Managing Cognitive Load Through Instructional Design

Adapting Instruction Across Stages of Learning

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Objectives

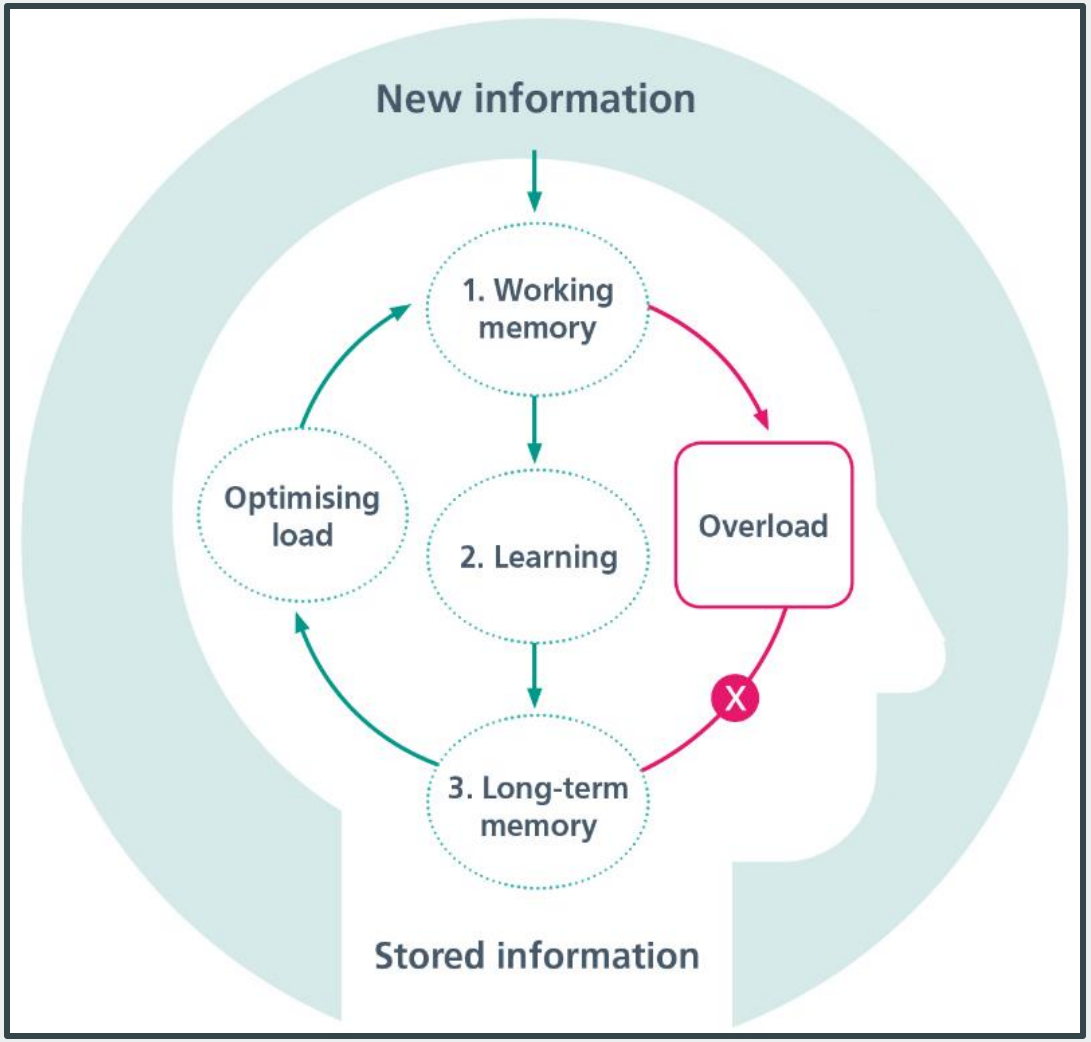
1. Establish a **common language** for related terms
2. Outline the **principles** of the Cognitive Load Theory (CLT)
3. Examine **causes** of cognitive overload
4. Discuss **implications** of cognitive load for **planning, delivering,** and **assessing learning**

Important Terms

Short-term memory	
Long-term memory	
Working memory	
Load	

“The human brain can only process a small amount of **new** information but can process large amounts of **stored** information.”

(Newby & Leung, 2023, p.4, Center for Education Statistics and Evaluation.)



Even the Most Well-Designed Lessons are Ineffective When They Exceed Students' Working Memory Capacity

Cognitive Load Theory

Sweller, 2011

Coyne et al., 2018

Jimerson, 2016

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Cognitive Load Theory (CLT)

"If the am **When information** to be processed in the learning task **exceeds capacity** limits, **learning** is **impeded**. **Cognitive Load Theory supports** with the engineering of **instructional design** in order to avoid overload of learners' cognitive systems, thus **enabling** the **efficient utilization of** their (limited) **cognitive resources**."

Beckmann, 2009, p. 251

Back to Working Memory…

- Essential for **completing tasks**, **comprehending**, and **communicating**
- Limited
  - Stores and processes only a few **elements** at any given time
  - Capacity is influenced by
    - Difficulty of the task
    - Complexity of information

An **element** is anything that needs to be or has been learned, such as a concept or a procedure.

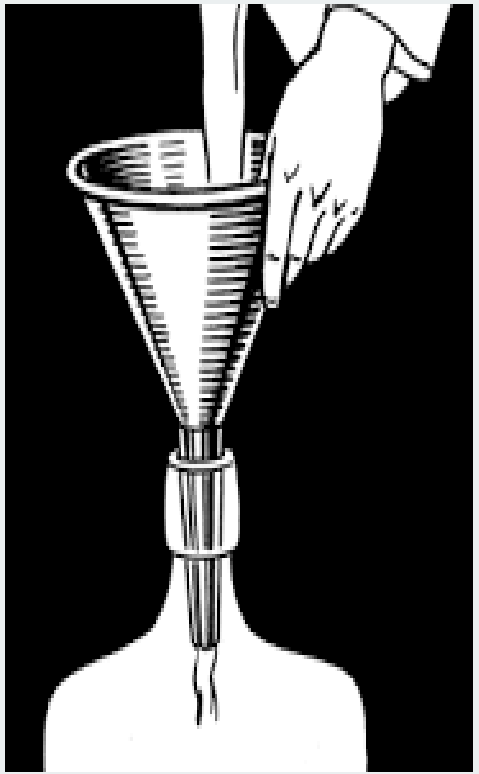
Sweller, 2010, p. 124

Working Memory Capacity

Information that exceeds working memory capacity interferes with learning.

- Information is forgotten
- Increased error rates
- Disengaged in learning
- Easily frustrated

When working memory is taxed, learning is ineffective and inefficient.



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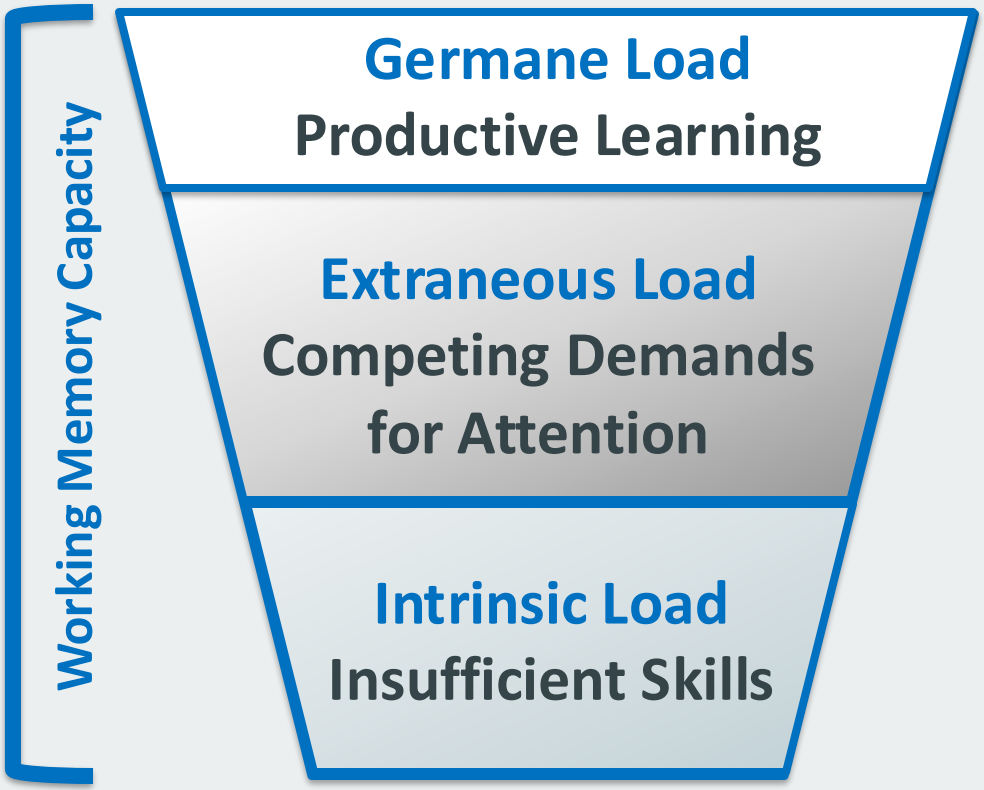
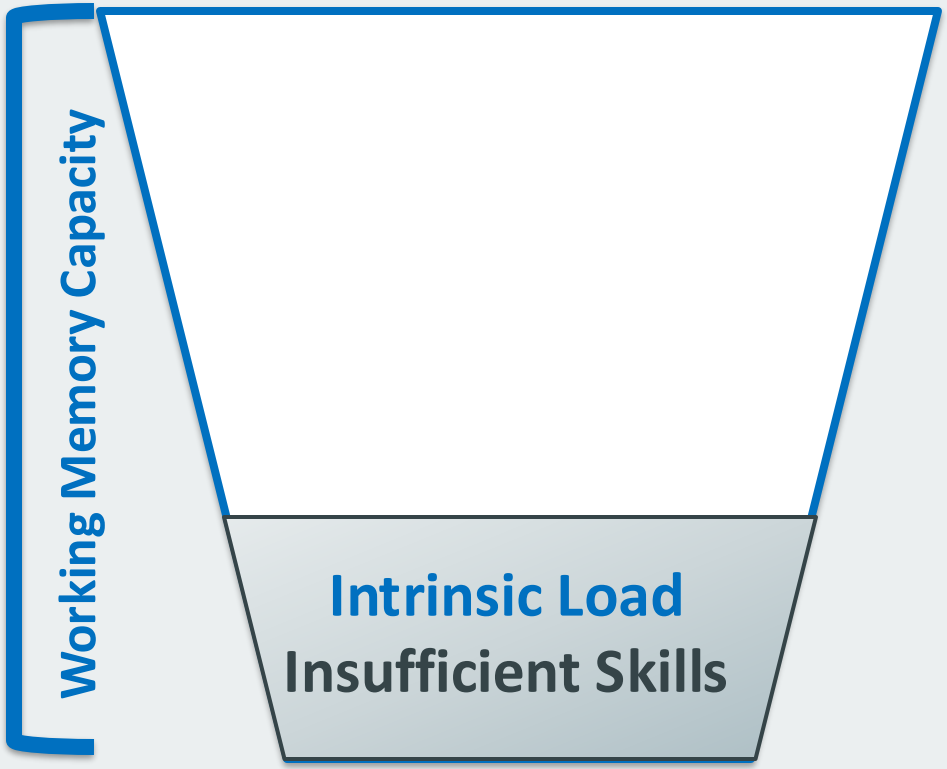
Three Types of Load



Managing intrinsic and extraneous loads allows more space for germane (productive) learning.

Capacity is limited, and each type consumes space.

Causes of Increased Intrinsic Load



- **Prerequisite** skills are not mastered
- **Error rates** are high
- **Retrieval** is slow and effortful
- **Knowledge** needed is complex
- Element **interactivity** is high

Strategies to Manage Intrinsic Load

Utilize a **backward design model** for planning

- Identify which prerequisite skills are needed for learning
- Ensure those skills are accurate and automatically retrievable

Strategies to Manage Intrinsic Load

Use assessment tools **strategically**

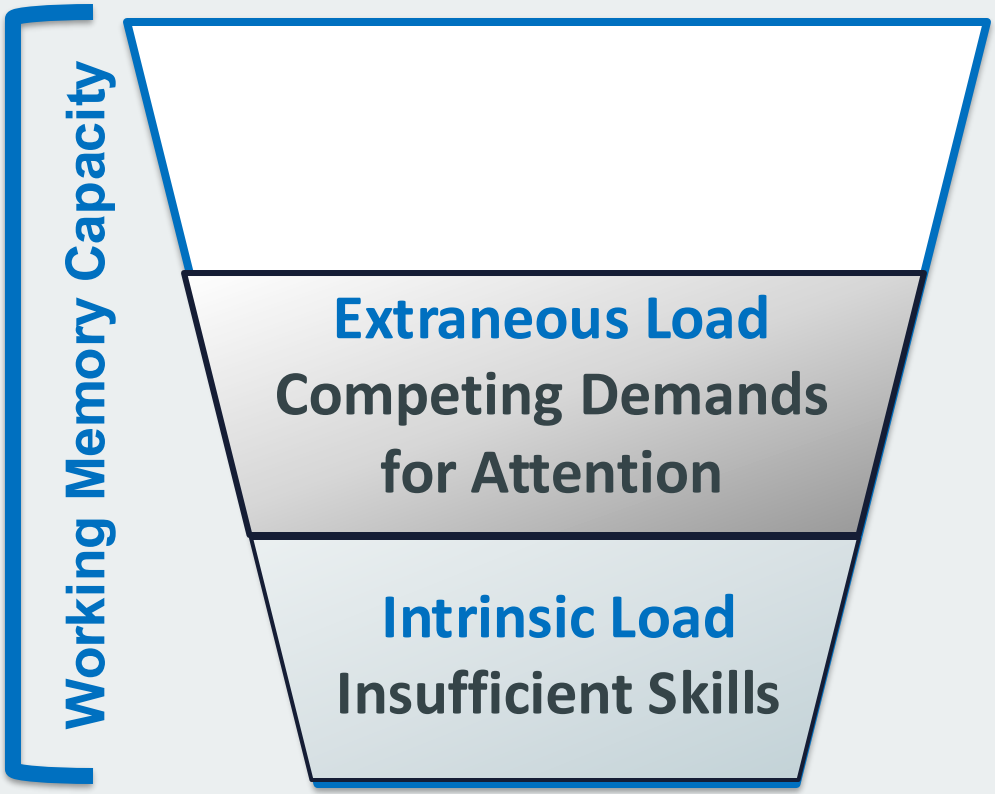
- Assess **prerequisite skills** well **ahead** of when they are needed
- **Prioritize** these skills for intervention to **prevent** overload

Strategies to Manage Intrinsic Load

Anticipate the **need for** more **scaffolding** and support through

- Visual prompts
- Verbal Prompts
- Frequent opportunities to respond
- Immediate feedback

Causes of Increased Extraneous Load



- Environmental **distractors**
- Poor **lesson design**
- **Multistep** procedures
- **Unclear** directions
- **Inconsistent** routines and procedures
- Modeling **does not match** the task

Extraneous Load

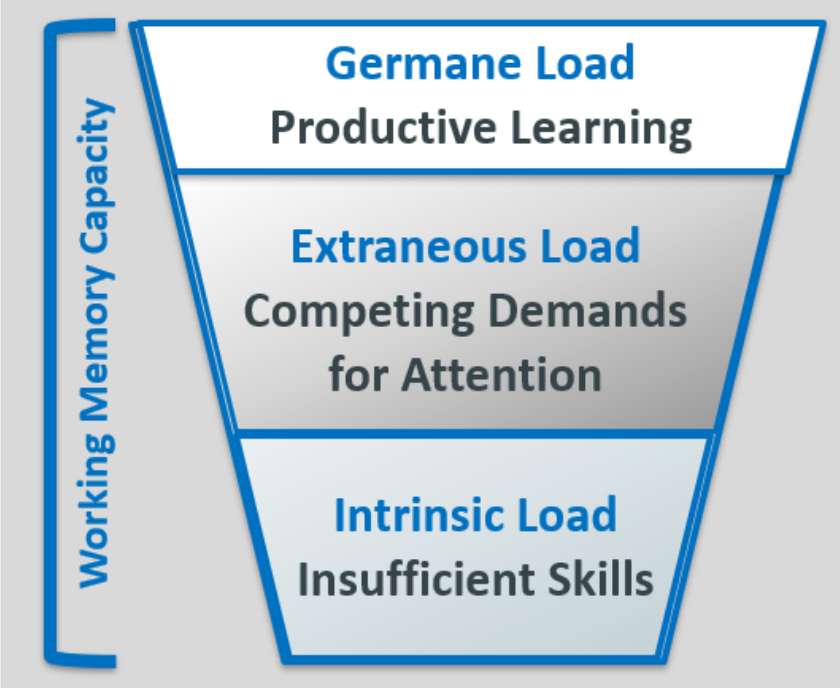
"Working memory load is not only imposed by the intrinsic complexity of the material that needs to be learned. It also may be **imposed by instructional procedures that are less than optimal**."

(Sweller, 2010, p.125).

Decrease Extraneous Load

- **Minimize** environmental **distractions**
- Use a **part-to-whole** lesson design
- **Model** the task or activity, followed by **guided practice**
- Use **consistent** lesson **routines**
- Provide **clear directions** with **concise language**
- Provide **immediate feedback**

Increasing Germane Load



Reduce Intrinsic & Extraneous Loads

- Use **familiar procedures** when teaching **new content**
- Use **familiar content** when teaching **new procedures**,
- **Connect** new with known (leverage schema)
- Provide **appropriate** forms of **practice**

Managing Environmental Distractors

Minimize environmental **distractions**

- Avoid unnecessary **visual clutter**
- Minimize **teacher-talk**
  - Use **nonverbal cues** when possible
  - **Limit interruptions** while working
- Consider room **arrangement**
  - **Placement** of additional **adults** in the room
  - Focus of **attention**

Managing Load Through Alignment

Ensure there is **alignment** across tiers

- Concepts
  - Magic e
  - Vowel, Consonant, e
  - Bossy e
  - Silent e
- Procedures
  - Arm-tapping
  - Elkonin boxes

Managing Load Through Lesson Design

- Use consistent lesson **routines**
  - Reduces the need to explain routines
  - Allows students to focus on content
- Use a **part-to-whole** lesson design
  - Each activity serves to prime students for the next
  - Provides opportunity for cumulative review

Managing Load Through Delivery

- Provide **clear directions** with **concise language**
- **Model** the task or activity, followed by **guided practice**
- Offer many opportunities for students to respond
- Provide **immediate feedback**

What does it mean to be proficient?

Instructional Hierarchy

Haring, Lovitt, Eaton, and Hansen, 1978

Daly et al., 1996

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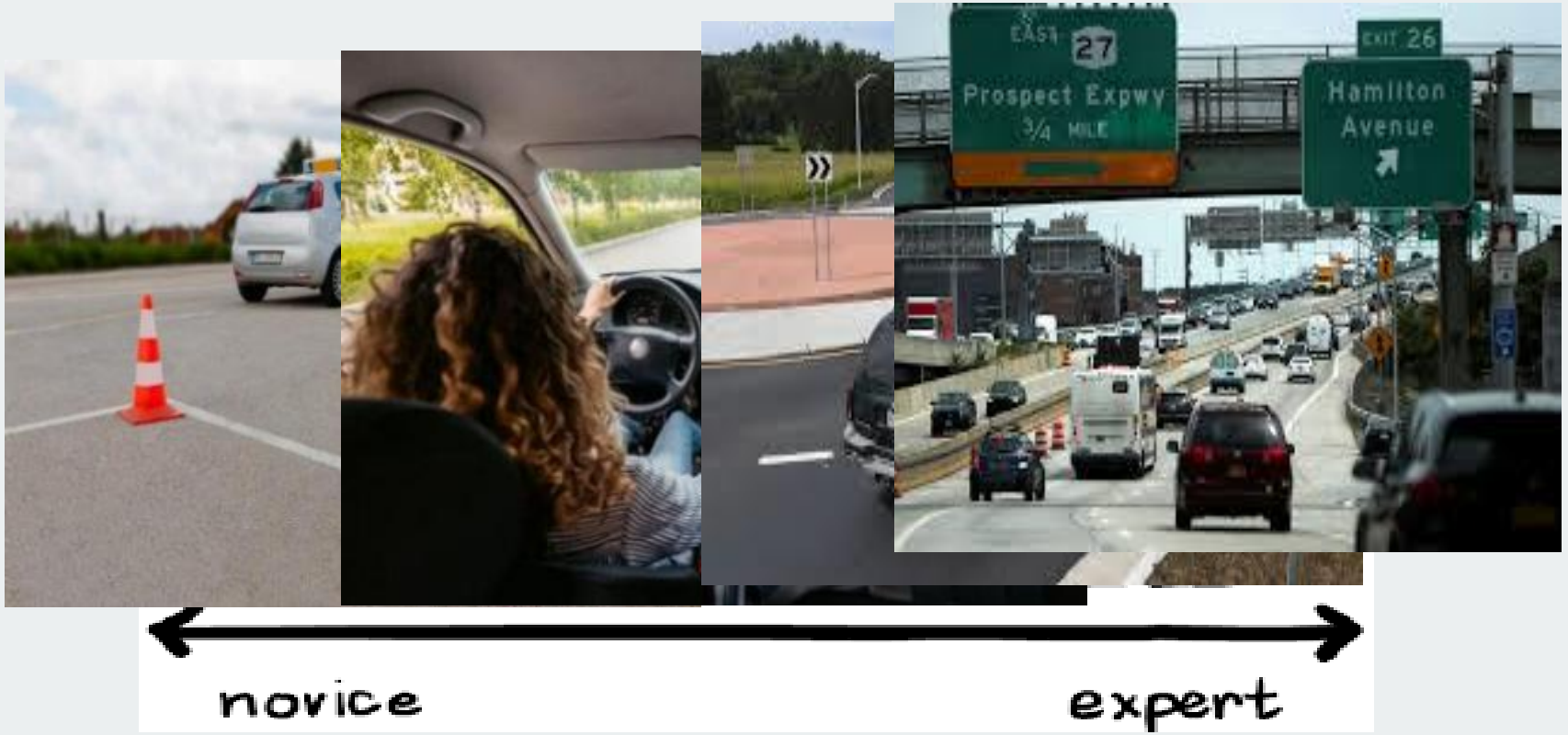
Proficiency Occurs Along a Continuum



Instructional Hierarchy Descriptors

Acquisition	• Error rates are high • Responses may be slow and effortful • Visual and verbal prompts may be needed to support retrieval
Fluency	• Error rates are lower, but may struggle to distinguish between similar skills (e.g., cap vs. cape) • Responses are becoming more automatic • Minimal prompts are needed and reserved for error correction
Generalization	• Accuracy rates are high, and responses are more automatic • Able to distinguish between similar skills • Skill can be applied broadly in new contexts
Adaptation	• Maintains high accuracy and automaticity rates • Skill can be applied in authentic contexts • Able to integrate the skill with other skills • Can engage in multistep processes to apply the skill

How can I implement these evidence-based practices?

Instructional Design

Archer and Hughes, 2011

Hultberg et al., 2018

Jimerson, 2016

Explicit Instruction

"Explicit instruction breaks up learning into smaller parts. This lightens the "cognitive load," or how much brain resources a student needs to process information. A lighter cognitive load frees up working memory. That's important because learning new skills requires a lot of working memory."

Understood.org

Provide Purposeful Practice

- Each form of practice accomplishes a different purpose
- More practice isn't as effective as providing the **right practice**
- Lesson design should consider how practice fits within a **gradual release** support structure

Match Practice Forms With Instructional Objectives

Organization relates to how the material is **presented** and **affects cognitive load.**

- **Blocked practice** reduces load
- **Interleaved/mixed practice** increases load

Frequency refers to how often the material is practiced, which in turn **affects retention.**

- **Massed practice** results in quick learning, but also quick forgetting
- **Spaced/distributed practice** results in slow learning, but long-term retention

The Blocked and Interleaved Continuum

ai	ay
wait	pay
paid	say
raid	day
claim	play
drain	stray
quaint	gray

stray	tray
strain	brain
play	aim
gray	pray
grain	aid
chain	plain
rail	clay

strainer	roaming
stern	stream
slope	scorned
calmly	sheath
cloak	bloat
brainy	soapy
trays	traits

Acquisition

"When something is first learned, the ability to use it is likely to be severely constrained."

Sweller, 1994, p. 297

Blocked Practice – Acquisition Stage

- Visibly groups similar items together
  - **Reduces** cognitive **load**
  - **Improves accuracy** and **automaticity**
- But… may result in a false sense of security

save	late
cape	shake
name	fade
wave	make
gate	safe
Jake	date

Fluency: The Importance of Automation

"**Automation** also has a significant effect on working memory. It **permits working memory to be bypassed**. Processing that occurs automatically requires less working memory space, and as a consequence, **capacity is freed for other functions**. In this sense, automation, like schema acquisition, may have a primary function of circumventing limited processing capacity."

Sweller, 1994. p. 299

Interleaved/Mixed Practice – Fluency Stage

- Mixes a variety of items
  - **Increases** cognitive **load** through more effortful retrieval
  - **Improves** skill **retention** and **generalization**
- More accurate performance measure

pan	tap
pane	tape
gap	sham
gape	shame
cap	man
cape	mane

Generalization Stage – Controlled Application

- Once high levels of accuracy and automaticity are reached, provide:
  - **distributed practice**, incorporating periods of rest between trials to **ensure retention**
  - opportunities for application in **more complex structures**
  - phrase, sentence, or passage-level reading
  - phrase or sentence dictation for spelling

Mixed and Distributed Practice - Generalization Stage

Before students generalize:

- High levels of accuracy and automaticity
- Distinguish between similar skills

Then, they can apply the skill broadly in new contexts

- **More accurate performance measure**

I have cash for the game.

Can we run to the lake?

I hope he tags the base!

Adaptation: Integration and Authentic Application

"In summary, **when a complex intellectual skill is first acquired,** it may be usable only by devoting **considerable cognitive effort** to the process. **With time and practice**, the skill may become automatic to the point where it may **require minimal thought** for its operation. **It is only then that intellectual performance can attain its full potential**. Without **automation**, performance is slow, clumsy and prone to error. It is an **essential mechanism of learning**."

(Sweller, 1994, p. 298)

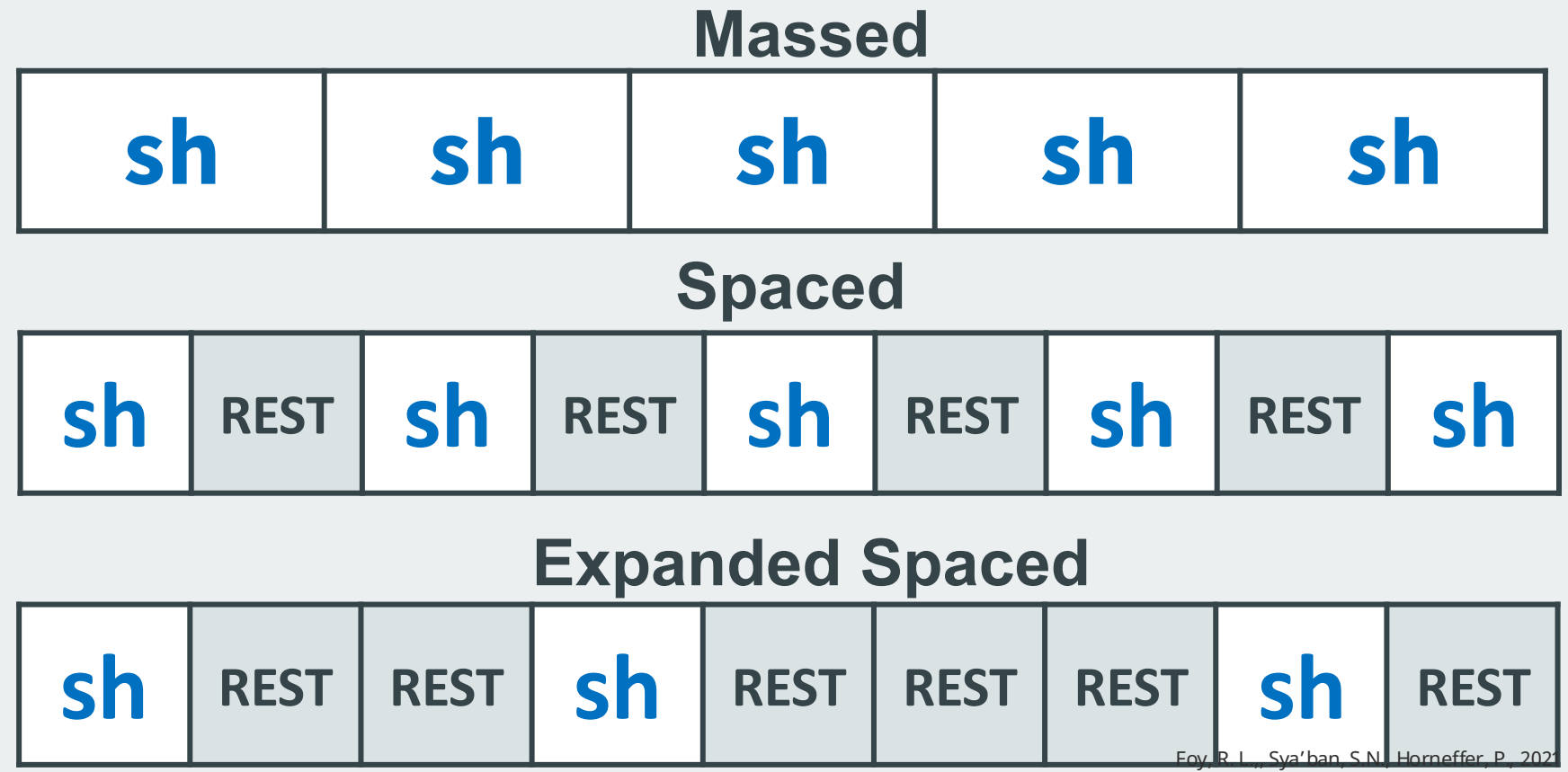
Mixed and Expanded Spaced Practice – Adaptation Stage

- Application in authentic contexts
- Integrates multiple skills
- Engages in multistep processes
- More advanced content

An ideal performance measure of what was understood and retained.

We sang and **danced** on the **stage** while they played the theme song.

Massed Versus Spaced/Distributed Practice



Foy, R. L., Sya'ban, S. N., Horneffer, P., 2021

Massed Versus Spaced

Massed Practice

- Repetition occurs within a **short time**
- Results in **quick learning** *and* **quick forgetting**

Spaced Practice

- Repetition is **spread over time**
- Periods of rest occur between practice sessions
  - by manipulating format (interleaved)
  - or taking time off between sessions
- Results in **slow learning**, *but* **long-term retention**

Instructional Strategies to Reduce Overload and Maximize Learning

Ashman, 2022

Centre for Education Statistics and Evaluation, NSW Government

Considerations for Instructional Design

New or **complex** information

Reduce load on students' working memories

Easy to understand information

Gradually increase complexity of lesson

Newby & Leung, 2023, p. 5

Strategies to optimise cognitive load

1. Tailor lessons according to students' existing knowledge and skill

2. Use worked examples to teach students new content or skills

3. Gradually increase independent problem-solving

4. Cut out inessential information

5. Present all essential information together

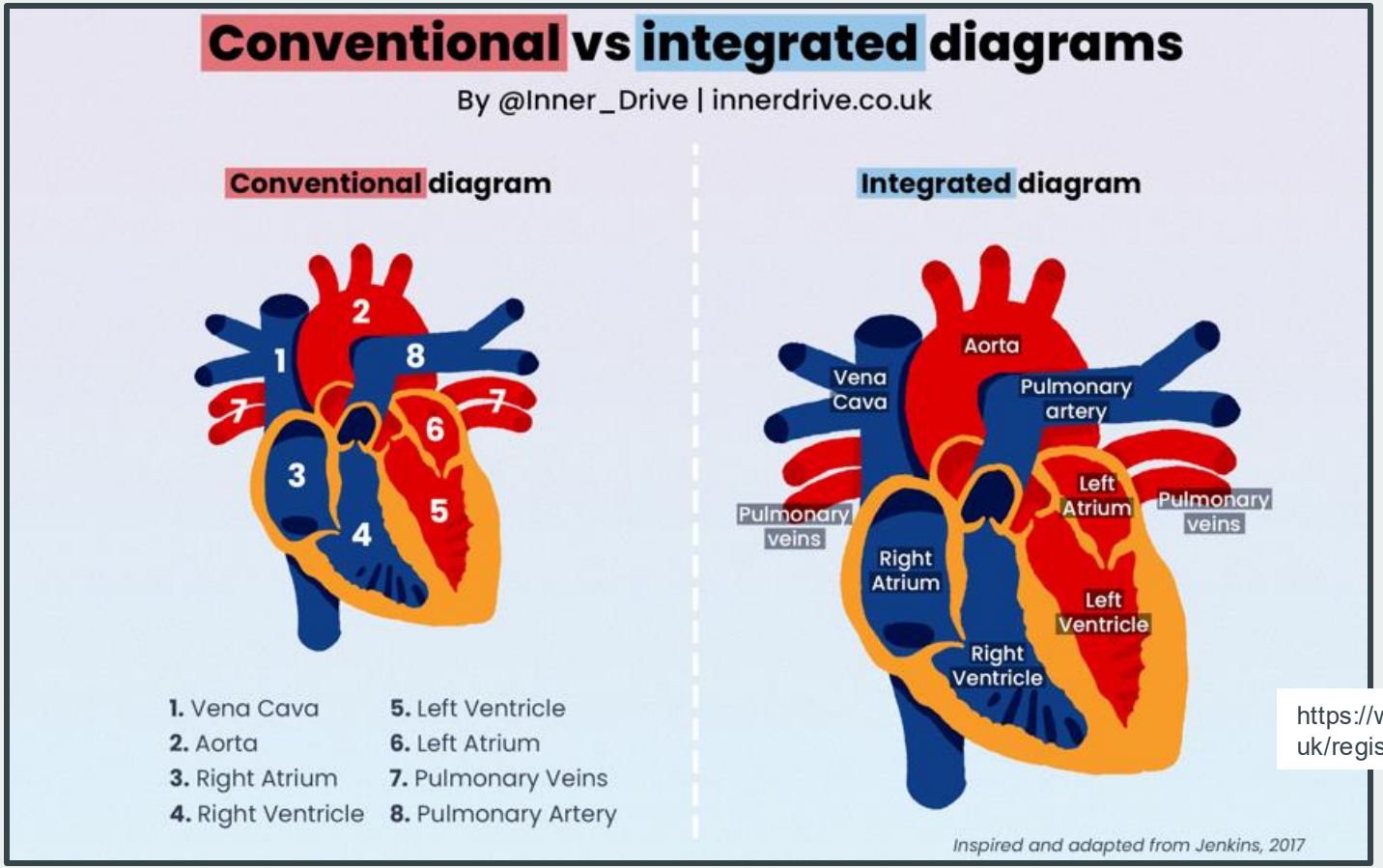
6. Simplify complex information by presenting it orally and visually

7. Encourage students to visualise concepts and procedures they have learnt

Example - Strategy 2: Worked Example Effect

Day 1	Day 2	Day 3
napkin - 2 animal - 3 basket - 2 tulip -2 fist -1 fantastic - 3 open - 2	napkin V V basket V V tulip V V open V V	nap.kin V c c V bas.ket V c c V mit.ten V c c V cop.per V c c V

Example - Strategy 5: Split Attention Effect



https://www.innerdrive.co.uk/registration-success/

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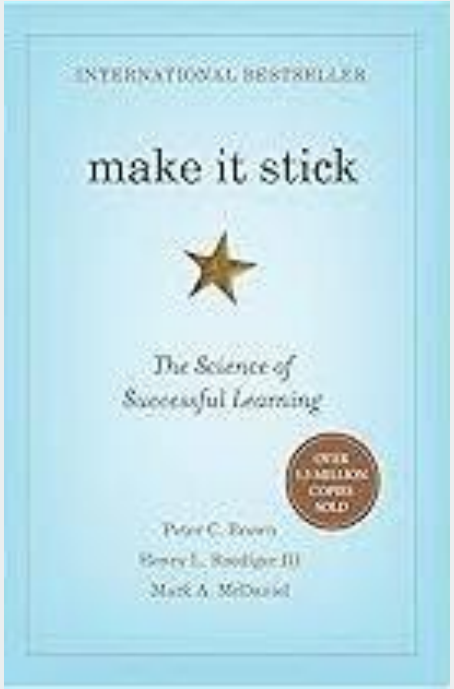

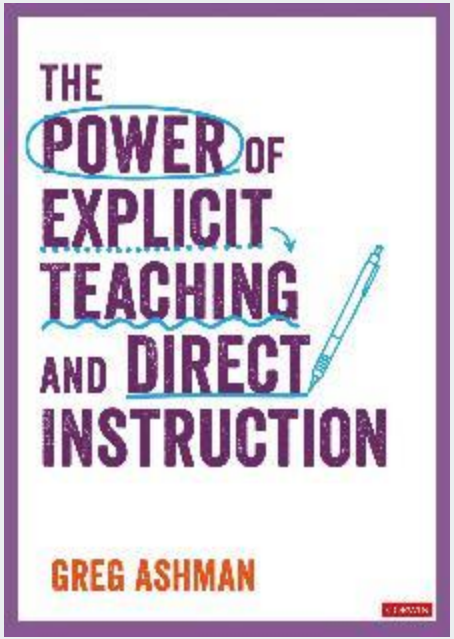

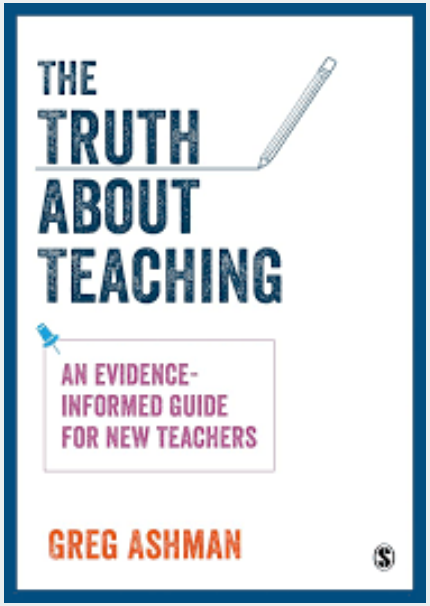

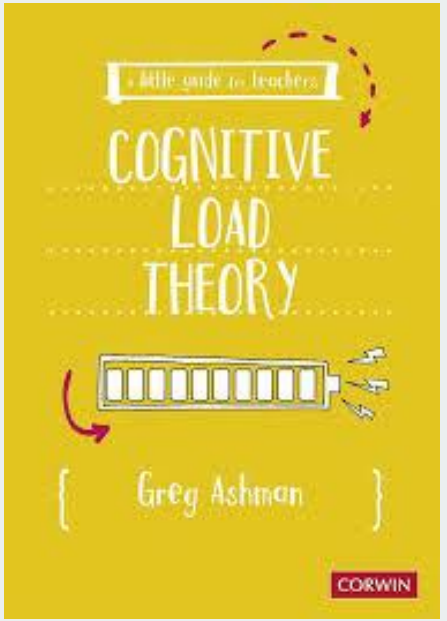

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