

Spatial Thinking and Problem-based Learning

Stacy Rebich

Department of Geography
UCSB

Fiona Goodchild

California NanoSystems Institute
UCSB

Spatial Analysis in the Social Science Curriculum:
Enhancing Undergraduate Learning

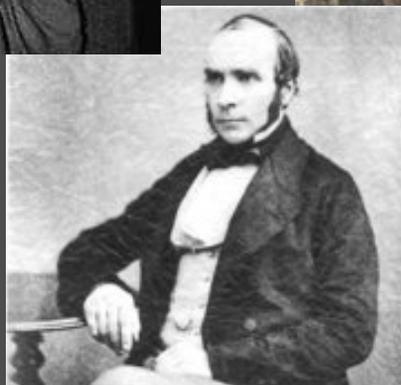
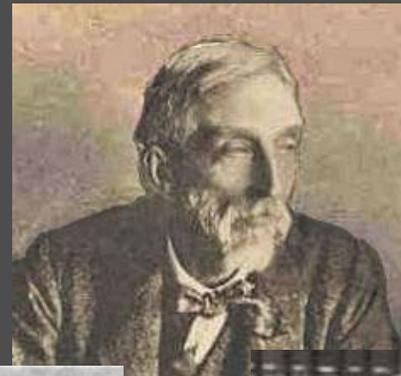
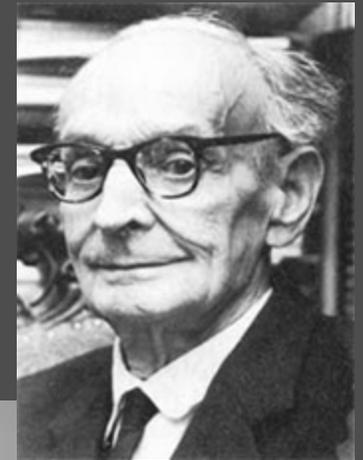
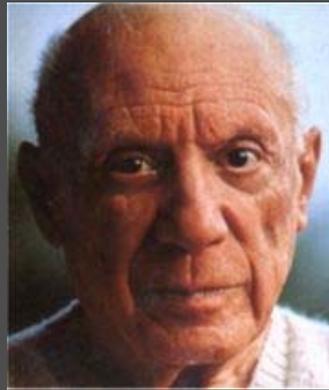
Center for Spatially Integrated Social Science
UCSB Department of Geography
Institute for Social, Behavioral, and Economic Research

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Spatial Thinkers in Social Science

- Who would you consider to be the great spatial thinkers in your field?
 - historical?
 - contemporary?
- What discoveries or insights have they contributed as a result of thinking spatially?

Spatial Thinkers

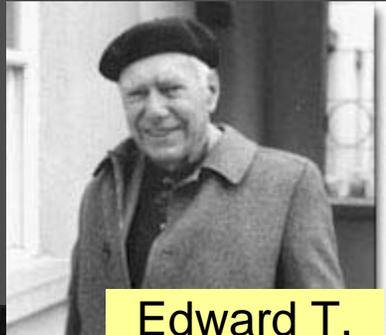


2006 SPACE workshop, Santa Barbara

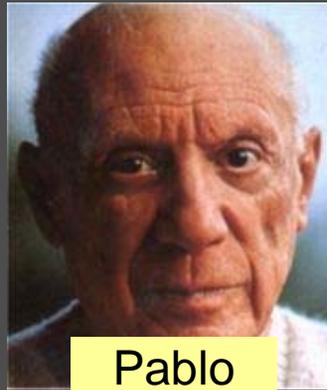
Spatial Thinkers



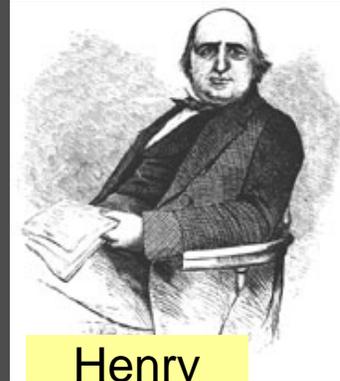
Florence
Kelley



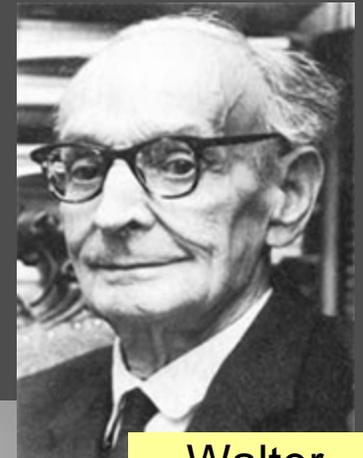
Edward T.
Hall



Pablo
Picasso



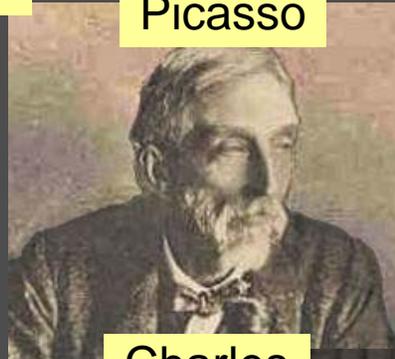
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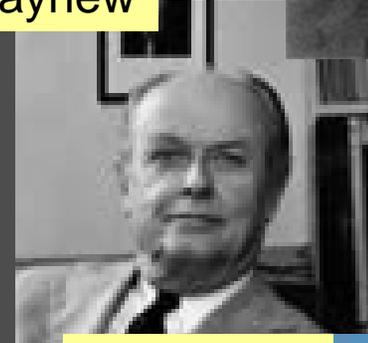
Walter
Christaller



Alice
Coleman



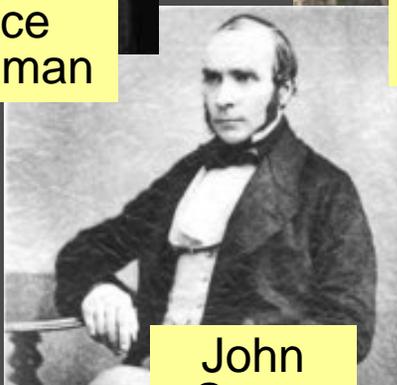
Charles
Booth



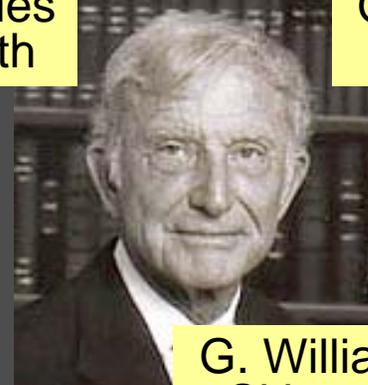
Gordon R.
Willey



Patrick
Doreian



John
Snow



G. William
Skinner



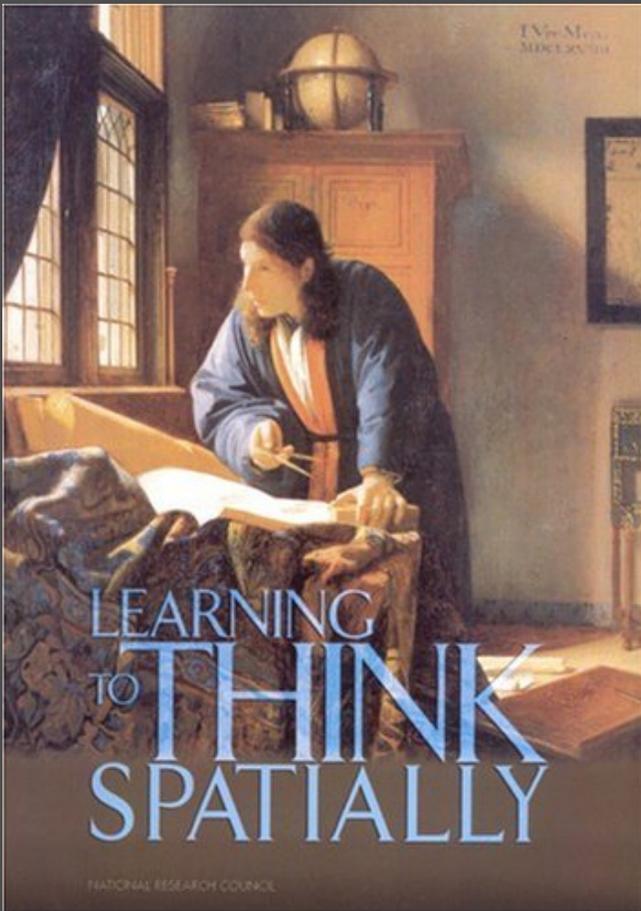
Melinda S.
Meade

What is Spatial Thinking?

- How would you define or characterize spatial thinking?
 - What skills or concepts are involved?
 - How does spatial thinking differ from other ways of thinking?
- Why is it important for you to help your students learn to think spatially?
- What are the most significant barriers your students will need to overcome to achieve spatial literacy?

What is Spatial Thinking?

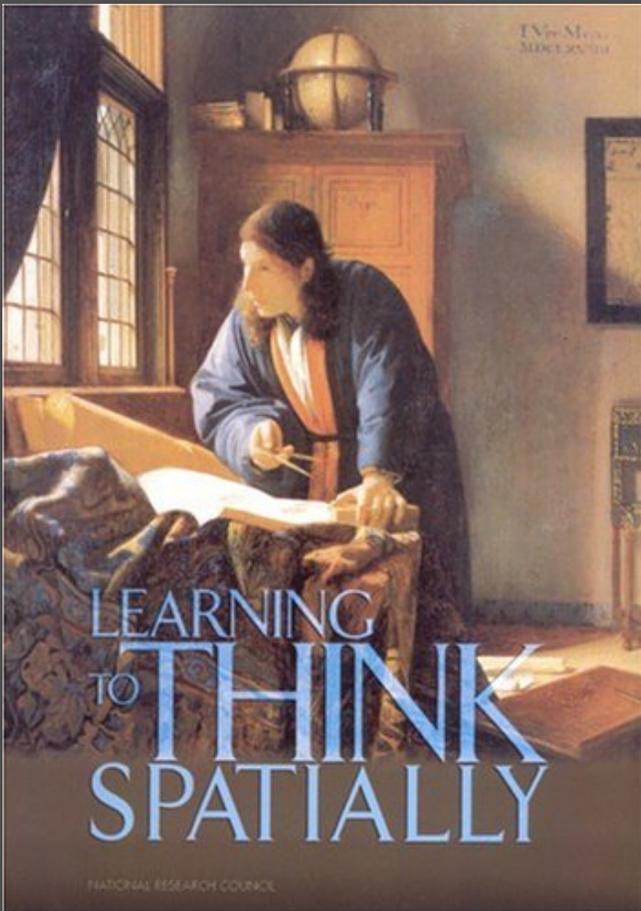
- Characteristics of a spatially literate student:



- Knows where, when, how, and why to think spatially
- Practices spatial thinking in an informed way
 - Has a broad and deep knowledge of spatial concepts and spatial representations
 - Has command over spatial reasoning using a variety of ways of thinking and acting
 - Has well-developed spatial capabilities for using supporting tools and technologies
- Adopts a critical stance to spatial thinking
 - Can evaluate the quality of spatial data based on source, likely accuracy, reliability
 - Can use spatial data to construct, articulate, and defend a line of reasoning or point of view in solving problems and answering questions
 - Can evaluate the validity of arguments based on spatial information

What is Spatial Thinking?

Three characterizations from NRC report on *Learning to Think Spatially*



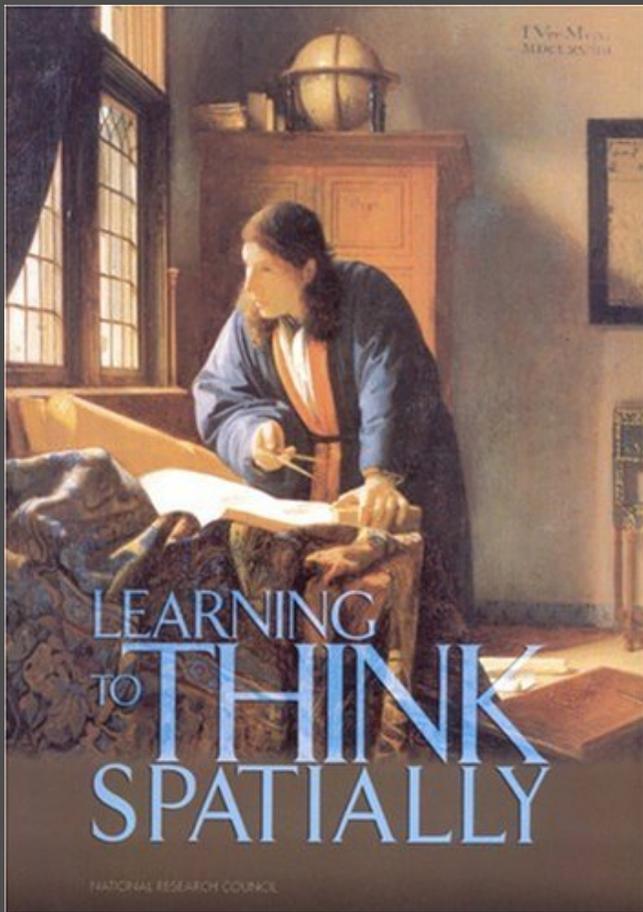
1

- **Spatial knowledge**
 - Symmetry, orientation, scale, distance decay, etc.
- **Spatial ways of thinking and acting**
 - Using diagramming or graphing in problem solving, recognizing patterns or clusters in data, separating change over space from change over time, etc.
- **Spatial capabilities**
 - Ability to use supporting tools and technologies such as spreadsheet, graphical, statistical, and GIS software

What is Spatial Thinking?

Three characterizations from NRC report on *Learning to Think Spatially*

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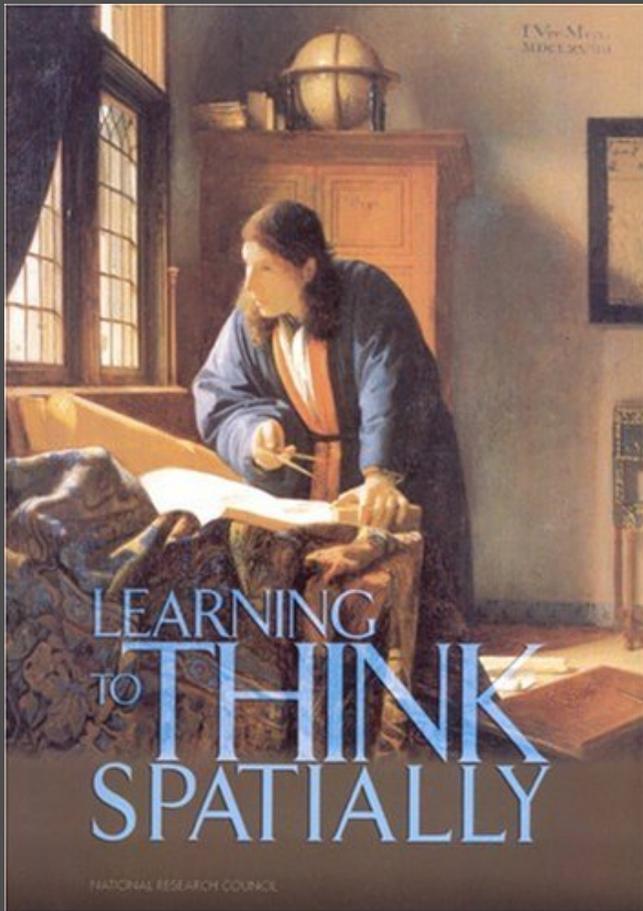


- **Concepts of space**
 - Relations among units of measurement, dimensionality, basis of coordinate systems, etc.
- **Tools of representation**
 - Require understanding of relationships between orthogonal and perspective views, effects of geographic projections, etc.
- **Processes of reasoning**
 - Ability to think about shortest distances in different ways (straight line vs. route), extrapolation and interpolation, etc.

What is Spatial Thinking?

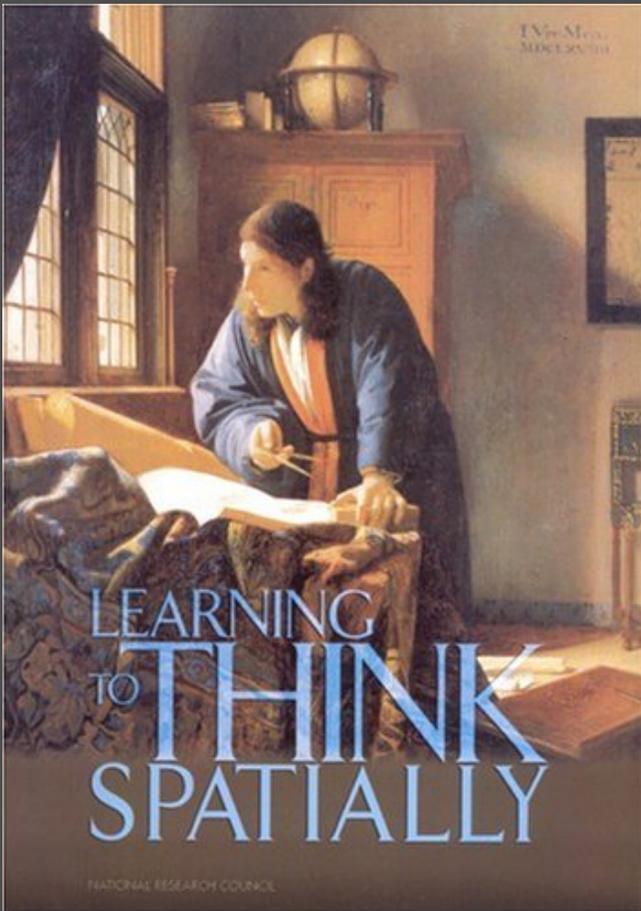
Three characterizations from NRC report on *Learning to Think Spatially*

3



- **Extracting spatial structures (encoding)**
 - Perception and/or creation of representation
 - Show elements and the spatial or conceptual relationships between elements with respect to reference frame
- **Performing spatial transformations**
- **Drawing functional inferences**
 - Complex spatial reasoning
 - Combining representations and transformations to evaluate or predict situations or events

What is Spatial Thinking?



For more information on spatial thinking:

- Golledge (2002), *The Nature of Geographic Knowledge*
- Nyerges (1991), *Analytical Map Use*
- Tversky (2005), *Visualspatial Reasoning*
- Newcombe (1989) *The Development of Spatial Perspective Taking*
- Liben et al. (1981), *Spatial Representation and Behavior across the Life Span*

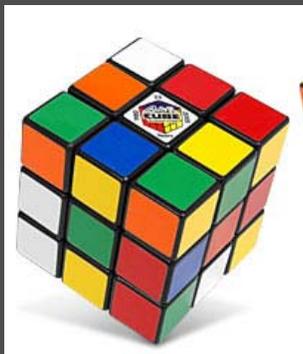
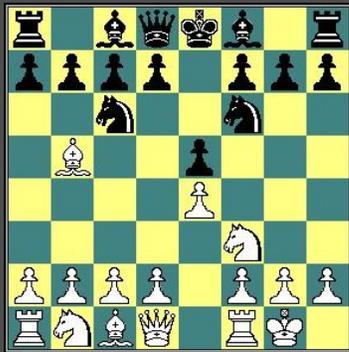
Expertise in Spatial Thinking

- What are some characteristics that distinguish experts from novices in your field?
- What are some characteristics that distinguish expert spatial thinkers from novices?
- What are some ways that educators can motivate, encourage, or support the learner's transition from novice to expert?

Expertise in Spatial Thinking

To help students acquire expertise:

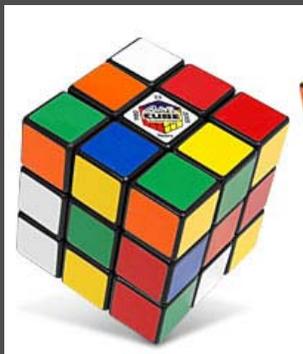
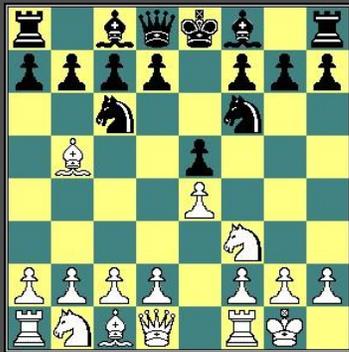
- Provide opportunity to study **domain-specific patterns**
- Provide practice with **domain-specific mental transformations of patterns in working memory**
 - Limited transfer from one domain to another
- Emphasize **metacognitive knowledge and learning how to learn:**
 - Understand that patterns can be multiply classified
 - Understand that studying patterns and practicing transformations will lead to faster recognition and better utilization of spatial working memory



Expertise in Spatial Thinking

To help students acquire expertise:

- Use spatial representations that follow design guidelines based on what we know about human perception and cognition
- Be aware that complex or unfamiliar representations (even if well-designed) may be confusing for students
- Scaffold spatial thinking with **language** and **extrapictorial devices** such as arrows, boxes, lines, and brackets
- Provide guidance and support as students work through first projects
 - Simplification of representation
 - Simplification of interface (Lloyd, 2001)



Expertise in Spatial Thinking

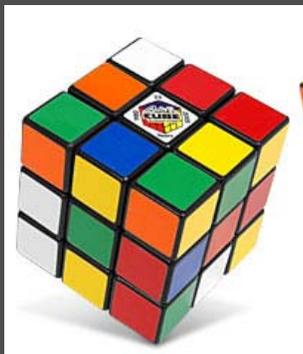
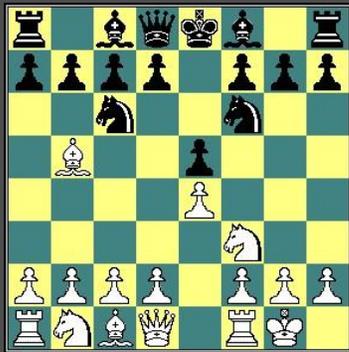
To help students acquire expertise:

– DON'T

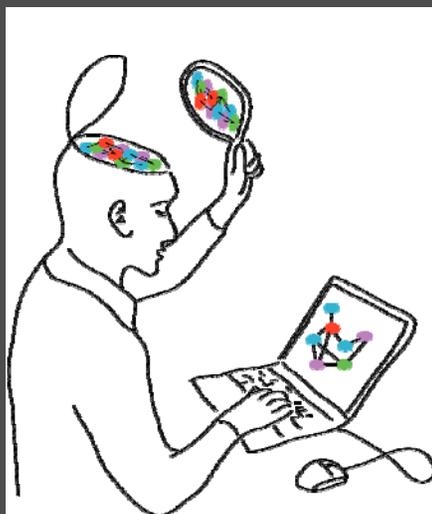
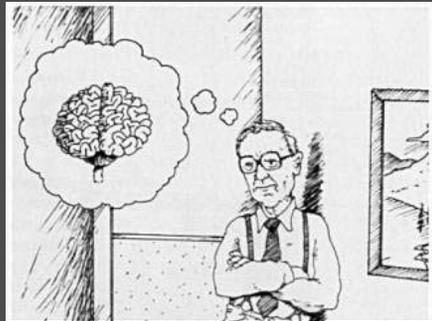
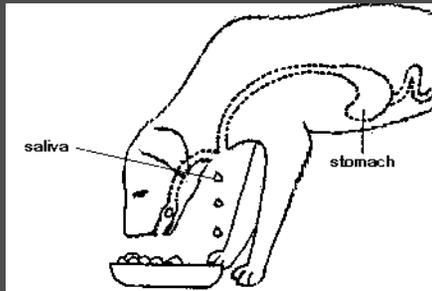
- Force students to use spatial approach when another would work as well or better
- Expect students to interpret a novel representation and engage in complex thinking at the same time
- Assume that animated representations are better

– DO

- Provide multiple, complementary representations of situations
- Use a wide variety of spatial representations
- Use spatial representations to convey a variety of kinds of thinking (deduction, description, prediction)
- Have students generate their own spatial representations



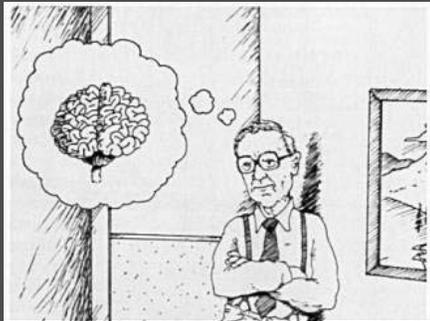
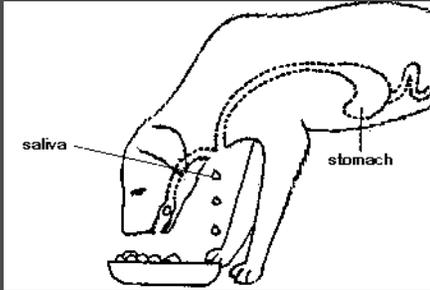
A Brief History of Learning Theory



Three dominant theories:

- Behaviorism (begins with Aristotle)
 - Focus on measurable behavior
 - Stimulus and reinforcement used to produce desired behavior
- Cognitivism (becomes strong in 1950s, influence on instructional design begins in 1970s)
 - Focus on mental representation and schema
 - Information processing model
- Constructivism (appears 1930s, associated with Piaget)
 - Learner has active role construction of meaning
 - Importance of knowledge structure and prior knowledge
 - Role for social negotiation of meaning

A Brief History of Learning Theory



Associated pedagogical approaches:

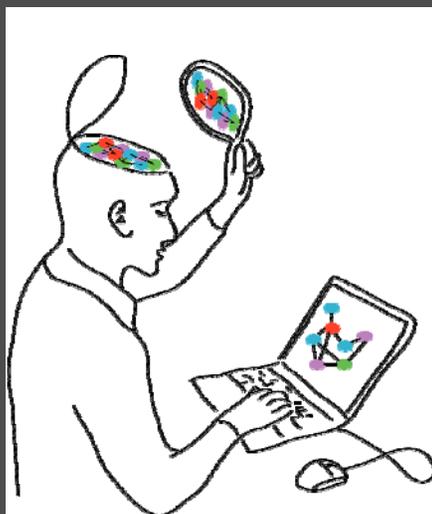
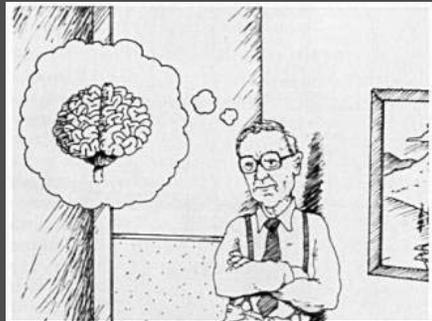
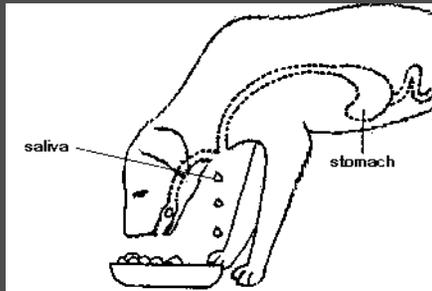
– Behaviorism

- Taxonomic analysis: task broken down into specific measurable tasks
- Drill and practice
 - Mastery learning
 - Programmed instruction
 - Computer-assisted instruction (CAI)

– Cognitivism

- Enhanced taxonomic analysis that takes into account mental representation
- Build from simple to complex schema
 - Advance organizers
 - Mnemonic devices
 - Metaphors
 - Chunking
 - Sequencing
- Algorithmic approaches

A Brief History of Learning Theory

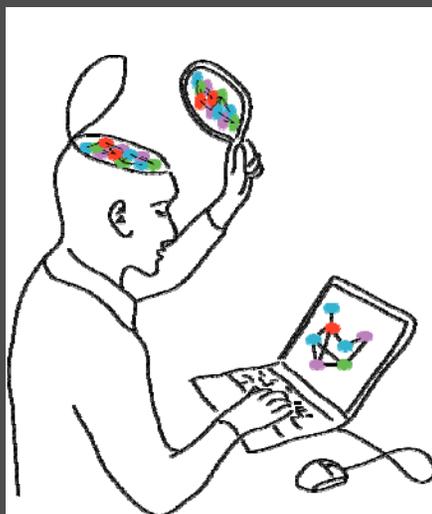
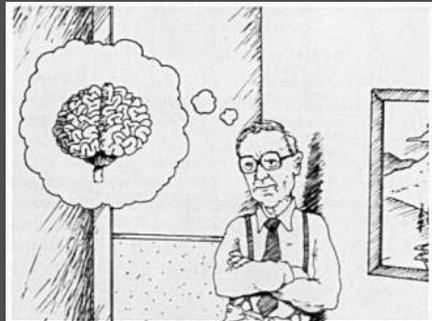
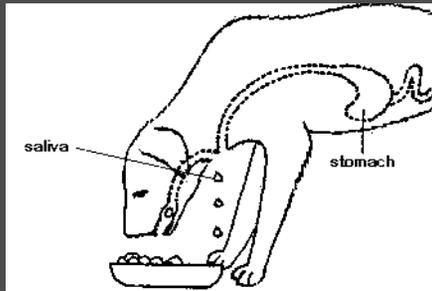


Associated pedagogical approaches:

– Constructivism

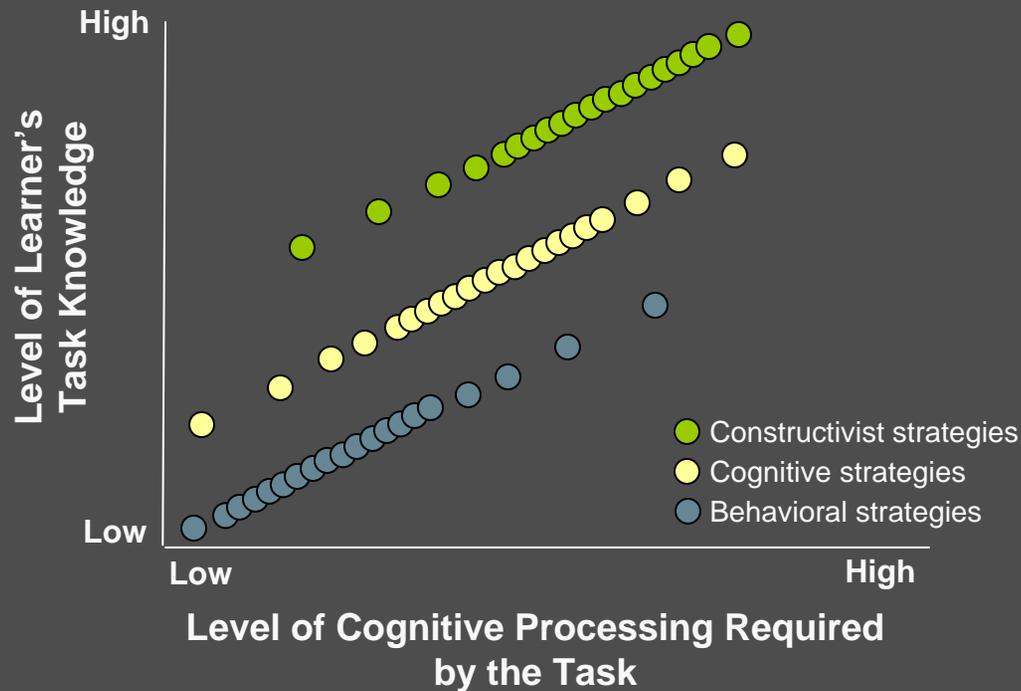
- Open-ended learning experience
 - Methods and results not necessarily the same for each learner
- Multiple representations of reality
 - Natural complexity
- Authentic tasks – “situated learning”
- Case-based learning (see Stepich et al.)
- Reflective practice
- Collaborative construction of knowledge through social negotiation
- Models for learners based on accomplished novices rather than experts
- Instructor as coach or mentor – “cognitive apprenticeship”
- Hypertext and hypermedia
 - Requires “anchoring”

Choosing an Instructional Approach



- Approach should be based on type of learning necessary or desired
- Most undergraduate learning situations best satisfied through a **combination of cognitive and constructive approaches**
 - **Cognitive:**
 - Classifications, schematic organization, analogical reasoning, algorithmic problem solving
 - **Constructive:**
 - Heuristic problem solving, ill-defined problem-solving, selection and monitoring of cognitive strategies

Choosing an Instructional Approach



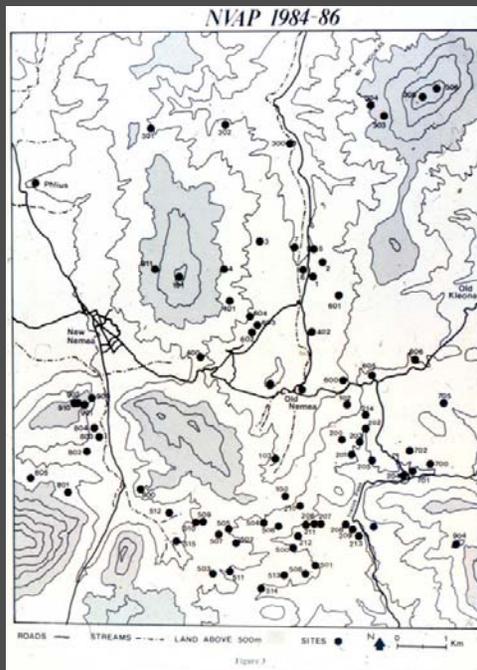
Comparison of the associated instructional strategies of the behavioral, cognitive, and constructivist viewpoints based on the learner's level of task knowledge and the level of cognitive processing required by the task.

Adapted from Ertmer & Newby: Behaviorism, Cognitivism, Constructivism: Comparing Critical Features from an Instructional Design Perspective

Learning through Problem Solving



- **Guided problem-solving activities**
 - Classic example from Jerome Bruner
 - Presented students with map of region that showed only rivers, lakes, and natural resources
 - Students decided where major cities are likely to be located
- The spatial problem-solving approach can be adapted to a wide variety of contexts through selection of appropriate datasets and tasks.



Problem-Based Learning

- “PBL is both a curriculum and a process. The curriculum consists of carefully selected and designed problems that demand from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation skills. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in life and career” (Barrows & Kelson)
- “PBL prepares students to think critically and analytically, and to find and use appropriate learning resources” (Duch, 1995)
- “Problem-based learning is a development and instructional approach built around an ill-structured problem which is messy and complex in nature; requires inquiry, information-gathering, and reflection; is changing and tentative; and has no simple, fixed, formulaic, “right” solution” (Finkle & Torp, 1995).
- <http://www.samford.edu/pbl/definitions.html>

Problem-Based Learning

- “problem-first learning”
- Often involves interdisciplinary collaboration
- Often instructional method of choice in applied fields where the knowledge base is rapidly changing
 - Medicine
 - Technical disciplines
- Many benefits reported in literature (see Pawson et al.)
- Potential risks
 - May be difficulty producing tangible results that support claims for advantages
 - Group dynamics
 - Uneven distribution of work and responsibility
 - Students with less background knowledge and skills may fall further behind when mature students take over
 - Student lack of familiarity with (and resistance to) this learning style
 - Students may prefer more structure
 - Focus may be on “doing”, to the excluding of thinking, reflection, and accommodation

Problem-Based Learning



- Starting points for success with PBL:
 - Problem scenarios that are multidimensional and complex enough to require teamwork
 - On the other hand, focused enough that they can be finished in the time available
 - PBL experience should begin at or near beginning of term
 - Instructor-assigned permanent work groups
 - Roles may also be assigned: leader, recorder, skeptic, etc.
 - Clear guidelines for conduct and expectations
 - Probing questions that help guide student inquiry
 - Clear product or outcome
 - Authentic assessment
 - Clearly established evaluation criteria that are understood by the students
 - Accountability
 - Individual and group evaluations
 - Self- and peer-assessment

Spatial Thinking Inventory

Appendix

Spatial Thinking Inventory

Learner demonstrates understanding of/ability to:

Concepts	yes	no	or	none		basic		advanced
symmetry								
isomorphism								
reflection								
orientation								
rotation								
dimensionality (e.g. 2-D vs. 3-D)								
frame of reference (absolute vs. relative)								
class or category								
frequency								
hierarchy								
distance								
relative vs. absolute distance								
adjacency								
proximity								
nearest neighbor								
similarity								
transition								
angle and direction								
sequence/order								
connection/linkage								
landmark								
scale (small vs. large)								
distance decay								
distance-similarity metaphor								
discrete vs. continuous (point vs. field)								
relations among units of measurement (e.g., kilometer vs. mile)								
basis of coordinate systems								

- Concepts
- Thought processes and problem-solving strategies
- Representation
- Use of technology

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