Theory and Practice of Teaching and Learning: Cognitive Psychology and Learning

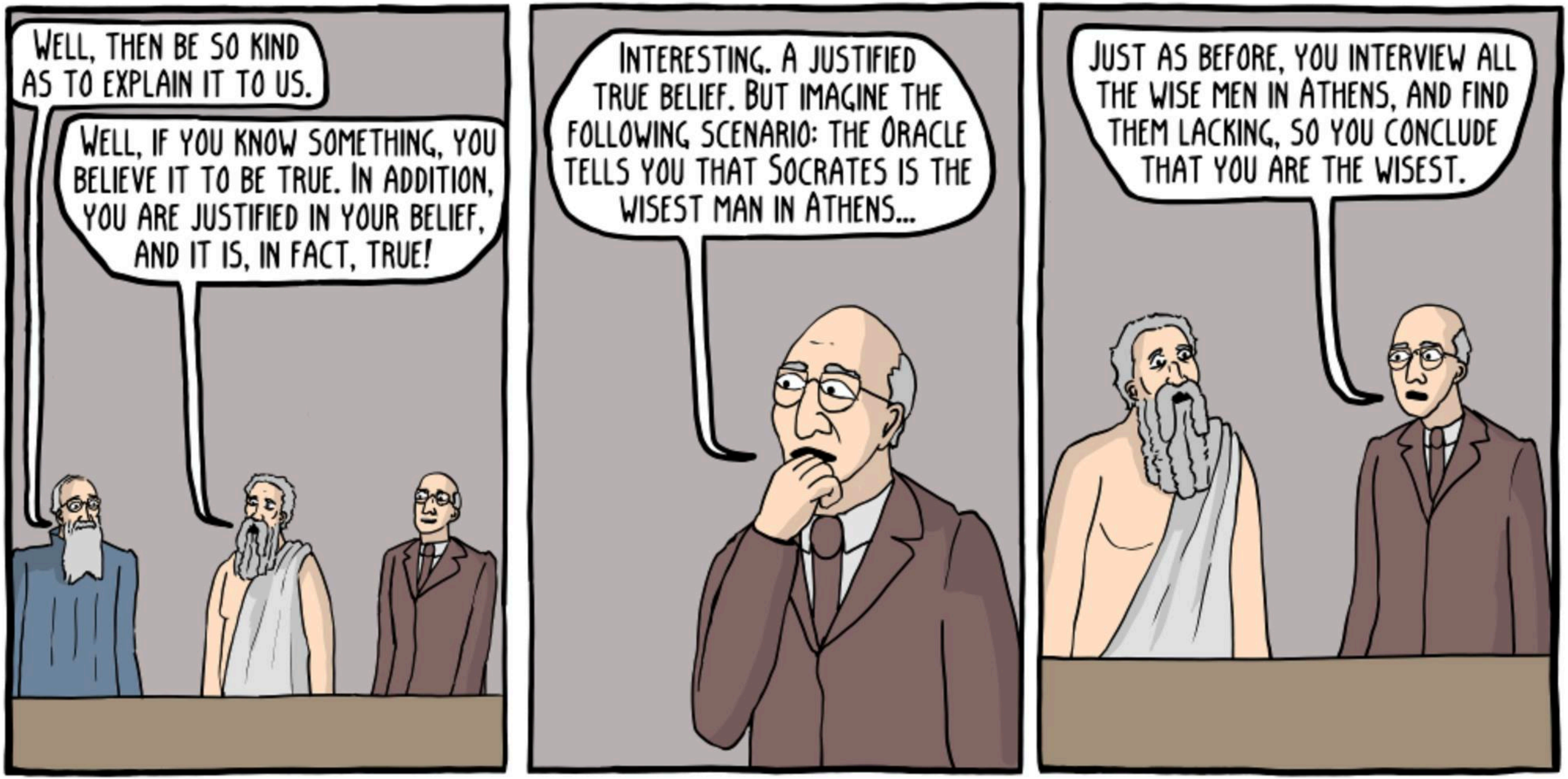
Bryan Scott | LSST-DA Data Science Fellowship Program Session 24

Brains at Work

Educational psychology is the study of when, how, and why learning occurs. Multiple complex, overlapping, and interacting regulatory pathways are involved in learning.

Neural learning proceeds changes in behavior. Similar behaviors may not correspond to the same neural state. What does it mean for the brain to know?

What is knowledge?


WELL, THEN BE SO KIND AS TO EXPLAIN IT TO US.
WELL, IF YOU KNOW SOMETHING, YOU BELIEVE IT TO BE TRUE. IN ADDITION, YOU ARE JUSTIFIED IN YOUR BELIEF, AND IT IS, IN FACT, TRUE!
INTERESTING. A JUSTIFIED TRUE BELIEF. BUT IMAGINE THE FOLLOWING SCENARIO: THE ORACLE TELLS YOU THAT SOCRATES IS THE WISEST MAN IN ATHENS...
JUST AS BEFORE, YOU INTERVIEW ALL THE WISE MEN IN ATHENS, AND FIND THEM LACKING, SO YOU CONCLUDE THAT YOU ARE THE WISEST.

Gettier Problems

What if you believe something that is true, but only by coincidence?

Empirical Theories of Knowledge

Educational theory is based on the assumption that knowledge is not **entirely** subjective, but that there is some overarching pattern to **how knowledge is stored and represented** in the brain.

Types of Knowledge

Knowledge is not a single category:

1. Different types of knowledge may be represented differently in memory.
2. Different representation schemes are possible.

Some possible categories of knowledge

Declarative knowledge: facts and concepts, integrated understanding, mental models of the world

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Self-regulatory: knowledge of the learning process itself (metacognition)

Reminder definition:

"Learning is adaptive reorganization in a complex system."

Learning in context

Learning can take place informally: emergent locations of learning

- meanings for skills, development of culture, formation of personal/professional identity.

The link between formal and informal learning:

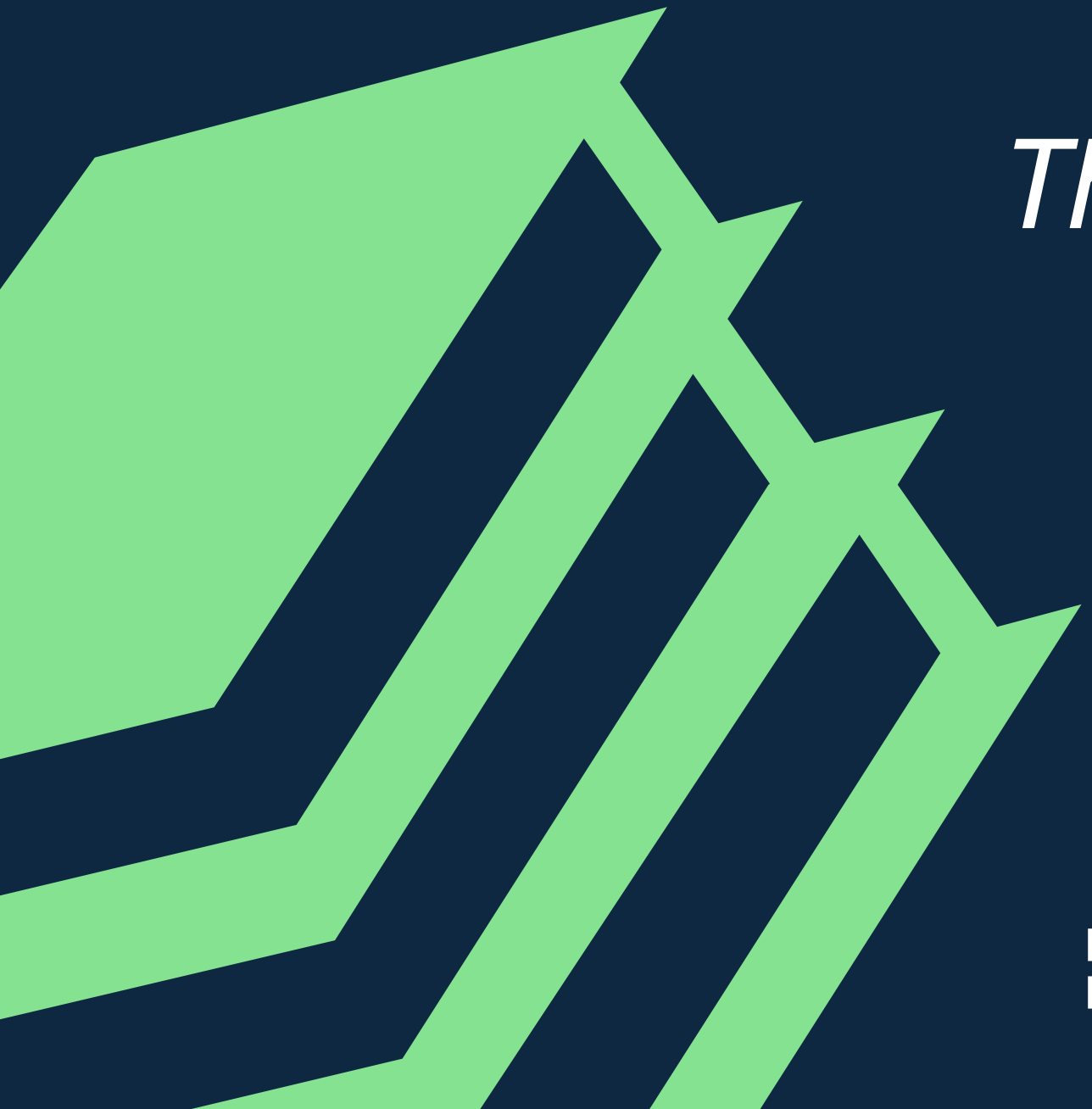
Learning which involves a change in self organization - in the perception of oneself - is threatening and tends to be resisted. [...]

Those learnings which are threatening to the self are more easily perceived and assimilated when external threats are at a minimum. [...]

Self-initiated learning which involves the whole person of the learner - feelings as well as intellect - is the most lasting and pervasive.

Questions in Formal Learning

1. *What do we want students to know and be able to do do?*
2. *How will we know if we've been successful?*
3. ***What is known about the process of learning?***



Theory and Practice of Teaching and Learning: Scaffold Building

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Sage on the Stage

Social Constructivist Account of Learning and Knowledge

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Reminder: Some possible categories of knowledge

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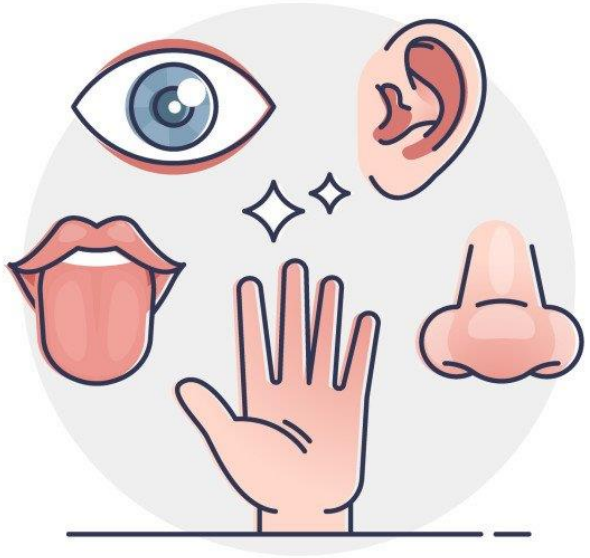
Declarative Knowledge

Semantic knowledge – understanding that is disconnected from a specific experience.

Episodic knowledge – events remembered as distinct entities

How the brain works

TYPES OF MEMORY



SENSORY MEMORY

SHORT-TERM MEMORY

LONG-TERM MEMORY

Implications

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Speculation that long term memory is actually a regulatory system for sensory experience and working memory.

Phenomenologically, we will treat LTM as an organized independent system.

Episodic Knowledge

Context and experience, flashbulb memories, usually autobiographical

Not very accurate

Possibly (really) the brain's way of modeling situations

Semantic knowledge in memory

Knowledge of this type is cross-listed. Memory works best with multiple retrieval points. Learning is developing a hierarchical organization schema – a mental framework for understanding – which reduces effort.

These schema are defined over a domain. Domains provide existing slots for new information.

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Procedural Knowledge

Knowledge of this type consists of:

I. Scripts or extended action sequences
II. Deterministic algorithms for completing a task
III. Heuristics and rules of thumb

Metacognitive/Self-regulatory knowledge

Knowledge of this type consists of domain/topic specific and domain general subtypes.

Domain specific knowledge can provide cues for learning on related topics. Domain experts excel at global planning before attempting a task.

Domain general knowledge is useful across domains, typically learning strategies. Empirical psychology has shown that skilled learners typically have a small number of flexible strategies. Teaching these strategies can be one of the most effective methods for supporting new/struggling learners.

How brains store and access information

Connectivist Models

"parallel distributed processing of information" developed through experience with little role for intention.

Information is processed via activation of neurons across the brain.

Knowledge is spread across many nodes in a continuum – patterns encode "units" of information. Activation spreads based on connection types. No account of the "mind" but does reflect what is seen in brain imaging.

Network Models of Knowledge

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Networks: Hierarchical Representations of Declarative Knowledge

Organizes declarative knoweldge into nodes, properties per node, and relational links

- different relational types, for example, disjunctive vs conjunctive, superordinate vs subordinate

When faced with a task, the brain "spreads activation" across nodes and nearby ones.

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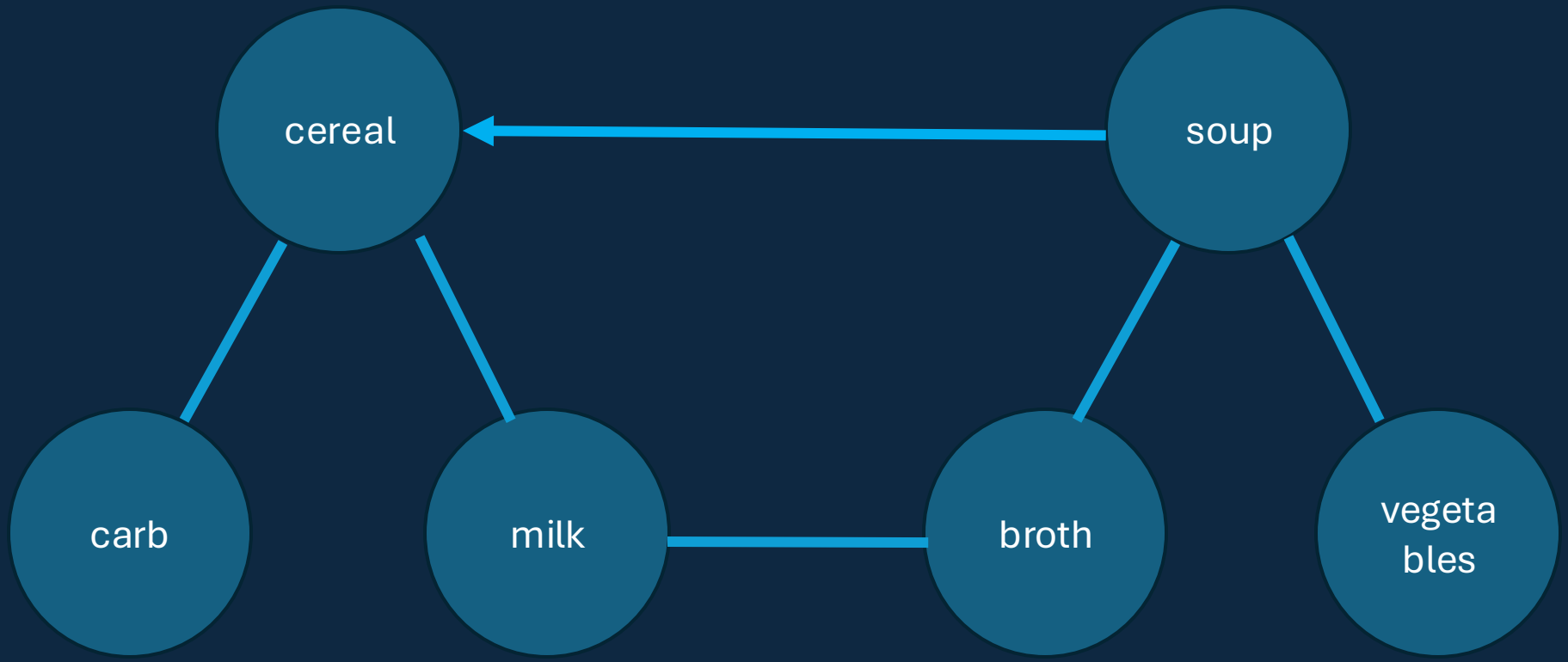


Other kinds of knowledge: Production Systems Theory

Procedural Knowledge and Associative Memory may be explained differently

The brain learns "production rules" that are combined to represent complex actions and enable problem solving.

Scaffold Building

"A style of instruction that provides students with intellectual support to function at the cutting edge of their individual development."

Elements of Scaffolding

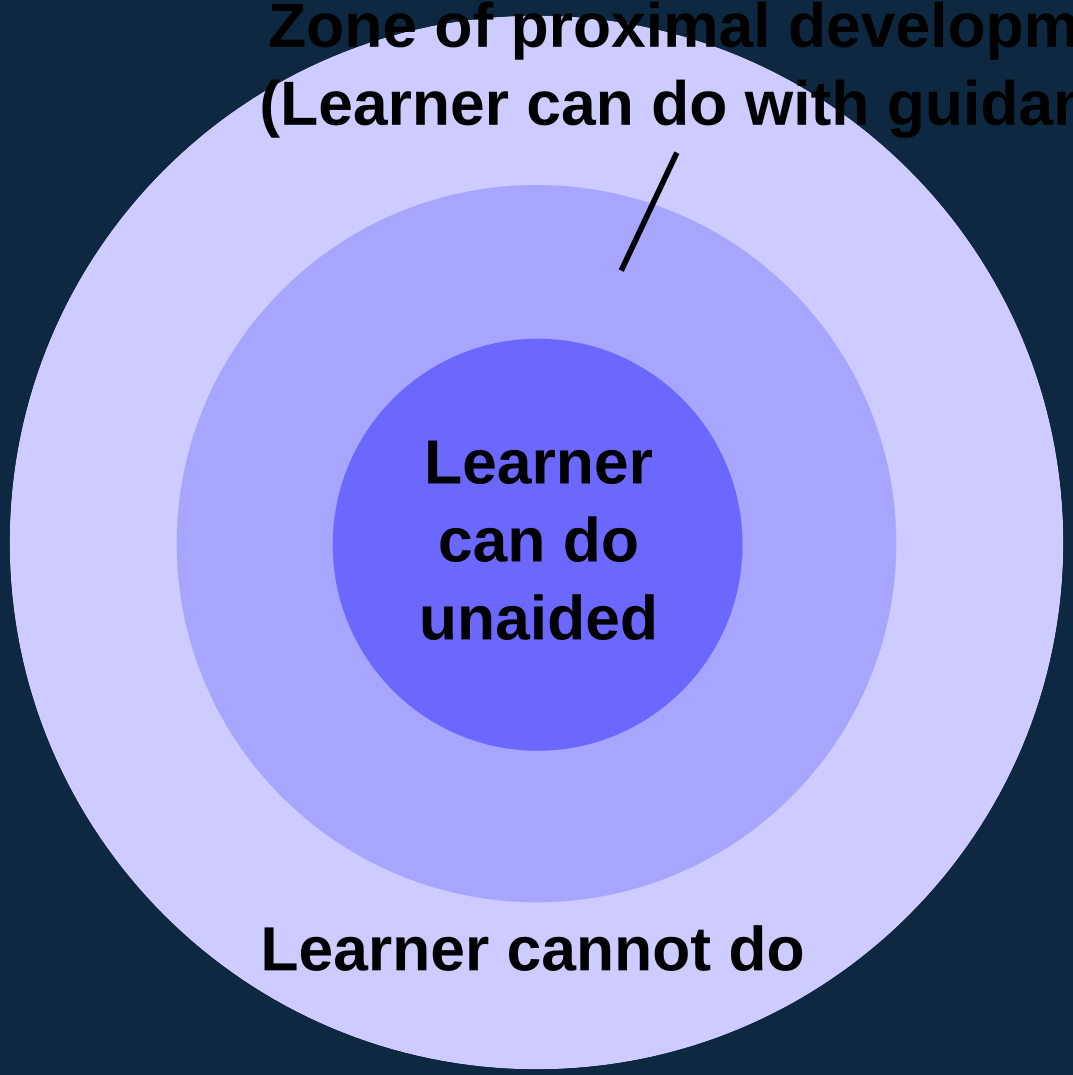
Scaffolding allows students to perform tasks that would be **slightly beyond their ability** without assistance and guidance.

Rather than transmitting knowledge, teachers enter into **conversational dialogues** with students, helping them **construct knowledge** and **understand their own thinking processes**.

Key Idea: "ZPD: Zone of Proximal Development"

The zone in which an individual's optimum learning can occur. The ZPD is measured as "the distance between the [student's] actual developmental level as determined by independent problem solving and the higher level of potential development under [expert] guidance"

Key Idea: "ZPD: Zone of Proximal Development"



Scaffolding is a type of assistance in the zone of proximal development.

Scaffolding controls the elements of a task that are initially beyond a learner's ability.

Allowing the learner to focus on completing tasks within the range of competence. Responsibility for new tasks is slowly transferred over to the learner.

Scaffold Building and Problem Solving

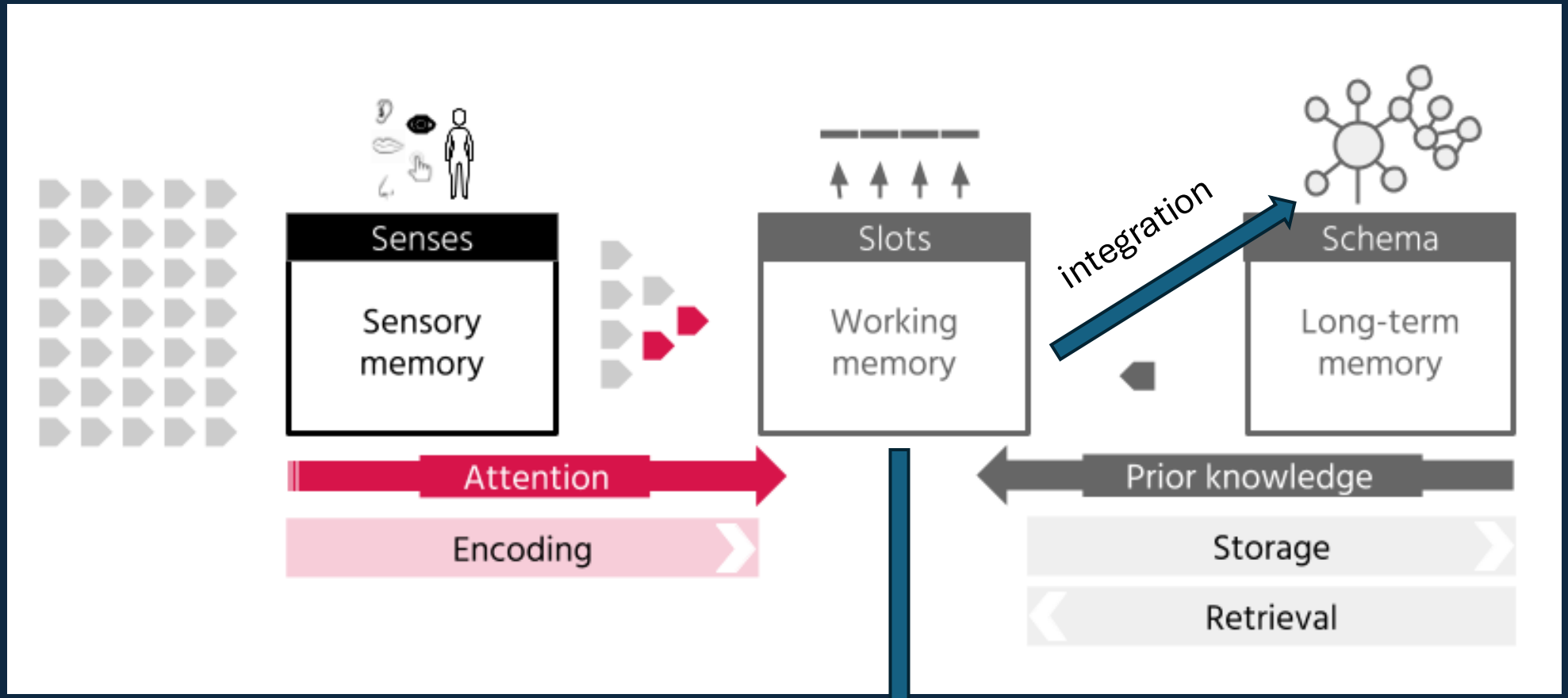
Discuss: What is problem solving?

Problem Solving is the **cognitive process** that aims to achieve a goal with **no obvious solution** (by **manipulating knowledge**) .

Situation Model: internal representation of the problem space including initial and final states plus all intervening configurations.

Involves self-regulatory knowledge. You must be able to assess whether the problem is being solved by the tasks you are executing.

Problem Solving and Cognition



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- Load Reducing Skills are key:
  - Drilling makes skills automatic
  - Guidance can help learners direct attention towards relevant tasks
  - Advance planning can help reduce mental load while performing a task
  - Cueing – an expert can help a learner by prompting related knowledge 'in the network'
  - Elaboration – learners can describe connections explicitly
  - Note taking – increases working memory and connects past knowledge
  - Questioning – an expert can prompt learning by generating meaningful questions
  - Guided Discovery: A problem that prompts authentic discovery of a key principle (see practical lesson this afternoon)

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Choosing the right problems

Early problems focus on assessing and identify the ZPD. Subsequent problems are based on assessment of the learner's progression – problems should be challenging but not impossible.

Students are informed that problems may be difficult. Students may also be given choices and asked to self-assess or justify their choice of which problem to work on. Problems are often given conceptual labels.

These steps both build meta-cognition/regulatory knowledge and support the building of networked semantic/declarative knowledge.

Solving Problems

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- Ignoring: Not all are consequential for learning.
- Forestalling: Scaffolding will sometimes involve trying to prevent errors before they occur. This works best when the teacher is monitoring and identifying recurring problems, either in the work of a single student or across many.
- Intervening: Direct and immediate correction of a problem. This should be limited to simple mistakes and not significant challenges in learning. The goal is to prevent simple mistakes from distracting the learner from acquiring complex and high level skills.

Solving Problems: Debugging

The final technique is to debug by asking leading questions or providing hints that prompt the learner to make new connections or recall key information to identify their own errors.

The extreme example is the "stepping through" technique where the learner is asked to explain each step they attempted while the teacher asks clarifying questions.

Reflection

After a problem is completed, the teacher will ask learners to reflect on the problem, describe their experience, and draw comparisons with other problems.

This keys both the organizational and retrieval mechanisms in the brain as well as prompting the formation of hierarchical networked knowledge structures.

Motivational Goals

Confidence: teachers should reinforce learners self-confidence and self-esteem.

Challenge: material presented should be authentic examples of problems beyond student's current capabilities. Failure should be both possible and expected.

Curiosity: Material should prompt learners to become invested in the process of learning.

Control: When presented with a difficult problem that one can not currently do, it's easy for learners to feel disempowered. Giving agency in the scaffolding process therefore returns control and empowers learners.

Tips and Tricks for Scaffolding Expertise

Tricky problems build self-regulatory and domain specific knowledge. Providing an increasing level of difficulty is crucial.

Technical and motivational expertise are both critical

Identity matters a lot. You should invest in knowing your learners as people.

Learning should be active and student-centered. Humility and reflection both matter a lot too.

Scaffolding is about self-regulatory knowledge as much as networked declarative knowledge.

Expertise

Properties of Experts (**You** are an expert)

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Expert knowledge is highly connected to core discipline specific ideas with strict conditions on relationships (for example, this idea is applicable in a specific situation)

Experts notice problems novices do not

- Experts can change their views/understanding because they are better at noticing than novices (this does not mean they will, of course)

Experts fail to understand what it is like to be a novice. Expert instructors have expert knowledge of how novices struggle.