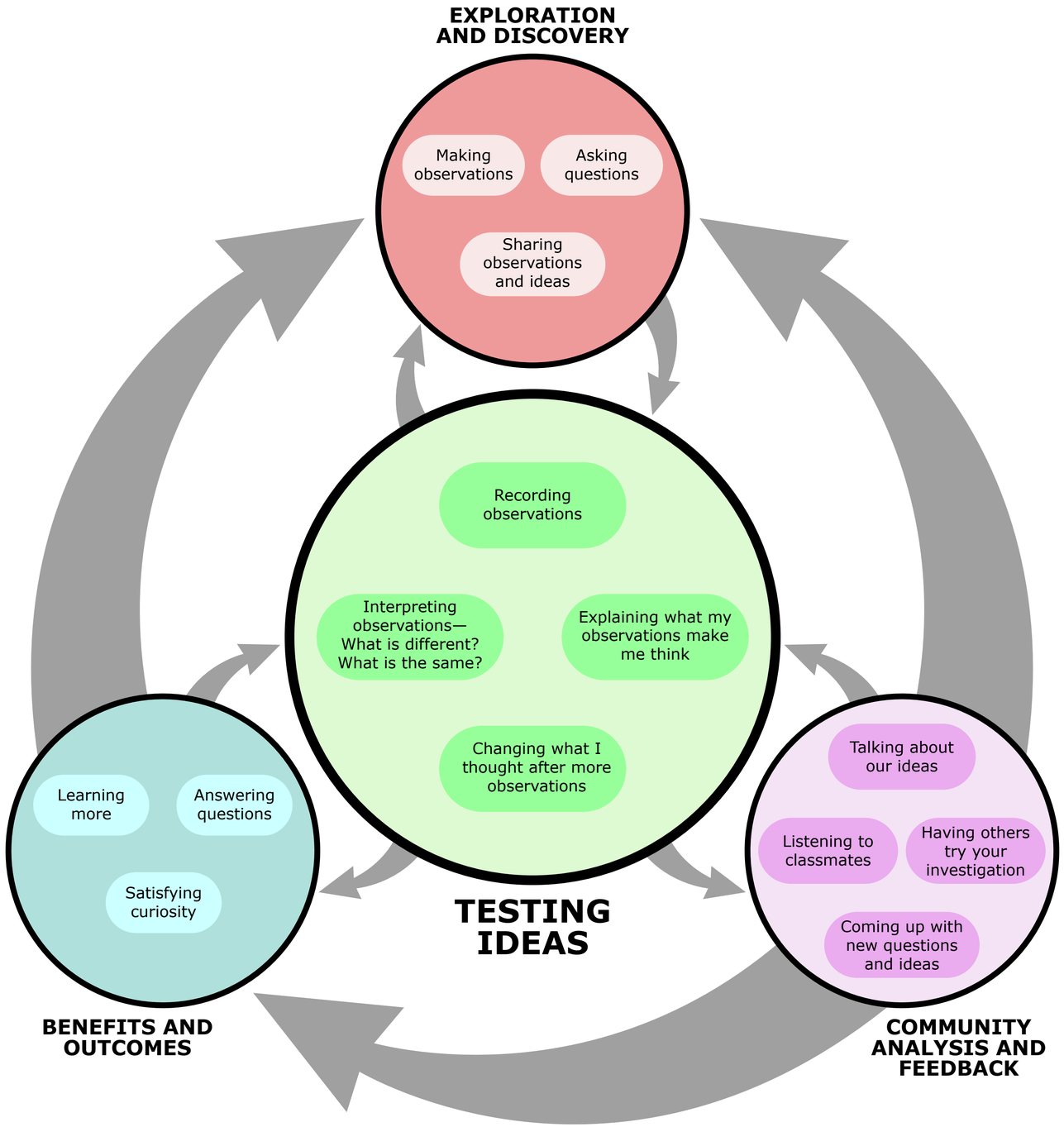
K–2

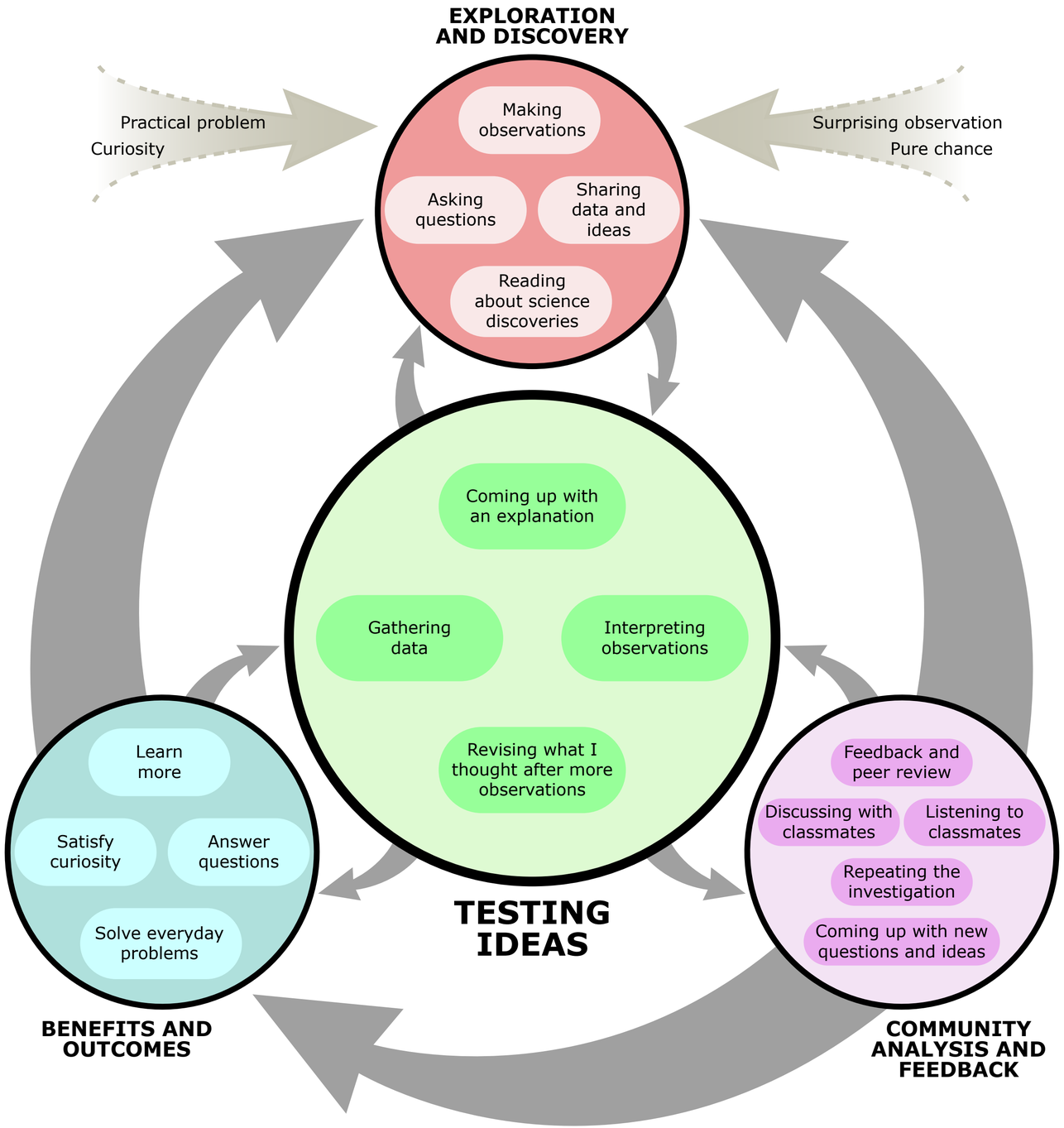


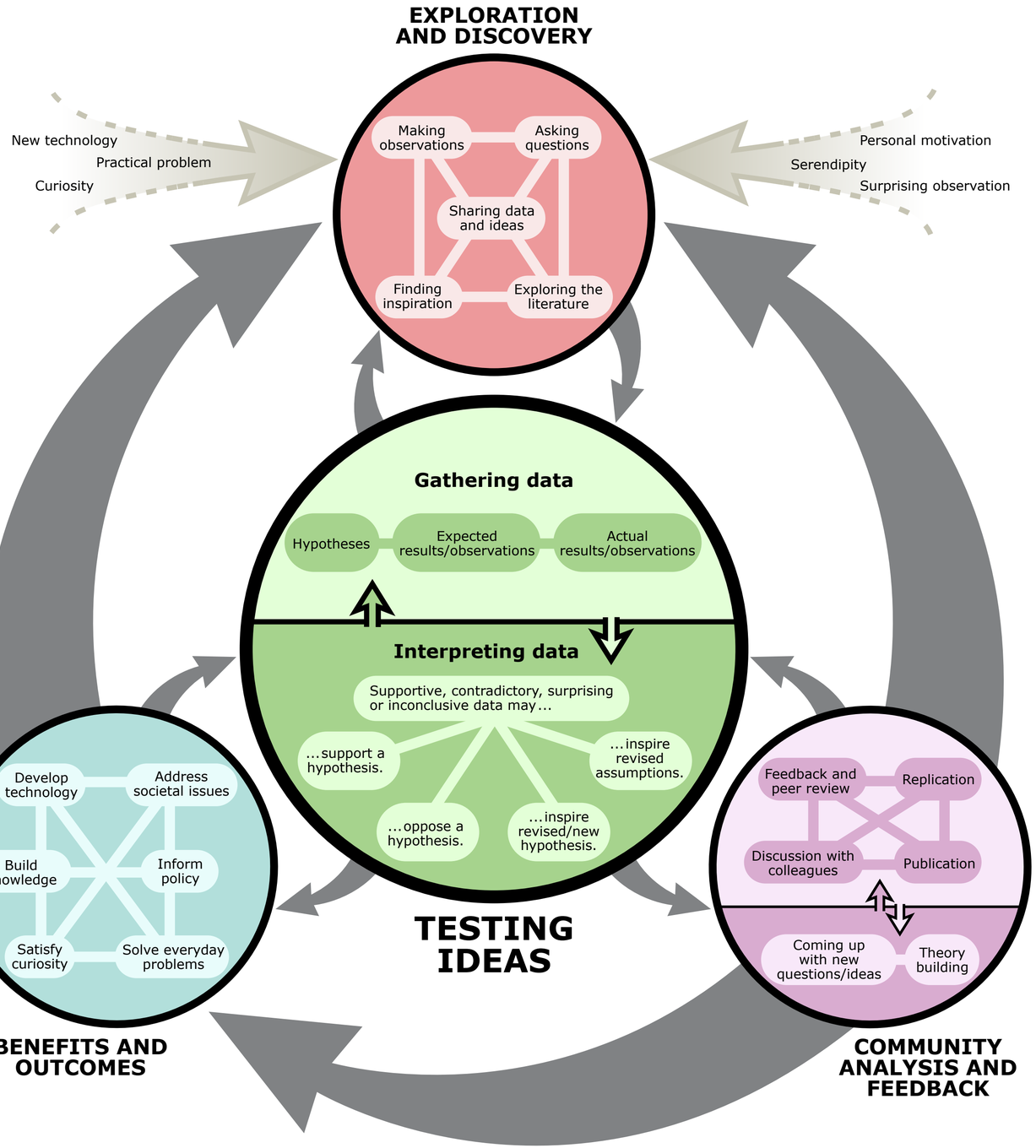
3–5



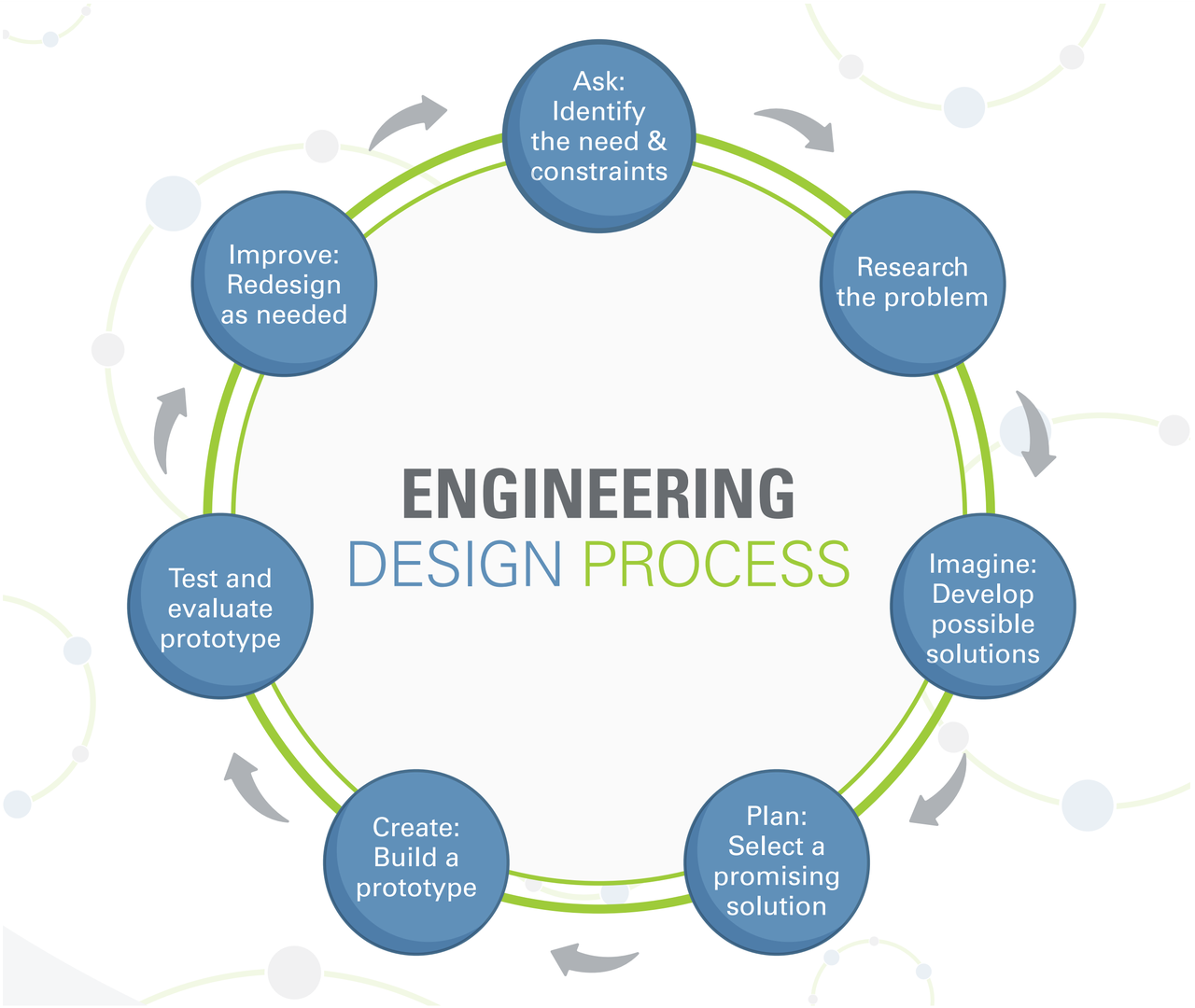
6–16


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

The Engineering Design Process



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

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.

Black and Wiliam: Defining Formative Assessment

"Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited."

Black, P. and Wiliam D. "Developing the theory of formative assessment." *Educational Assessment, Evaluation and Accountability*. 21:5-31 (2009)

Wiliam: A Framework for Formative Assessment

	Where the learner is going	Where the learner is right now	How to get there
Teacher	1 Clarifying learning intentions and criteria for success	2 Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding	3 Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions and criteria for success	4 Activating students as instructional resources for one another	
Learner	Understanding learning intentions and criteria for success	5 Activating students as the owners of their own learning	

Dylan Wiliam, *Embedded Formative Assessment*. Solution Tree (2011)

Rubric Example #1: A Classical Rubric for Concept Maps (M. Besterfield-Sacre et al., 2004)

	1	*2*	*3*
Comprehensiveness – covering completely/broadly	The map lacks subject definition; the knowledge is very simple and/or limited. Limited breadth of concepts (i.e. minimal coverage of coursework, little or no mention of employment, and/or lifelong learning). The map barely covers some of the qualities of the subject area.	The map has adequate subject definition but knowledge is limited in some areas (i.e., much of the coursework is mentioned but one or two of the main aspects are missing). Map suggests a somewhat narrow understanding of the subject matter.	The map completely defines the subject area. The content lacks no more than one extension area (i.e., most of the relevant extension areas including lifelong learning, employment, people, etc. are mentioned).
Organization – to arrange by systematic planning and united effort	The map is arranged with concepts only linearly connected. There are few (or no) connections within/between the branches. Concepts are not well integrated.	The map has adequate organization with some within/between branch connections. Some, but not complete, integration of branches is apparent. A few feedback loops may exist.	The map is well organized with concept integration and the use of feedback loops. Sophisticated branch structure and connectivity.
Correctness - conforming to or agreeing with fact, logic, or known truth	The map is naïve and contains misconceptions about the subject area; inappropriate words or terms are used. The map documents an inaccurate understanding of certain subject matter.	The map has few subject matter inaccuracies; most links are correct. There may be a few spelling and grammatical errors.	The map integrates concepts properly and reflects an accurate understanding of subject matter meaning little or no misconceptions, spelling/grammatical errors.

Table 4. Concept Map scoring rubric (Understanding of Engineering Field).

Besterfield-Sacre, Mary, et al. "Scoring concept maps: An integrated rubric for assessing engineering education." *Journal of Engineering Education* 93.2 (2004): 105-115.

Rubric Example #2: A Rubric for Sociology Online Discussion (S. Evans, 2010)

	4 Points	**2 Point**	**0 Points**
Content	You show that you can apply or extend the idea you are discussing.	Some of your messages analyze, interpret, or apply the material well, but some do not. This might either be because the analysis was not done well, or because it was not attempted (that is, was simply opinion or hearsay).	Your messages generally show little evidence of analysis, consisting instead of opinion, feelings and impressions.
Accuracy	You accurately represent the concepts discussed.	You generally represent the concepts accurately, but you do not do so in all cases.	You have significant issues with regard to accurately representing the concepts.
Use of material	You use and cite sources, including the text and articles and/or bring in an outside source, all of which clearly add *significantly* to the discussion.	You clearly refer back to a definition, example or concept from the reading or lecture.	You do not bring in or refer to any material from the text, outside sources, or lectures.
Sociological Analysis	You focus on the sociological implications of the issue at hand (e.g., social meaning, the outcomes for society or groups, the social function served).	You touch on some sociological issues, but focus also on individual ones.	You focus primarily on individual issues.
	2 Points	**1 Point**	**0 Points**
Responses	You extend or politely question the post of another person in a way that advances the discussion.	You add new examples that continue the idea created by another person.	Your responses are primarily agreement.
Participation	You write at least three or more substantive comments (using the above criteria) based on the discussion assigned.		You write fewer than three substantive comments.
Time of Posting	Your posts are spread widely during the discussion.	You post at two significantly different times.	Your posts are clustered within a short period of time.
Posts Read	You have read at least 75% of the posts in the discussion.	You read at least 50% of the posts in the discussion.	You read less than 50% of the posts in the discussion.
Clarity	You use standard grammar and spelling and your meaning is clear.	Your posts have some grammar or spelling mistakes or your meaning is not entirely clear.	Your posts have significant grammar or spelling mistakes or your meaning is not clear.

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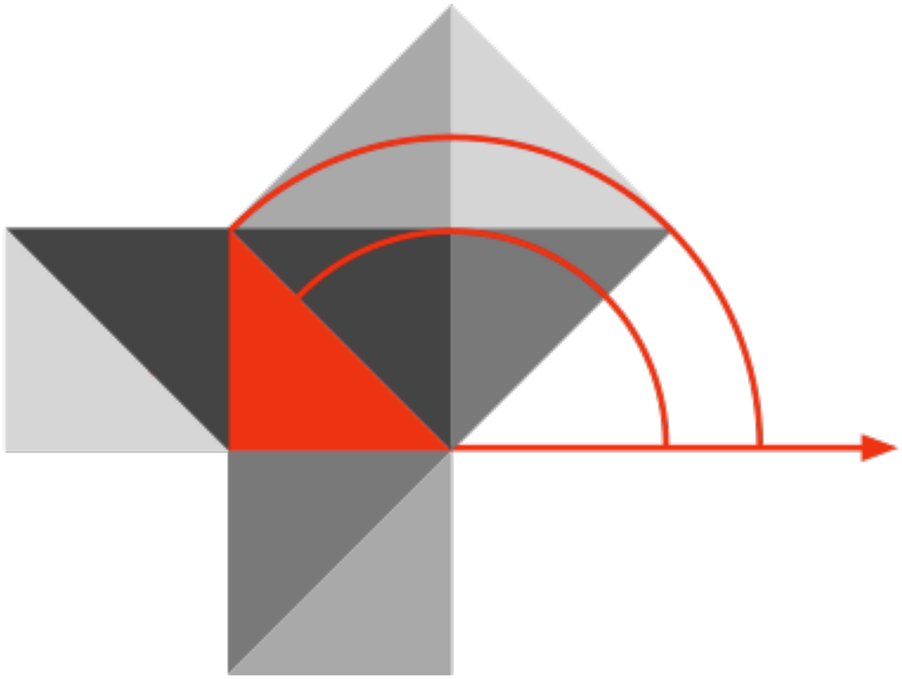

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