Designing courses that minimize cognitive overload in learners

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Overall Goal

To outline a methodology for **designing courses** that **minimize cognitive overload** in learners

Outline

Part I: Theories of Memory Processing and Learning

1. Information Processing Theory
2. Cognitive Load Theory

Part II: Cognitive Load Theory and Course Design

1. Identify Learner Personas / Types
2. Mental Models
3. Formative Assessments
4. Improving Course Content and Delivery

Learning Objectives

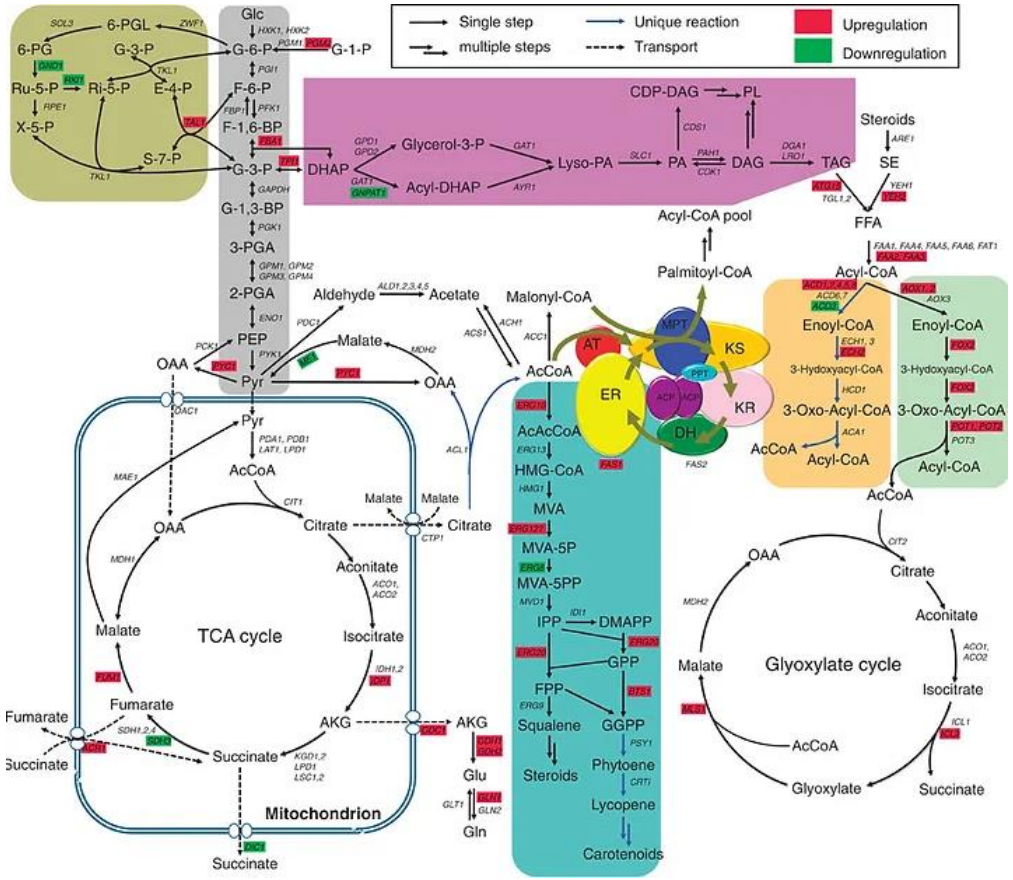
- Describe the main types of cognitive load and the limits of human memory.
- Explain the differences between various learner types / personas.
- Define mental models and create concept maps.
- Create formative assessments that diagnose flawed mental models.

Part I: Theories of Memory Processing and Learning

Prof. X's Biochemistry 101 Lecture

Prof. X

Today we will learn about metabolic pathways!

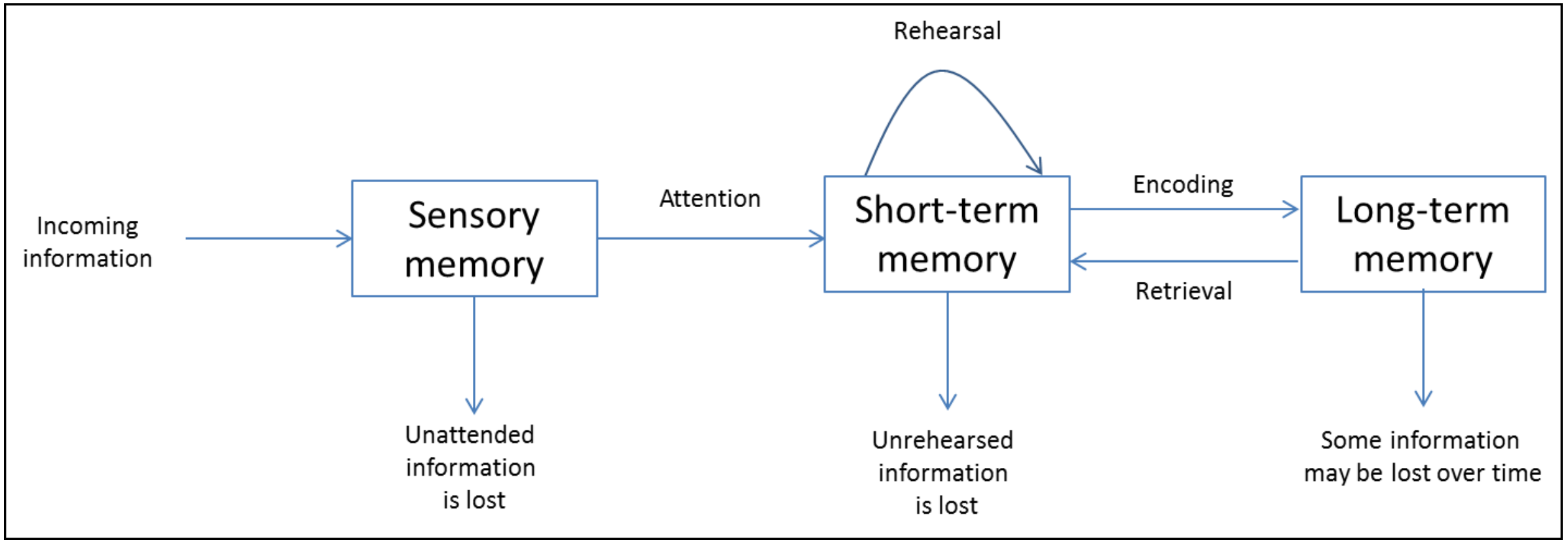


1. https://monicanasseri.wixsite.com/biochemical-pathways/biochemical-pathways

Information Processing Theory and Cognitive Load

1. Information Processing Theory

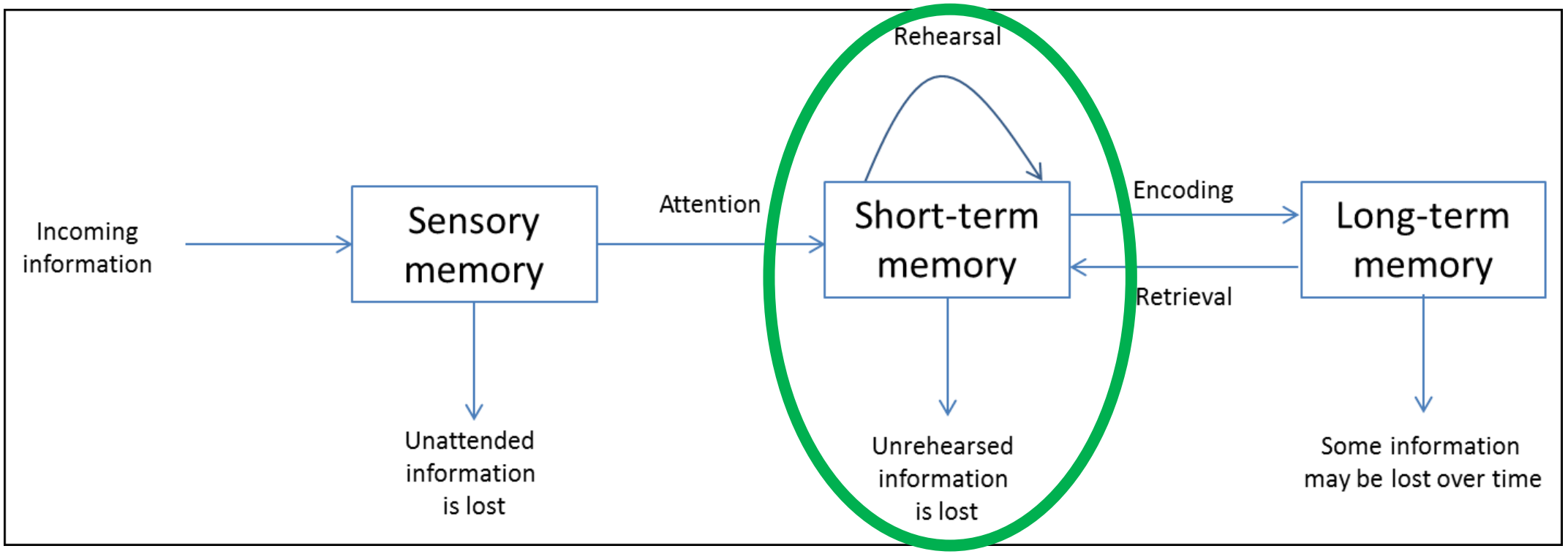
A framework for understanding how information is encoded into memory



1. Atkinson and Shiffrin (1968) Psychology of Learning and Motivation (2) 89-195
2. https://www.simplypsychology.org/multi-store.html

2. Cognitive Load

Available amount of information that the working / short-term memory can hold at a specific time (7 +/- 2 chunks of info at a time)



1. Atkinson and Shiffrin (1968) Psychology of Learning and Motivation (2) 89-195
2. https://www.simplypsychology.org/multi-store.html

3. Cognitive Load Theory

Describes how the human mind processes new information

3 Main Types of Cognitive Load

Intrinsic

Extraneous

Germane

1. Sweller, J. (1998) Cognitive Science 12(2): 257-285
2. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

3. Cognitive Load Theory

Intrinsic

- Innate difficulty of a task and complexity of new information.
- Influenced by age and/or educational background.

Example: High School Math Student

$2 \times 4 = 8$

Increasing Load

$$\int_0^2 x^2 \, dx$$

Low Load

High Load

1. Sweller, J. (1998) Cognitive Science 12(2): 257-285
2. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

3. Cognitive Load Theory

Extraneous

- Load due to poorly designed instructional material.

- Distracts working memory from processing the required information.

1. Sweller, J. (1998) Cognitive Science 12(2): 257-285
2. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

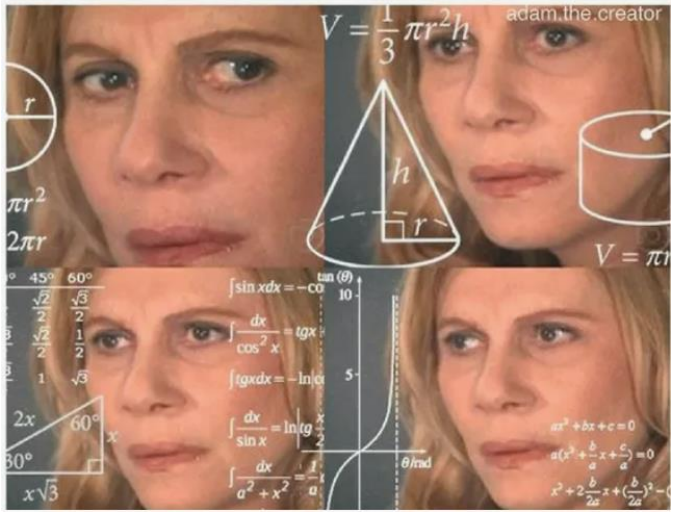
3. Cognitive Load Theory

Extraneous

Examples

Useless Animations

Memes



Use of unnecessarily complex words

- Sagacious vs. Wise

Other forms of load:

1. Software freezing
2. Files not loading
3. Links not working/paywalls
4. Internet and connectivity issues

1. Sweller, J. (1998) Cognitive Science 12(2): 257-285
2. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

3. Cognitive Load Theory

Germane

- Mental capacity used to integrate new information with existing knowledge
- Effort required to learn and retain the material
- Influenced by level of training (Math Professor vs 1st grader)

1. Sweller, J. (1998) Cognitive Science 12(2): 257-285
2. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

3. Cognitive Load Theory

Summary

Intrinsic	→	Simplify
Extraneous	→	Reduce
Germane	→	Maximize

1. https://mcdreeamiemusings.com/blog/2019/10/15/the-good-the-bad-and-the-can-be-ugly-the-three-parts-of-cognitive-load

Formative Assessment

Link in zoom chat

https://app.sli.do/event/oURSecWo4Su1juP7z13aKW

Extra credit: Short test of working memory

https://miku.github.io/activememory/

Can try during your free time / breaks

Break

5 minutes

Part II: Cognitive Load Theory and Course Design

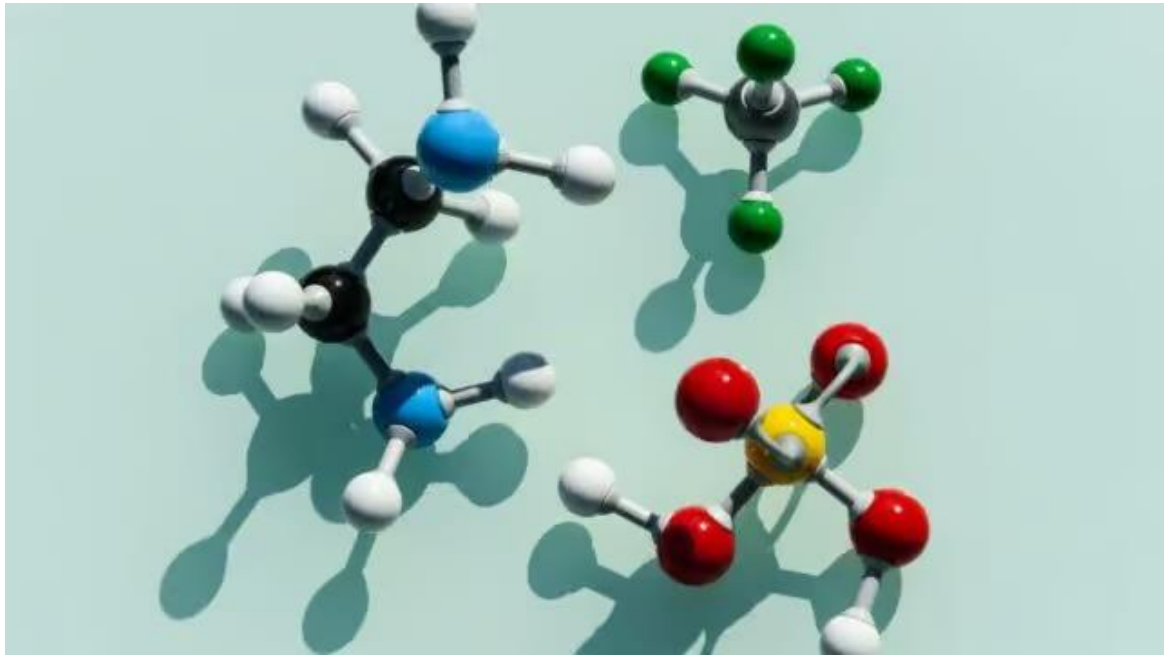
1. Identify Learner Personas / Types

Learners can be distinguished by the mental models they use to solve problems

1. https://carpentries.github.io/instructor-training/
2. Benner P. (2004) *Bulletin of Science, Technology & Society*, *24*(3), 188–199

2. Mental models

"A **simplified representation** of the most important parts of some problem domain that is good enough to enable problem solving."



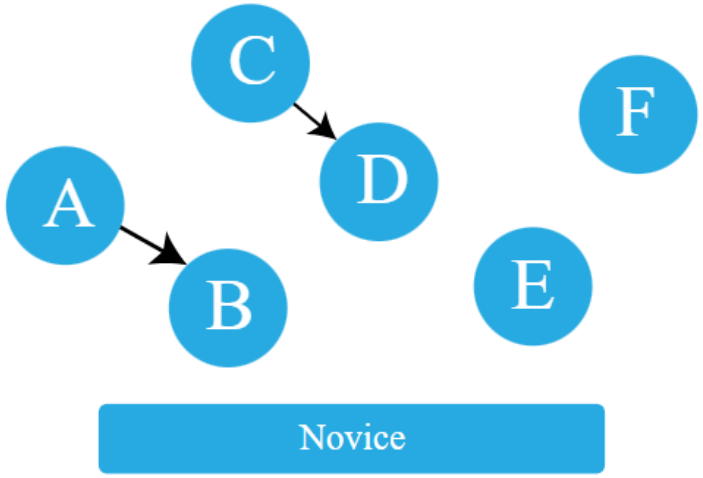
Ball-and-stick model

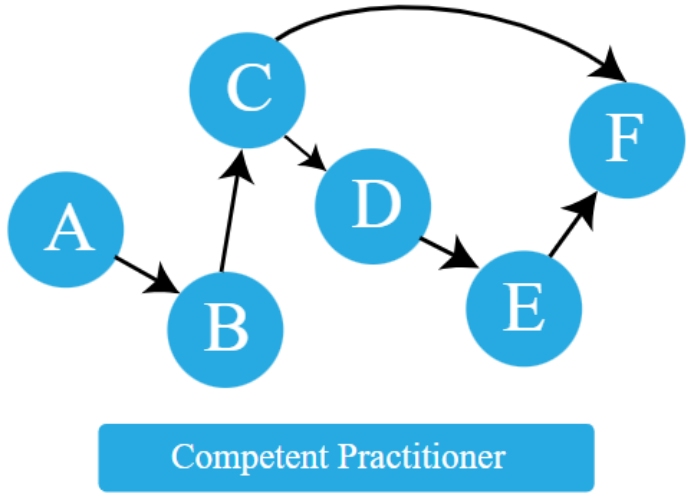
Limitations

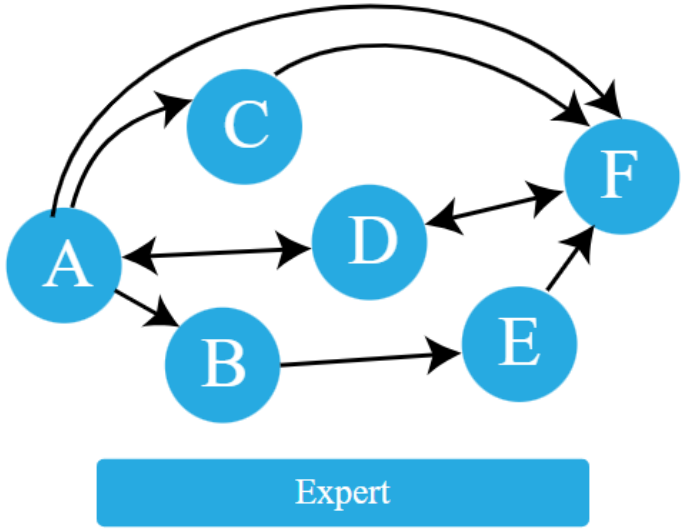
1. Simplified representation.
2. Atoms are not balls and sticks are not bonds.

1. https://commoncog.com/teaching-tech-together/
2. https://education.riaus.org.au/a-better-way-to-see-molecules/

2. Mental models







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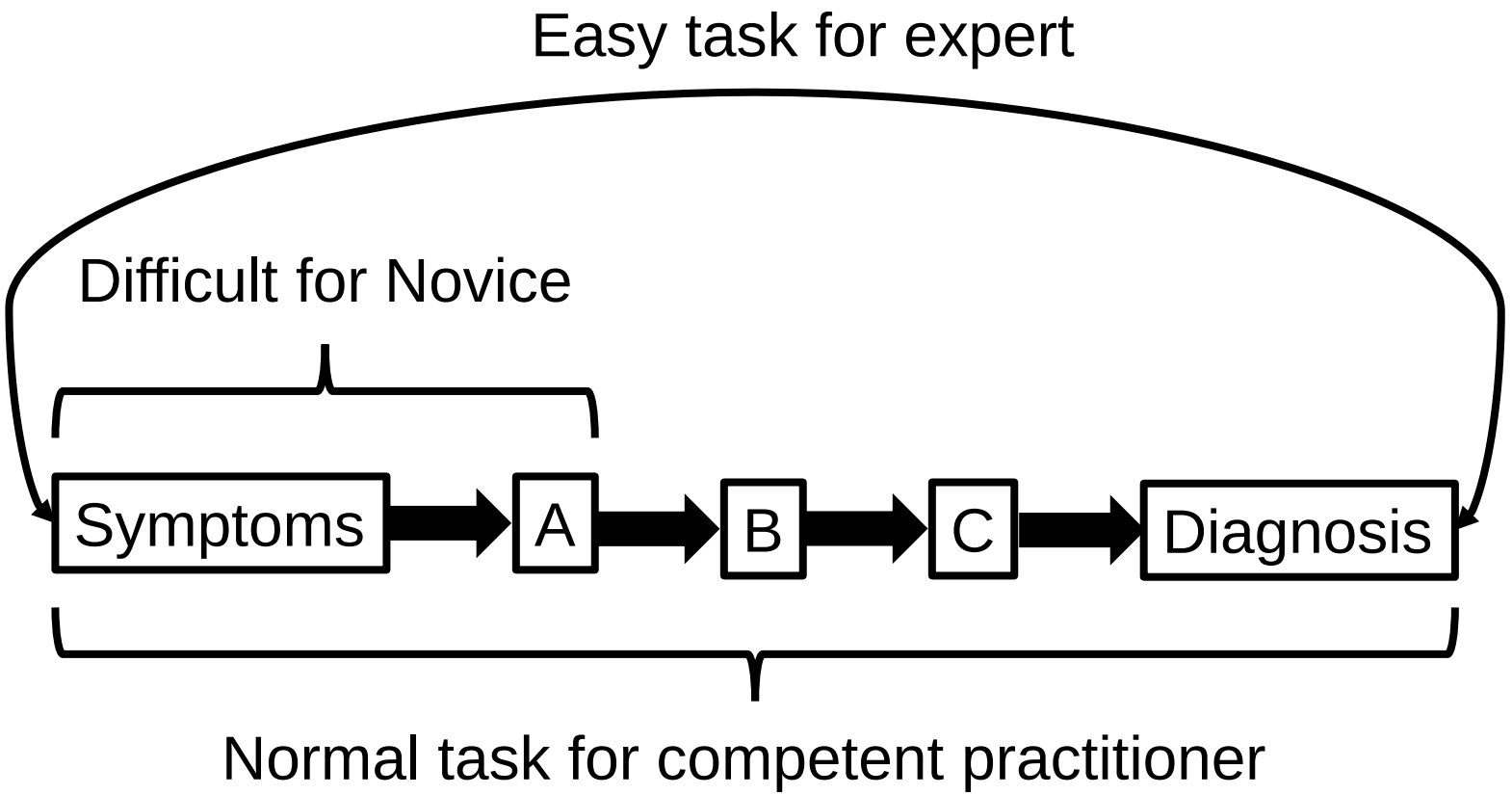
2. Mental models



3. Formative Assessments

Help to identify common misconceptions and broken mental models

1. **Factual errors**: The Capital City of Sweden is Doha.
2. **Broken models**: Motion and acceleration must always be in the same direction.
3. **Fundamental beliefs**: Some people are computational and others are not.

1. https://carpentries.github.io/instructor-training/

3. Formative Assessments

Example

Q: What is 27 + 15 ?

a) 42 → Correct

b) 32 → Forgotten to carry the 1

c) 312 → Treating each column independently

d) 33 → Carrying the 1 to the same column

Each incorrect answer has diagnostic power and will guide correction

1. https://carpentries.github.io/instructor-training/

3. Formative Assessments

Memory management

Parson's Problem

A.
```
ggplot(data = …, aes(x = …, y = …)) +
    geom_point()
```

B.
```
geom_point() +
    ggplot(data = …, aes(x = …, y = …))
```

C.
```
(data = …) +
    ggplot(aes(x = …, y = …)) +
    geom_point()
```

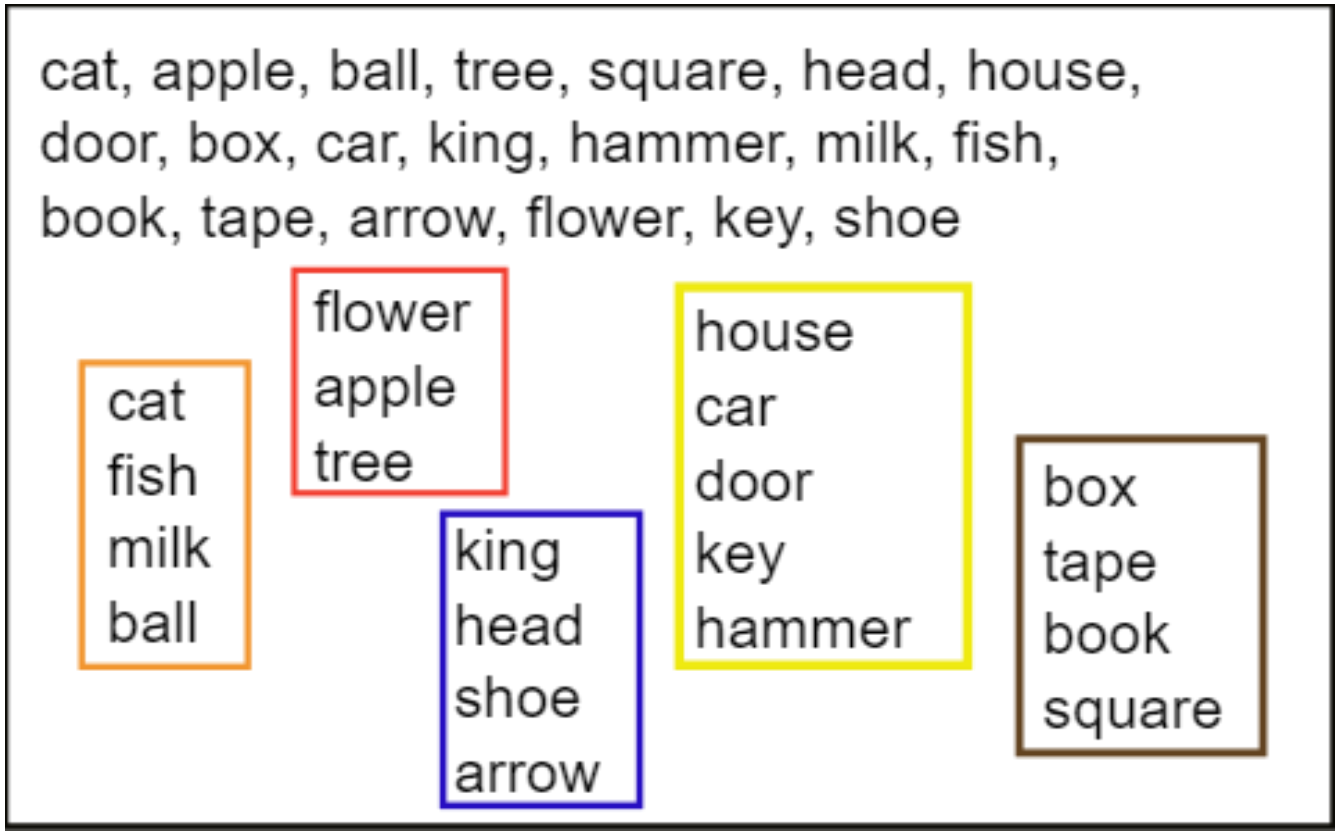
4. Improving course content and delivery

Chunking

Commonly used

cat, apple, ball, tree, square, head, house, door, box, car, king, hammer, milk, fish, book, tape, arrow, flower, key, shoe

Ideal



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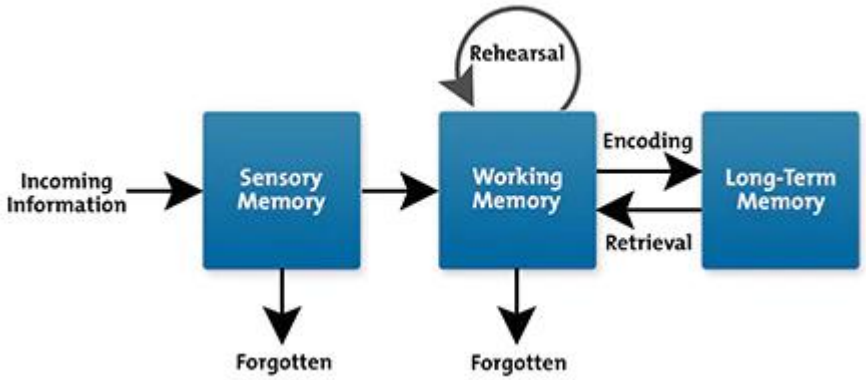
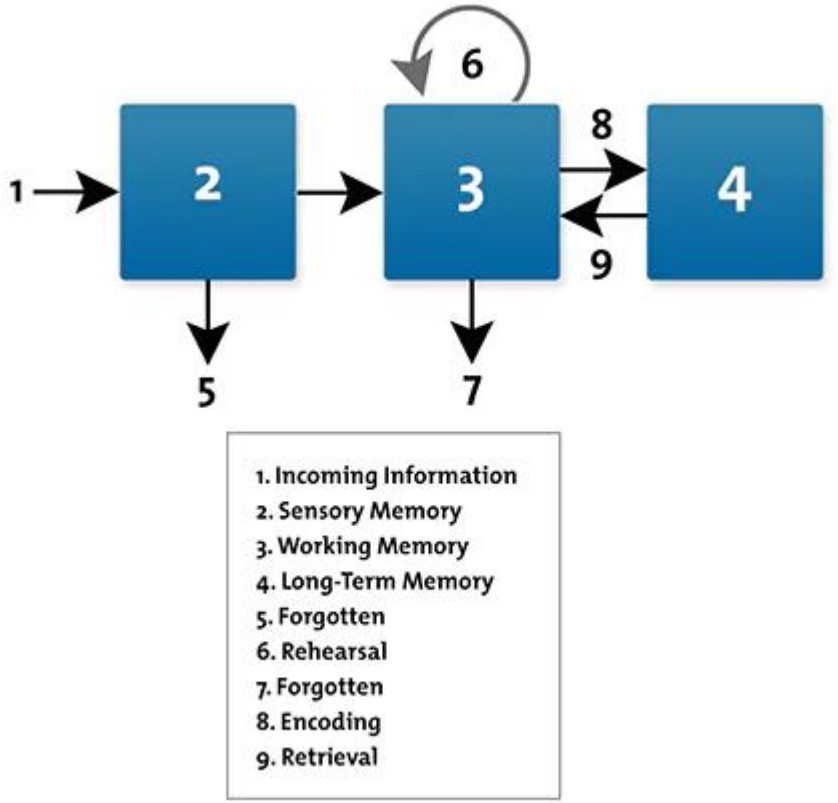
4. Improving course content and delivery

Reduce split-attention effect



vs

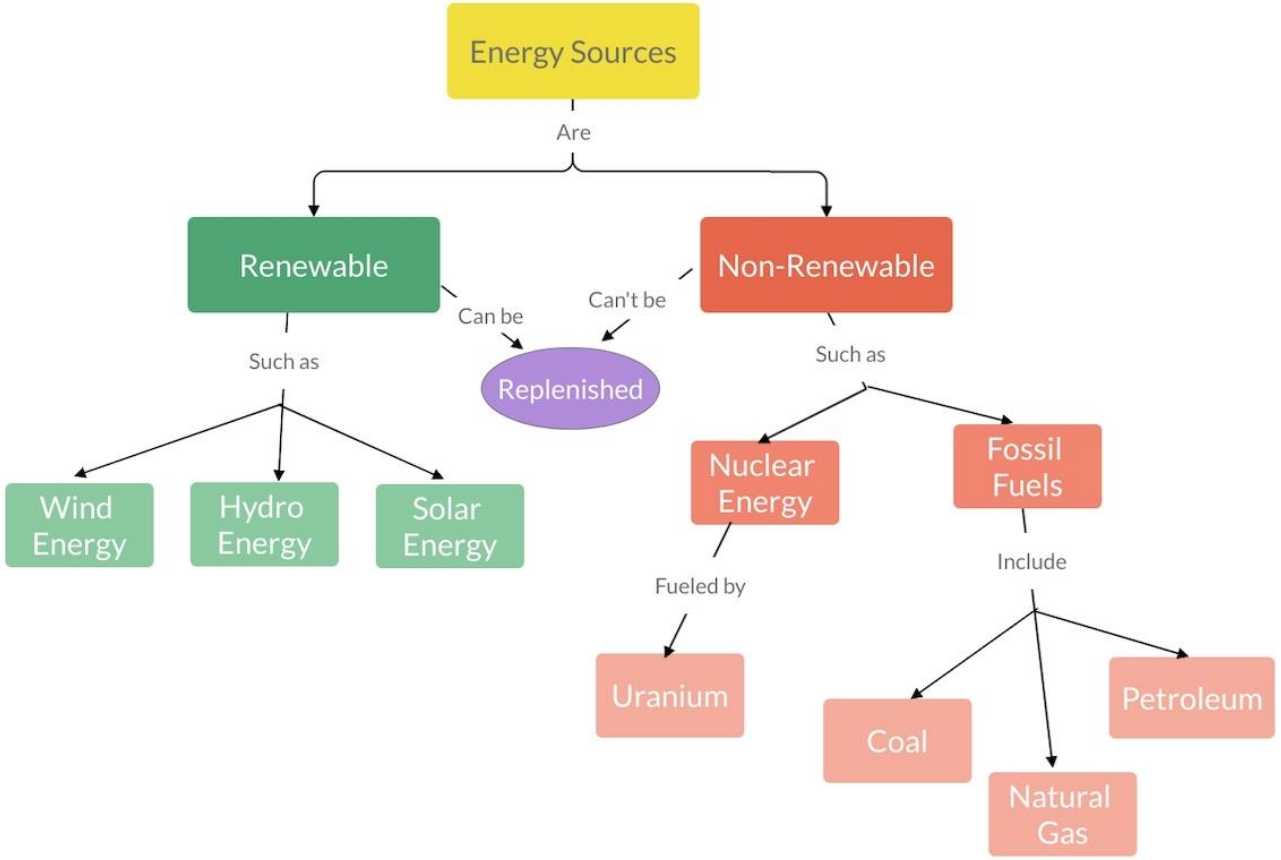


1. MindTools: https://www.mindtools.com/aqxwcpa/cognitive-load-theory

4. Improving course content and delivery

Encourage the use of concept maps

Example Discussion:
Renewable and Non-renewable Energy Sources



https://visme.co/blog/how-to-make-a-concept-map/

4. Improving course content and delivery

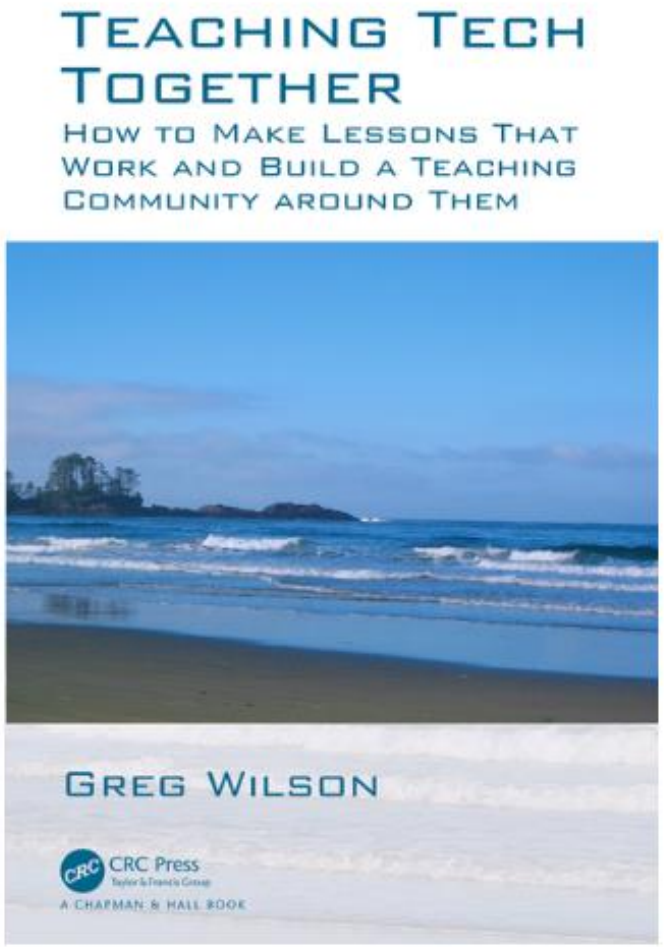
- Go slow and repeat if necessary
- Be aware of expert blind spots
- Use authentic tasks and examples to teach
- Give and receive appropriate feedback

1. https://carpentries.github.io/instructor-training/

Conclusions

- Cognitive load and working / short-term memory have a significant impact on learning outcomes.
- Knowledge of learner types and personas and the mental models they use is critical for effective teaching.
- Formative assessments should be incorporated into lessons to identify misconceptions and receive teaching feedback.

References



https://teachtogether.tech/

1. https://monicanasseri.wixsite.com/biochemical-pathways/biochemical-pathways
2. Atkinson and Shiffrin (1968) Psychology of Learning and Motivation (2) 89-195
3. https://www.simplypsychology.org/multi-store.html
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8. https://commoncog.com/teaching-tech-together/
9. https://education.riaus.org.au/a-better-way-to-see-molecules
10. https://www.mindtools.com/aqxwcpa/cognitive-load-theory
11. https://visme.co/blog/how-to-make-a-concept-map/

Discussion Questions

- Where have you identified “expert blind spots” in your own teaching?
- How can you reduce cognitive overload in the subjects that you teach?
- Based on what you have learnt, how will you structure your courses differently?