Inside the brain, it’s all neurons
Getting to abstractions
Comparison to language

- Levels: phonetics, syntax, semantics, pragmatics
- Space and spatial representations have their own structures
  - Space: objects, relations
  - Representations: marks and place
  - Meaning: static/structure, dynamic/change/behavior, causal
Acquiring skills

- **Piecemeal**: practicing skills
  - Getting good at pattern recognition or mental rotation isn’t sufficient for getting good at understanding & inference

- **Wholistically**, by creating

  - **Language**: writing and speaking
  - **Visual**: descriptions, explanations, narratives
Creating explanations

- Students taught STEM content
- Test
- Create visual or verbal explanation
- Second test

Bobek & Tversky
Hey, I'm Sodium

Hey, I'm Chlorine

What?

I need a suit like the whole sharks

No, I can't go in the water anymore

Will you come over?

Jay

Sodium

Chlorine

THE END
Ionic Bonding

Non-Polar Covalent Bonding

Non-Polar Covalent Bonding

Polar Covalent Bonds

NACL + CI = NaCl + CO2

NACL
In an ionic bond, one atom gives another one electrons so that they both end up with a stable outer shell. They both become ions—each atom will have a charge. In a covalent bond, no electrons are given and no ions form; instead, the atoms share electrons so that they are both stable. The atoms do not end up with charges, but if it is polar covalent bonding, they will have partial charges.
Visual explanations: more structural & functional information
Test 2 > test 1

- Improvement in learning with no teaching!
- Visual 20% > verbal
Advantages of visual explanations

- Natural mapping: meaning to space
- Abstract essentials
- Check for completeness
- Check for coherence
- Encourage inference from structure to function
From space to abstractions: cross-cutting concepts

- Networks/trees: ideas & relations
  - Hierarchies of various kinds
  - Time lines, decision trees
- Patterns in space and time
- Boundaries (categories)
- Dispersion

- Notation, (diagramming)
Networks
Sets, subsets, intersections,….
Patterns in space
Patterns in space & time
Boundaries
Diffusion, dispersion
Forward!