# STEAM - CT

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# Critical Thinking

Critical thinking means linking together “atomic” pieces of knowledge and thus **constructing mental schemata** – whereby these pieces of knowledge comprise fact-based knowledge and procedural knowledge.

# Ten Steps to Complex Learning

J. Van Merrienboer | P. Kirschner | J. Frerejean

Quote:

“The problem is that these skills [critical thinking skills – domain-general skills] can only be acquired and carried out when the necessary domain-specific knowledge and skills **have already been acquired.**”

(A Systematic Approach to Four-Component Instructional Design 4C/ID)

# Brief digression on **Schemas and Mental Models**

**David Didau**

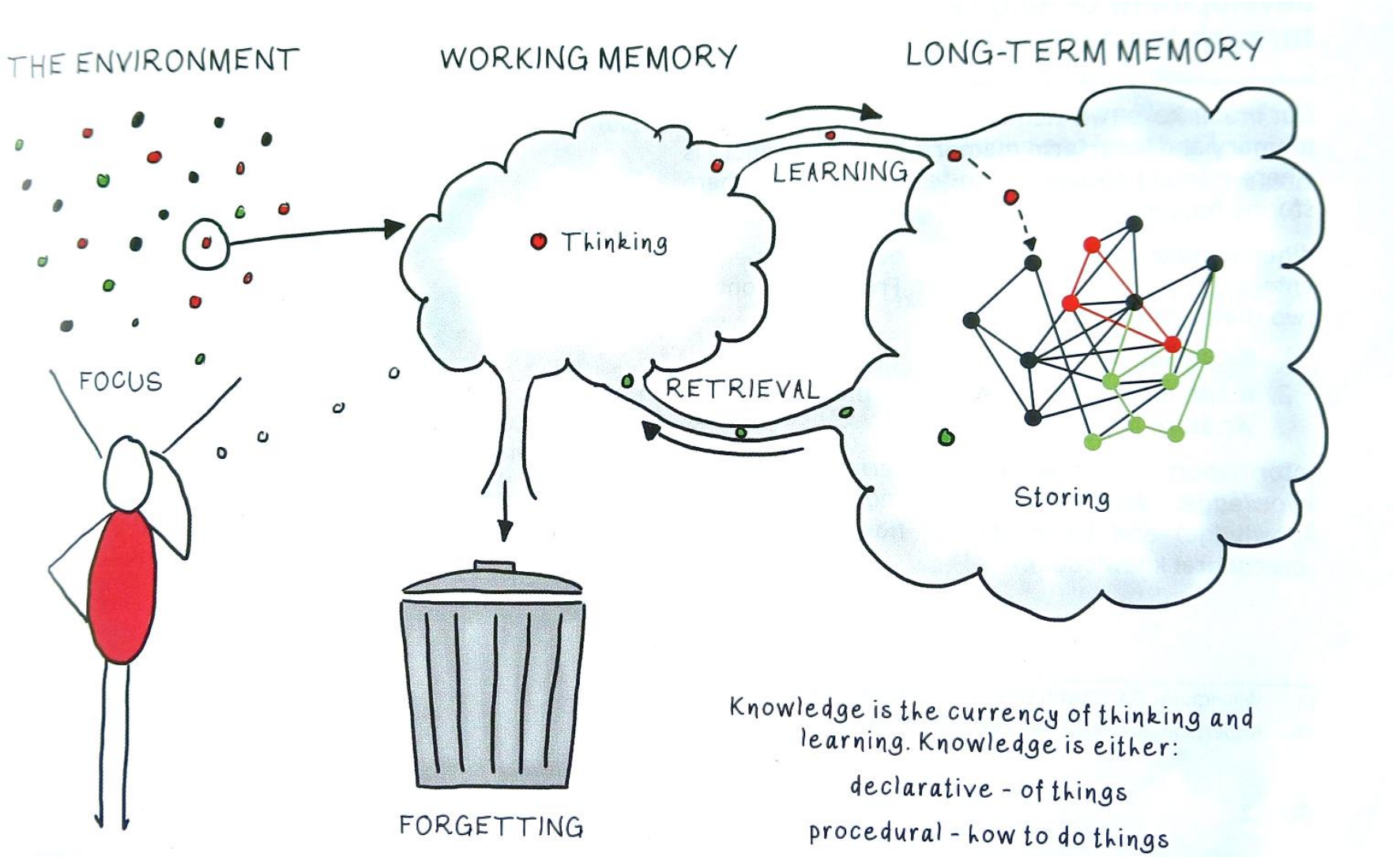
https://daviddidau.substack.com/p/schemas-vs-mental-models-does-the

# First fluency – then understanding

Quote:

For novices, we must first build schemas, automatic recognition and fluent recall of patterns. Only once those are solid should we move to mental models, enabling reasoning about systems. In that sense, schema-building and model-building represent successive stages in learning: **first fluency, then understanding**.

(David Didau)

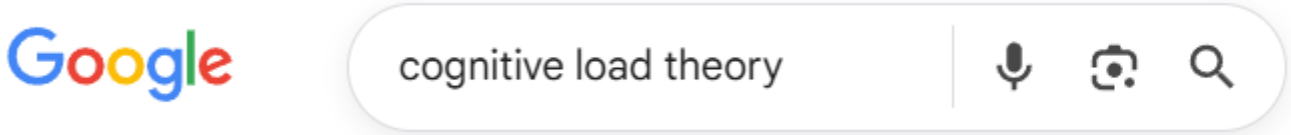




Power up  your pedagogy | John Catt Publication

# Clear connection to **C**ognitive **L**oad **T**heory

→ **Cognitive Load Theory** (John Sweller)



# Process complex material

There is strong evidence for *schema theory* itself. Decades of research confirm that knowledge is stored and retrieved through interconnected frameworks. **Schema formation** reduces cognitive load by allowing information to be chunked, meaning we can **process complex material** without overloading working memory.

David Didau et al.

# Design of Teaching

The trouble is, we have no direct access to long-term memory. No one can inspect the contents of LTM or observe its architecture. All we can do is construct explanatory models that allow us to speculate about how our minds work and why we behave as we do. Terms like *schema* and *mental model* are not discoveries of mental furniture but metaphors for unseen processes, useful fictions that help us organise our thinking about cognition. Their value lies not in what they reveal about the brain but in how they guide the **design of teaching.**

# Basics

In teaching we might begin by developing *schemas* of patterns: repeated, guided practice that builds automatic recognition. Only once these patterns and **basic vocabulary are fluent** do we shift toward *mental models*.

# You need anything to reason with …

Schemas and mental models may help by making explicit the different cognitive demands placed on students at different stages of learning. **If everything is treated as ‘understanding,’ we risk asking novices to reason before they have anything stable to reason with.**

# Schema-building & Model-building

By separating schema-building and model-building, teachers can see that fluency and understanding are not simultaneous but sequential. Schema-building tasks aim to automate recognition and recall, so that working memory is freed for higher-order reasoning. Mental model tasks, by contrast, require that freed capacity to be used for deliberate manipulation: planning, predicting, evaluating.

# Patterns – early and advanced

For early instruction, the focus is on automaticity: imitating and internalising patterns until they no longer consume attention. For advanced instruction, the focus is on reasoning: manipulating those patterns to achieve deliberate effects.

# Task design

**Designing sequences of instruction that move students from imitating and internalising patterns to deeper understanding.**

# Two tracks to follow …

**Schema building** → Factual recall → Retrieval Practice → Building fluency

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**Model building** → Procedural skills and conceptual knowledge → Functional dependencies → Building deeper understanding

# David Didau - Quote

“Knowledge must be stable and retrievable before it can be flexibly applied. It justifies repetition, modelling, and tightly scaffolded practice, the kinds of teaching sometimes dismissed as mechanical but which are essential to long-term retention. Using the language of schema helps to legitimise the deliberate cultivation of fluency, and to explain why **overloading novices with open-ended reasoning tasks is counterproductive**.”

# From consolidation to application

*Once the fundamentals are in place, the mental model can serve as a productive metaphor as the goal* ***shifts from consolidation to application***. It invites teachers and students to think of knowledge as something that can be run, tested, and revised: a simulation that allows us to predict, explain, or imagine outcomes.

# Building mental models

Framing a lesson around “building mental models” could legitimise exploratory and reflective activity once sufficient knowledge exists to support it. It suits discussion, hypothesis-testing, or creative recombination: the phase of learning where we begin to reason about why things work rather than simply knowing that they do.

# Unification

The available evidence seems to suggest that schemas and mental models are two faces of the same process: the gradual organisation of knowledge into structures that first automate performance and then enable flexible reasoning.

# Possible framework for us …

Basic framework & first steps:

The first step aims at the development of a series of whole tasks that serve as the backbone for the educational blueprint.

- Design Learning Tasks.
- Design Performance Assessments.
- Sequence Learning Tasks.

# Learning intentions

The starting point of the design process is a domain-specific problem, which can often be most effectively formulated as a question. Questions naturally spark interest—**framing a learning objective as a question** may be a better way to convey the intended learning in a series of tasks than phrasing it as a statement.

# Learning intentions

Students need to know **what they are learning**.

# Success criteria

Once the learning objective has been formulated (preferably in the form of a question or task), **success criteria** must be formulated that relate to the evidence a teacher can use to determine whether students have understood what they have learned.

# Success criteria

Students need to know **if they have learned what they are supposed to.**

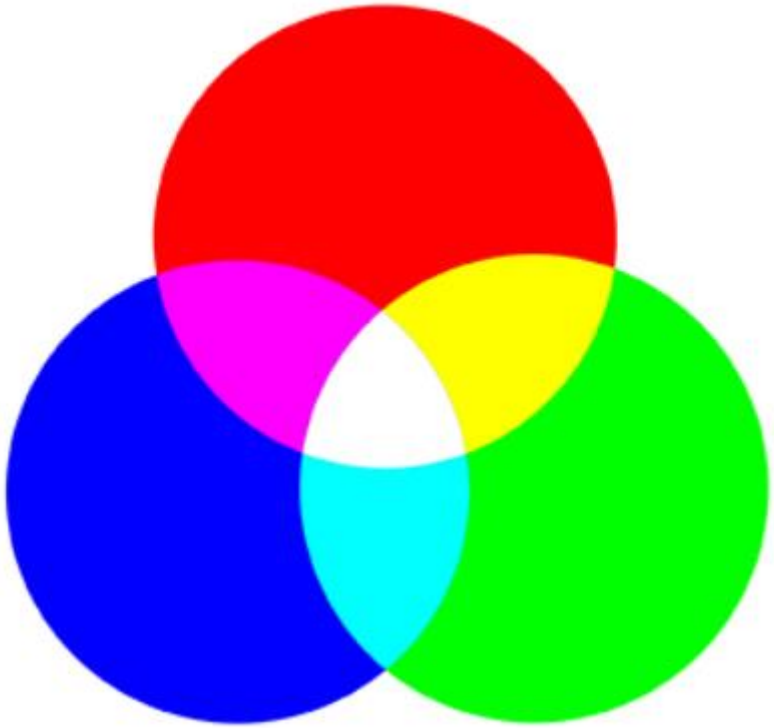
# Examples of Learning tasks

Suitable initial questions could be, for example:

- What do we know about Antimatter?
- What do we know about Black Holes?
- What do we know about the Interior of the Earth?
- What do we know about Solar Wind?
- What do we know about Cosmic Rays?

# CT … a blend of …

Factual knowledge at your fingertips …

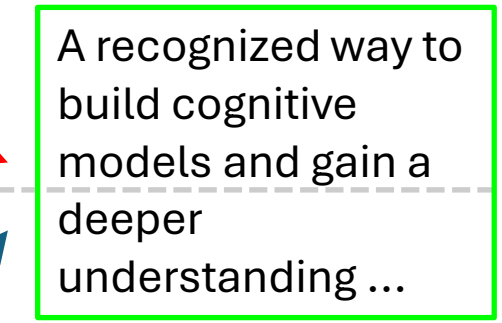


Procedural knowledge through lots of examples and non-examples …

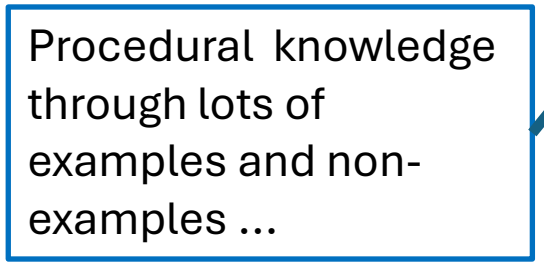
A recognized way to build cognitive models and gain a deeper understanding …

# Two tracks to follow …

**Schema building** → Factual recall → Retrieval Practice → Building fluency


**Model building** → Procedural skills and conceptual knowledge → Functional dependencies → Building deeper understanding



# What can we do about it ?

1

**Find a topic** ( = Learning intention)

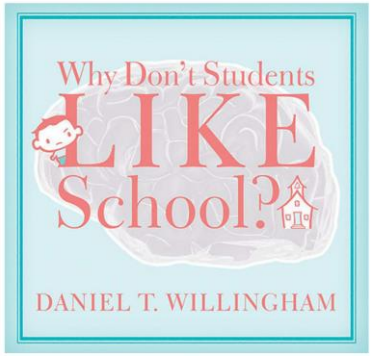
For example:

**What do we know about the Interior of the Earth?**

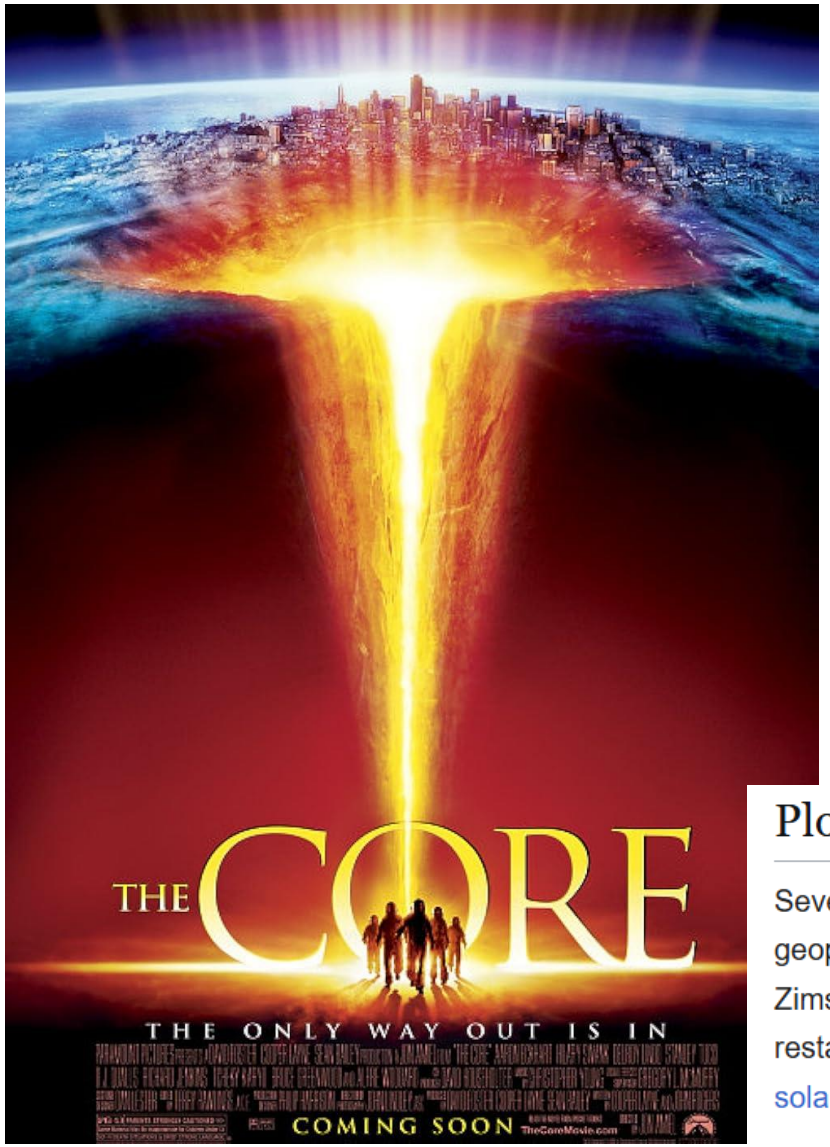
2

**Find an introductory story** ( → educational value of storytelling)

see for example D. Willingham



For example: a movie plot




## Plot

Several small, disparate incidents involving the Earth's magnetic field cause geophysicist Dr. Joshua Keyes and scientists Dr. Serge Leveque and Dr. Conrad Zimsky to conclude that the Earth's molten core has somehow stopped rotating. Unless restarted, the field is set to collapse within months, exposing the surface to devastating solar radiation.


Find associated factual knowledge

Find associated procedural knowledge

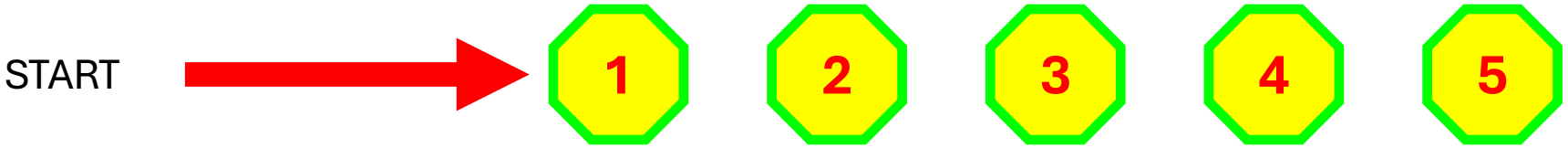
Find associated conceptual knowledge


# Find functional dependencies for cognitive model building

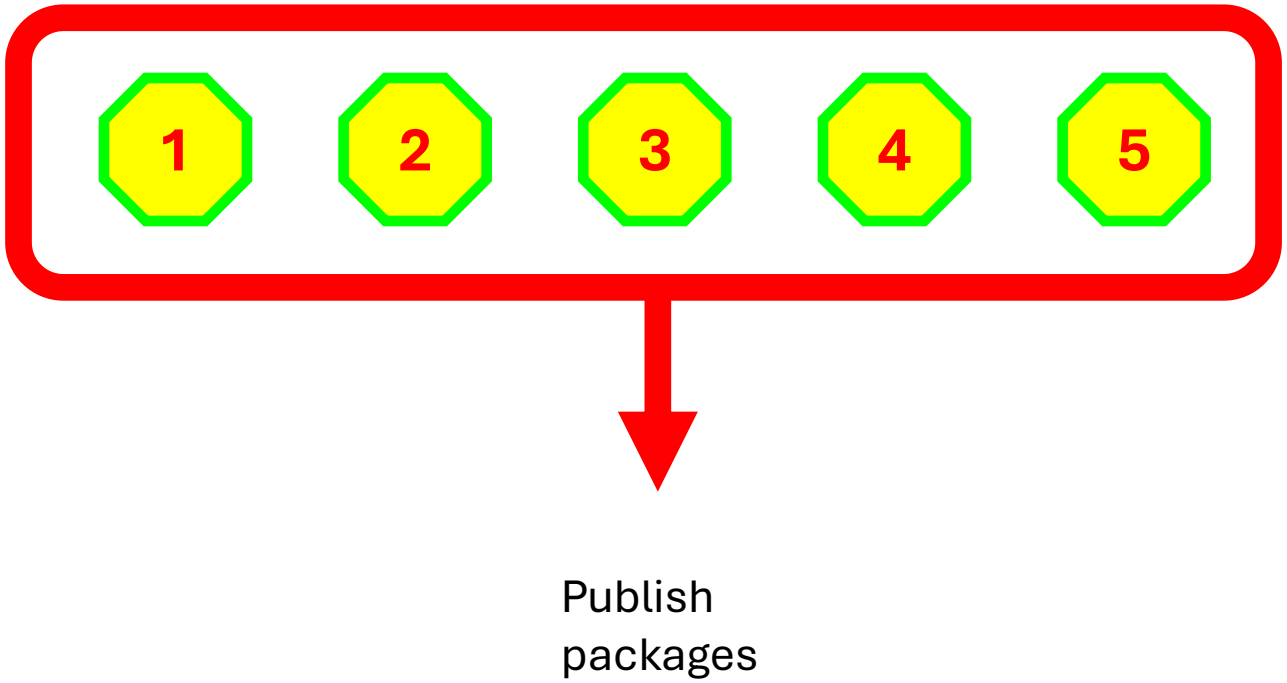

**Write tasks to find out what students have learned.**

**(→ Success criteria)**

# STEAM – CT … in 5 steps



# STEAM – CT … in 5 steps



# My own efforts so far:

Related publication:

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Related blog:

https://klausalbrecht.substack.com/about

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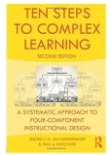


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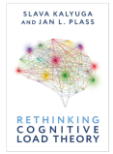


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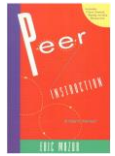


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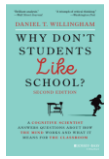


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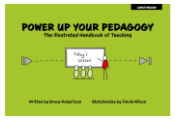


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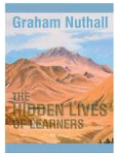


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# Thank you!

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