



How Learning Works: Working Memory and Cognitive Load

Types of Memory

- **Long-term** or **persistent** memory – unbounded, slow to access
- **Short-term** or **working** memory – faster, small
 - Can store 7 +/- 2 items for a short period (e.g. telephone numbers, programming)
 - Important in teaching
 - Lots of info, no practice vs.
 - Smaller amounts of info, interspersed with practice -> transfer into long-term memory
- This is why concept maps and formative assessments are so useful

Exercise 1: Test Your Working Memory



- Take a look at a short online test of working memory. You will be presented with a list of words, each shown for only a very short time. At the end, you will be asked to list as many of the words as you can remember.
- How many did you remember? Write your answer down.
- **Serial-position effect** - tendency to recall the first and last items in a series best

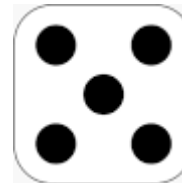
Strategies For Memory Management



- Techniques that we can use to improve our effective working memory and how this is applicable to our workshops
 - Formative assessment
 - Chunking
 - Concept maps as an instructional planning tool
 - Guided practice
 - Faded examples

Chunking

- Store larger number of facts in short-term memory by creating **chunks**, or relationships among separate items, causing them to be remembered as a single item
 - “cat” vs. “c-a-t”
 - Pattern of spots on a dice



Exercise 2: Improving Short-term Memory with Chunking



- Repeat the memory exercise you did earlier, but this time, try to form short stories or phrases, or a visual image, from the words you see.

Write the number of words you remembered.
How does this compare with your first attempt?

Concept Maps as Instructional Planning Tools



- A picture of someone's **mental model** of a domain
- **Facts** are bubbles, and **connections** are labelled arcs
- Identify the number of concepts introduced
 - Facts and relationships both count!

Concept Map Example: Loop in Python



```
for ch in "abc":  
    print(2*ch)
```

- Start with some concepts...

```
for ch in "abc":  
    print(2*ch)
```

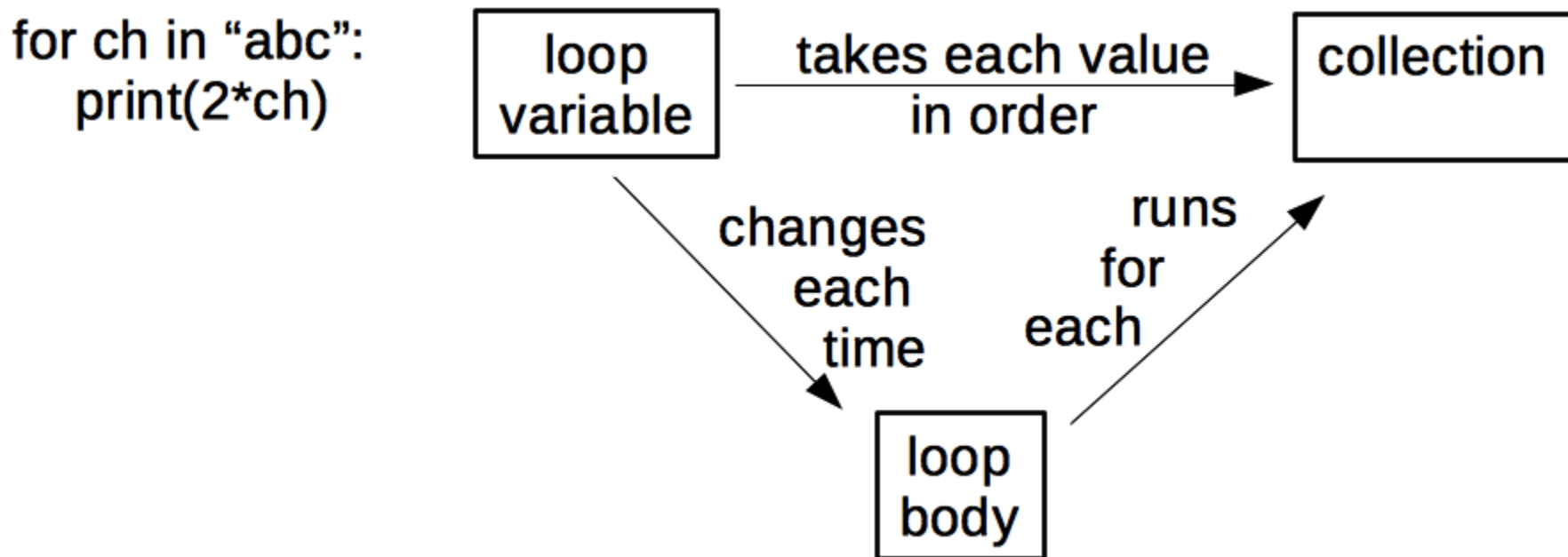
loop
variable

collection

loop
body

Concept Map Example: Loop in Python

- Add key relationships...

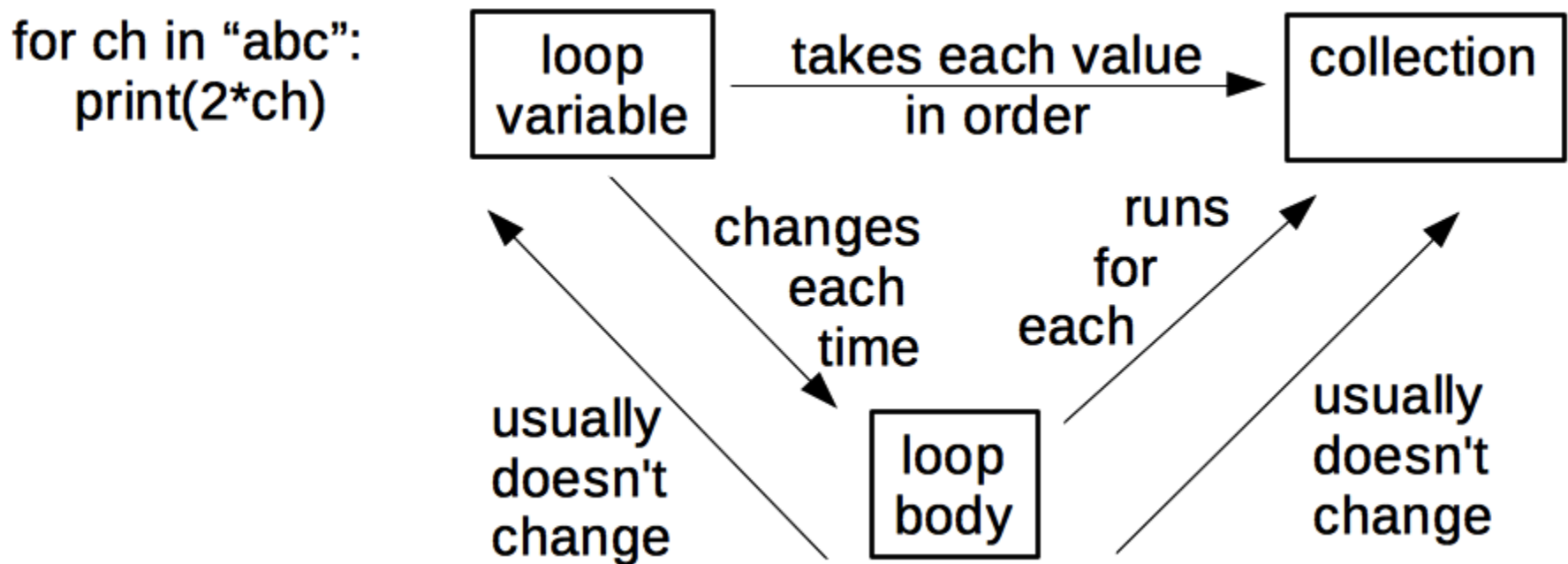


- There are 6 things here, not 3!

Concept Map Example: Loop in Python



- Add 2 facts to show what is usually true...



- That's 8 things – good size for a teaching episode

Other Concept Map Examples

- Array Math
- Conditionals
- Creating and Destroying Files
- Sets and Dictionaries in Python
- Input and Output
- Lists and Loops

Exercise 3: Concept Maps

- Create a hand-drawn concept map for a part of a Carpentry lesson you would teach in five minutes
- You can use the same subject about which you created a MCQ, or a different subject
- Trade with a partner, and critique each other's maps
- Are there any concepts missing? Are there more than a handful of concepts?

The Wonderful World of Concept Maps



- Help solo design of lessons
- Aid communication with fellow lesson designers
- Communication with learners
 - Group discussion
 - Formative assessment
- Sketching out concepts for presentations or papers or at a project team meeting

Concept maps externalise cognition

Guided Practice

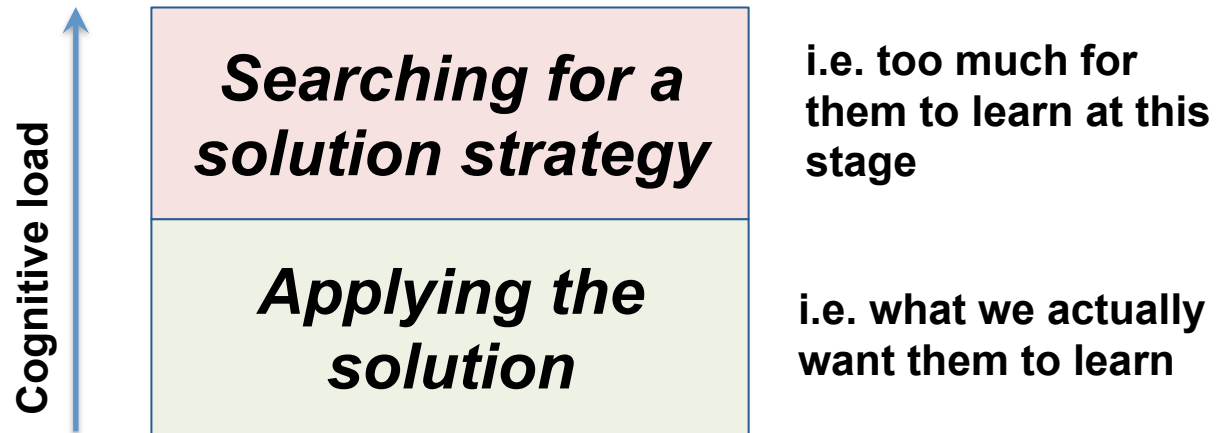
- Learners can test their skills and get feedback on their progress
- In 2006, Kirschner, Sweller, and Clark published a paper titled “Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching”
- The reason: **cognitive load is too high**

Types of Cognitive Load

- **Intrinsic** – needed to carry out a learning task
- **Germane** – (desirable) mental effort to create links between new information and old
- **Extraneous** – everything else that distracts or gets in the way (undesirable)
- **Cognitive load theory**: eliminating extraneous cognitive load accelerates learning

Reducing the Burden

The problem:



- So:
 - Remove extraneous cognitive load
 - Give learners a solution strategy – so they don't have to find one

Cognitive Load: Split-Attention Effect



- **Linguistic** and **visual** input are **processed** and **stored** separately by different parts of the brain
- Correlating linguistic, auditory and visual streams of information takes cognitive effort
- Brain reconciles the information – is it the same?
- Learning is more effective when information being presented simultaneously on two different channels is **redundant**
- Instructors says the commands out loud while typing

Faded Examples

- According to cognitive load theory, searching for a solution strategy is an extra burden on top of applying that strategy
- Accelerate learning by:
 - Presenting a step-by-step solution
 - Followed by a set of faded examples
- A couple of blanks to fill in
- At each step - a new problem to tackle
 - “scaffolding” of support gradually removed
- Less intimidating than a blank paper
- Encourage creating linkages between various approaches

Faded Example Example

```
def total_length(words):  
    """Returns the total length of all words in a list combined.  
  
    Example:  
        total_length(["red", "green", "blue"]) => 12  
    """  
    total = 0  
    for word in words:  
        total += len(word)  
    return total
```

```
def word_lengths(words):  
    """Returns a list of lengths of each word in a list.  
  
    Example:  
        word_lengths(["red", "green", "blue"]) => [3, 5, 4]  
    """  
    lengths =       
    for word in words:  
        lengths.append(len(word))  
    return lengths
```

Faded Example Example

```
def concatenate_all(words):
    """Combines all words in a list into one.

    Example:
        concatenate_all(["red", "green", "blue"]) => "redgreenblue"
    """
    result = ""
    for word in words:
        result += word
    return result
```

```
def acronymize(words):
    """Returns the first letter of each word in a list capitalised in a single string.

    Example:
        acronymize(["red", "green", "blue"]) => "RGB"
    """
    _____
```

Exercise 4: Create a Faded Example From a Lesson

- Split into groups of 2-3
- Pick a block of code from an existing Software or Data Carpentry lesson, or from another lesson you have taught recently
- Replace 2-3 pieces of the code with a blank
- Write a question to test a student's ability to correctly fill in that blank

Summary

- Most adults can store only a few items in **short-term memory** for a few seconds before they lose them again
- Things seen together are remembered in **chunks**
- Teaching consists of loading short-term memory and **reinforcing** it long enough for items to be transferred to long-term memory
 - Formative assessment
- Decreased cognitive load aids learning
 - Faded examples