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Concept Mapping as a Meaningful Learning Tool to Promote Conceptual Understanding and Clinical Reasoning for Resident and Distance Learning Students

Gregory G. Passmore  
*Georgia Regents University, gpassmor@gru.edu*

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Concept Mapping as a Meaningful Learning Tool to Promote Conceptual Understanding and Clinical Reasoning for Resident and Distance Learning Students

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Department of Medical Laboratory, Imaging, and Radiologic Sciences
Georgia Regents University
Augusta, Georgia
gpassmor@gru.edu
WORKSHOP ACTIVITIES

- Introduction
- Exploration
  - How to make and use C maps
- Explanation
  - Learning Theory, Research, and C maps
- Application
  - Practice making and using C maps
Introduction: Student Radiation Protection Concept Maps

Map with relationships and interconnectivity:

- **Characteristic**: Less exposure time = less radiation exposure
- **Characteristic**: More time elapses = less activity
- **Characteristic**: Lower activity = lower exposure

Map as “flow diagram”: no relationships

- **Radiation protection**
  - **Time**
    - Increase time
      - Decrease activity
  - **Distance**
    - Increase distance
      - Decrease activity
  - **Shielding**
    - Reduce exposure
    - Increase thickness
      - Decrease activity
    - Syringe shields
    - Lead plates
INTRODUCTION: CONCEPT MAP WITH REMEDIATION COMMENTS/CORRECTIONS

Radiation Protection

Leads to

Reduced Exposures

3 Simple Steps

Time

Distance

Shielding

As time gets longer, activity of radioactive material reduces

Def

Half life

Inverse Square Law
radiation intensity at a distance is equal to the inverse square of the distance

Def

ex

I1 D1 = I2 D2
I1 D1 2 = I2 D2 2

Hinders exposure
More shielding
Less exposure

Attenuation

Scatter

Absorption

measured as

Half value layer
or Thickness
EXPLORATION: CONCEPT MAPPING

HOW DO YOU MAKE CONCEPT MAPS?

• Simplest Unit is a Concept Dumbbell
  – two concepts and their relationships in the form of two nodes and the link between them

INTENSIVE STUDYING \(\rightarrow\) Leads to \(\rightarrow\) GOOD GRADES

Gregory Passmore
EXPLORATION: CONCEPT MAPPING

HOW DO YOU MAKE SIMPLE CONCEPT MAPS?
• Linking Relationships

<table>
<thead>
<tr>
<th>DESCRIPTIVE</th>
<th>DYNAMIC</th>
<th>ELABORATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (T)</td>
<td>Leads to (L)</td>
<td>Example (EX)</td>
</tr>
<tr>
<td>Part (P)</td>
<td>Next (N)</td>
<td>Analogy (A)</td>
</tr>
<tr>
<td>Characteristic (C)</td>
<td>Influences (I)</td>
<td>Comment (CO)</td>
</tr>
</tbody>
</table>

(Dansereau & Cross, Knowledge Mapping. 1990)
EXPLORATION: CONCEPT MAPPING

HOW DO YOU MAKE CONCEPT MAPS?

  - Deductive
  - Good grasp of knowledge domain
  - Top to Bottom Approach most Efficient
    - Most Inclusive or General Concepts at Top
    - Narrow and Specific Concepts Underneath
    - Important to Identify Linking Relationships

EXPLORATION: Focus Question Mapping

Concept List Parking Lot with Focus Question

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Universe</th>
<th>Focus question: What is the structure of the Universe?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecules</td>
<td>Mass</td>
<td></td>
</tr>
<tr>
<td>Matter</td>
<td>Energy</td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>Heat</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>Stored</td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>Elements</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>Space</td>
<td></td>
</tr>
<tr>
<td>Transformations</td>
<td>State of Matter</td>
<td></td>
</tr>
<tr>
<td>Motion</td>
<td>Gases</td>
<td></td>
</tr>
<tr>
<td>Kinetic energy</td>
<td>Liquids</td>
<td></td>
</tr>
<tr>
<td>Potential energy</td>
<td>Solids</td>
<td></td>
</tr>
</tbody>
</table>

Focus Question, Concept List, and Hierarchical Skeleton

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Molecules</th>
<th>Focus question: What is the structure of the Universe?</th>
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</thead>
<tbody>
<tr>
<td>Heat</td>
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<td></td>
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<tr>
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<td>Solids</td>
<td>Stored</td>
<td></td>
</tr>
</tbody>
</table>

EXPLORATION: RELATIONSHIP-GUIDED SEARCH - RGS

• Start with a central concept and ask the following:
  – Can this concept be broken down into different types?
  – What are the characteristics of each type?
  – What are the important parts of each type?
  – What led to the starting concept? Or where does it lead to?
  – What influences the starting concept? Or what does it influence?
  – What happens next? Can I elaborate with an analogy or example?

(Dansereau & Cross, Knowledge Mapping, 1990)
EXPLORATION: RELATIONSHIP-GUIDED SEARCH - RGS
EXPLORATION: Fill in the blank concept and/or linking relationship
EXPLORATION:
Fill in the blank concept and/or linking relationship
EXPLORATION: Fill in the blank concept and/or linking relationship
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Fill in the blank concept and/or linking relationship
EXPLORATION:
Fill in the blank concept and/or linking relationship
EXPLORATION:
Fill in the blank concept and/or linking relationship
EXPLORATION: Fill in the blank concept and/or linking relationship

INSECT \( T \) ANT

FLU \( C \) FEVER

EYE \( \text{An} \) CAMERA

CAR \( P \) Tire

PARTY!!! \( L \) POOR GRADES

EAT MAIN COURSE \( N \) DESSERT
EXPLORATION:
Fill in the blank concept and/or linking relationship
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EXPLORATION: Fill in the blank concept and/or linking relationship
EXPLORATION: Construct a Concept Map from the statements provided.

<table>
<thead>
<tr>
<th>RAPTORIAL BIRDS INCLUDE EAGLES AND CONDORS, A TYPE OF AMERICAN VULTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>FRONTAL DISPLAYS AND LATERAL ATTACKS ARE TWO KINDS OF AGGRESSIVE BEHAVIOR IN THE PARADISE FISH</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
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EXPLORATION: Construct a Concept Map from the statements provided.

RAPTORIAL BIRDS INCLUDE EAGLES AND CONDORS, A TYPE OF AMERICAN VULTURE

FRONTAL DISPLAYS AND LATERAL ATTACKS ARE TWO KINDS OF AGGRESSIVE BEHAVIOR IN THE PARADISE FISH
EXPLORATION: Construct a Concept Map from the statements provided.

**RAPTORIAL BIRDS**
- Include Eagles and Condors, a type of American Vulture

**FRONTAL DISPLAYS AND LATERAL ATTACKS**
- Are two kinds of aggressive behavior in the Paradise Fish
EXPLORATION: Construct a Concept Map from the statements provided.

RAPTORIAL BIRDS include eagles and condors, a type of American vulture.

Frontal displays and lateral attacks are two kinds of aggressive behavior in the paradise fish.

- RAPTORIAL BIRDS
  - Eagle
  - American Vulture
    - T
    - T or Ex: Condor

- Paradise Fish
EXPLORATION: Construct a Concept Map from the statements provided.

RAPTORIAL BIRDS INCLUDE EAGLES AND CONDORS, A TYPE OF AMERICAN VULTURE

FRONTAL DISPLAYS AND LATERAL ATTACKS ARE TWO KINDS OF AGGRESSIVE BEHAVIOR IN THE PARADISE FISH

PARADISE FISH

AGGRESSIVE BEHAVIOR
EXPLORATION: Construct a Concept Map from the statements provided.

RAPTORIAL BIRDS INCLUDE EAGLES AND CONDORS, A TYPE OF AMERICAN VULTURE

FRONTAL DISPLAYS AND LATERAL ATTACKS ARE TWO KINDS OF AGGRESSIVE BEHAVIOR IN THE PARADISE FISH

RAPTORIAL BIRDS

- T
  - EAGLE
- T
  - AMERICAN VULTURE
  - T or Ex
    - CONDOR

PARADISE FISH

- C
  - AGGRESSIVE BEHAVIOR
    - FRONTAL DISPLAY
    - LATERAL ATTACK
EXPLORATION: Construct a Concept Map from the statements provided.

RAPTORIAL BIRDS INCLUDE EAGLES AND CONDORS, A TYPE OF AMERICAN VULTURE

PARADISE FISH

FRONTAL DISPLAYS AND LATERAL ATTACKS ARE TWO KINDS OF AGGRESSIVE BEHAVIOR IN THE PARADISE FISH
**EXPLORATION: Construct a Concept Map from the statements provided.**

<table>
<thead>
<tr>
<th>CONGRESS IS COMPOSED OF THE SENATE AND THE HOUSE OF REPRESENTATIVES</th>
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<tr>
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CONGRESS

P

SENATE

P

HOUSE OF REPRESENTATIVES

EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION
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EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION

PRINCIPLE OF VACCINATION
EXPLORATION: Construct a Concept Map from the statements provided.

CONGRESS IS COMPOSED OF THE SENATE AND THE HOUSE OF REPRESENTATIVES

CONGRESS

SENATE

HOUSE OF REPRESENTATIVES

EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION

PRINCIPLE OF VACCINATION from EXPERIMENTS
EXPLORATION: Construct a Concept Map from the statements provided.

CONGRESS IS COMPOSED OF THE SENATE AND THE HOUSE OF REPRESENTATIVES

CONGRESS

P

SENATE

P

HOUSE OF REPRESENTATIVES

EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION

PRINCIPLE OF VACCINATION

from

EXPERIMENTS

with

2 POX
CONGRESS IS COMPOSED OF THE SENATE AND THE HOUSE OF REPRESENTATIVES

EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION

PRINCIPLE OF VACCINATION from EXPERIMENTS with 2 POX

COW T

T SMALL
EXPLORATION: Construct a Concept Map from the statements provided.

CONGRESS IS COMPOSED OF THE SENATE AND THE HOUSE OF REPRESENTATIVES

EXPERIMENTS WITH TWO DISEASES OF THE POX STRAIN, COW POX AND SMALL POX, RESULTED IN THE PRINCIPLE OF VACCINATION
YOUR TURN:

Using the RGS questions and linking relationships listed in your handout, develop a simple concept map for the concept of COMMON COLD.
EXPLORATION: RGS – COMMON COLD

What are some types of colds?

What are some characteristics?

What leads to a cold?

What happens next?
EXPLORATION: RGS – COMMON COLD

What are some types of colds?

- Common Cold
  - Head
  - Chest

What are characteristics of a cold or types?

- Fever w/Flu
  - Comment
- NOT Fever
  - Characteristic
    - Common Cold
      - Type: Head
      - Characteristic: Congestion
      - Type: Chest
      - Characteristic: Cough
EXPLORATION: RGS – COMMON COLD

What leads to a cold?

- Fever w/Flu
- Common Cold
  - Head
  - Chest
  - Congestion
  - Cough

What happens next with a cold?

- Exposure to Cold Virus
  - Fever w/Flu
  - NOT Fever
    - characteristic
  - Common Cold
    - type
      - Head
      - Chest
    - characteristic
      - Congestion
      - Cough
  - characteristic
    - Recovery
    - Bronchitis Pneumonia Sinusitis
    - next
      - characteristic
      - next
      - next
      - next
      - Cough
EXPLANATION: LEARNING & TEACHING

LEARNING THEORY

ACTIVE LEARNING
- Knowledge is built from experiences
- Learning is a structuring process
- Teacher facilitates student learning

CONSTRUCTIVIST PHILOSOPHY
- Conceptual, Relational, Hierarchical
- Knowledge is stored in idiosyncratic cognitive structures
- Prior knowledge influences new learning
- Knowledge is constructed through meaningful learning

OBJECTIVIST PHILOSOPHY
- Teacher conveys structure to student
- Teacher elicits behaviors

Behavior indicates learning
- Rote Memorization
- Arbitrary Assimilation
- Memory Schemes

COGNITIVE LEARNING THEORY
- Integration
- Differentiation
- Metacognitive Activity
- Assimilation
- Accommodation
- Equilibrium

AUSUBEL
- Integration
- Differentiation
- Metacognitive Activity

NEEDFUL LEARNING PRINCIPLES
- Concept maps
- Vee Diagrams

TEACHING STRATEGIES
- Teaching should help student make connections
- Learning has to be elicited in some fashion
- Teaching elicits behaviors

Student - passive recipient
- Teacher conveys structure to student
- Teacher elicits behaviors

Student - active participant
- Teacher facilitates student learning
- Knowledge from objective measurements & discovery
- Learn the inherent structure of the discipline
- Teacher conveys structure to student

Behavior indicates learning
- Rote Memorization
- Arbitrary Assimilation
- Memory Schemes

Teaching elicits behaviors
- Concept maps
- Vee Diagrams

Knowledge is constructed through meaningful learning
- Knowledge can be elicited using Concept maps & Vee Diagrams
Meaningful learning continuum

Meaningful learning principles applied in LTM = Computer Storage

Information processed and retrieved in chunks of 5-7 units

Computer processor and storage as model for learning

WM = Computer Processor

LTM = Computer Storage

EXPLANATION: LEARNING & TEACHING

MEANINGFUL LEARNING PRINCIPLES

TEACHING STRATEGIES

IP

PCK

Help Student Organize Knowledge Structure

Similar to Discipline Knowledge Structure

Monitor & Control

Facilitation

Elicit Student Knowledge Structure

Misconception Identification & Remediation

Ascertain what the student knows and teach accordingly

EXTERNALIZE & MODIFY

CONCEPTUAL CHANGE

PROBLEM SOLVING (IDEAL)

SHARE (Maps/Diagrams)

APPLY (Problem solving)

FOCUS (Analogy)

CHALLENGE (Discrepant Event)

EXPOSITORY L/L (with application)

Misconception Identification & Remediation

knowledge is stored in conceptual, relational, & hierarchical structures

knowledge is constructed meaningfully through non-arbitrary assimilation

knowledge can be elicited through maps and diagrams

Auspell

Identify the problem

Define the variables

Explore solutions

Apply solutions

Look for alternatives

types include

def'n

Identify the problem

Define the variables

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Apply solutions

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types include

Auspell

Identify the problem

Define the variables

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Apply solutions

Look for alternatives

Advances and complexities in the field of Nuclear Medicine require that NMT students move away from dependency on memorization and learn with a meaningful understanding of the discipline's principles.

Metacognitive learning strategies are based on instructional learning theory which promote deep, meaningful learning.

Test both resident and distance learning NMT students to determine if students perform better when traditional instruction is supplemented with the non-traditional metacognitive learning strategy commonly known as concept mapping.
EXPLANATION: CONCEPT MAPPING
EMPIRICAL EVIDENCE - STUDENT COMPARISONS

- Quasi-experimental 2 group design: O X O: O _ O
- First study: 2 resident student groups separated by time but equalized on SAT scores
- Second study: 2 distance learning student groups separated by time but equalized on admissions scores
- Concept map used as metacognitive learning strategy
- Additional course content included the standard homework problem assignment, laboratory, and opportunity for question-answer sessions;
- Laboratory on Interactions of radiation, detection, stats and NM QC
- Concept mapping group used maps as the template for misconception identification and remediation interactions between the instructor and the student.
- The control groups relied on homework problems and question-answer sessions alone.
- The course final examination was used to facilitate a quantitative comparison between the performance of concept mapping students and non-mapping students.
Note: results of applying Concept Map intervention to Radiation Physics w/Laboratory Course. Significant performance gains noted. Some interaction.

Course performance as a function of SAT scores and Mapping intervention

- Low SAT: Control - 73.4, Concept-Map - 91.8
- Moderate SAT: Control - 88.3, Concept-Map - 91.3
- High SAT: Control - 88.5, Concept-Map - 95.1

**ANCOVA**

\[ F = 5.123; p = 0.0340; N = 24 \]
EXPLANATION: CONCEPT MAPPING
EMPIRICAL EVIDENCE – DISTANCE
STUDENT COMPARISONS

Note: comparison between mapping and non-mapping groups in Radiation Physics And Protection Course w/Laboratory

*Mann Whitney U Test:
Z = -2.0381, p = 0.0415, n = 25
Explanation: Learning – Instruction Continuum
Meaningful Learning from Concept Mapping

Novak & Canas, 2006
EXPLANATION: MEANINGFUL LEARNING FROM LABORATORY

From the Theory/Continua: A student who learns by….

- Rote Learning + Reception Instruction
  - Memorize clinical protocol
  - Unable to work with new protocol/change/modification/variation

- Meaningful Learning + Guided Discovery (Problems w limits)
  - Know protocol and Understand protocol
  - Able to work with new protocol/change/modification/variation

- Meaningful Learning + Autonomous Discovery (Problems w/o limits)
  - Understand protocol
  - Creates new protocol for each application
  - Process not suitable for clinical education/application
EXPLANATION: LEARNING AND LABORATORY

• Students need to be helped to recognize
  – What concepts they already know that relate to the observed events or objects
  – What events or objects they are observing
  – What records are worth making

• Bridge the gap: the “doing” or procedural part of the laboratory needs to be related to the conceptual or “thinking” part of the laboratory for meaningful learning to come from a laboratory activity

• “Knowledge is not discovered like gold or oil, but rather is constructed like cars or pyramids”
  -Novak & Gowin (1984)
EXPLANATION: CONCEPT MAPPING
LEARNING AND ASSESSMENT TOOL

- Used as a comprehension/misconception check
- Can be assessed using a scoring rubric according to accuracy, depth, and degree of integration or synthesis of knowledge
  - 1 point each valid relationship
  - 5 points each valid level of hierarchy
  - 10 points each valid and significant cross link between different segments in the map as evidence of synthesis of knowledge

Novak & Gowin, Learning How to Learn. 1984
EXPLANATION: LEARNING, ASSESSMENT, AND REMEDIATION

APPLICATION: CONCEPT MAP

YOUR TURN!

• Construct a concept map from the paragraphs on memory that follow.
THE INFORMATION PROCESSING MODEL OF MEMORY

- **Information processing** begins with the **stimulus** from the external environment. If we do not pay **attention** to the new information coming in, it’s **forgotten**; if we do pay attention to it, it moves to the **short-term memory (STM)** storage system. Short term memory is **conscious/working memory** - all that we are aware of at one time. The **capacity** of this store is **limited** to about 7 +/- 2 chunks of information. Information in STM can be **bumped out** by new information (**forgotten**).

- Information in STM, if **rehearsed** or **encoded**, remains the **focus of attention** and is passed along to the **long-term memory (LTM)**. Information that is encoded without attention to **prior knowledge** is **rotely learned**. Information that is encoded with attention to prior knowledge is **meaningfully learned**. This is accomplished via concept **assimilation**: integration or differentiation.

- The **capacity** of LTM is probably **unlimited**. The information stored in LTM is **rarely forgotten**, although we may have **difficulty in retrieving** it because of the way we search for it.
HOW DO WE REMEMBER ACCORDING TO THE INFORMATION PROCESSING MODEL OF MEMORY?

• Information processing
• stimulus
• attention
• forgotten
• short-term memory (STM) conscious/working memory
• STM capacity limited
• 7 +/- 2 chunks
• bumped out (forgotten).

• rehearsed
• encoded
• focus of attention
• long-term memory (LTM)
• prior knowledge
• meaningful learning
• Assimilation
• Concept integration
• Concept differentiation
• rote learning.
• LTM capacity unlimited
• rarely forgotten
• difficulty retrieving
FOCUS QUESTION: How do we remember according to the IPM of memory?
HOW DO WE REMEMBER ACCORDING TO THE INFORMATION PROCESSING MODEL OF MEMORY?

- Information processing
- stimulus
- attention
- forgotten
- short-term memory (STM) conscious/working memory
- STM capacity limited
- 7 +/- 2 chunks
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- Assimilation
- Concept integration
- Concept differentiation
- rote learning.
- LTM capacity unlimited
- rarely forgotten
- difficulty retrieving
CONCEPT MAP for the FOCUS QUESTION: How do we remember according to the Information Processing Model of Memory Chunking Rule?
APPLICATION: IPM MEMORY LEARNING TASKS

• What follows is an application/test of the IPM of memory, specifically “chunking”. Your map on memory will serve as the conceptual understanding for what you will experience next.

• To participate, you will need a clean area in which to write.

• You will be exposed to items to memorize for 30 seconds, you will then have 30 seconds to write them down.

• You will then be able to review how many items you could put in STM and score yourself

• A show of hands will tell us if chunking is being used

• Ready… Set… Go!
<table>
<thead>
<tr>
<th>EVALUATION: VEE AND MEMORY LEARNING TASKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>
EVALUATION: VEE AND MEMORY
LEARNING TASKS

How many did you remember?

Write them down now!
EVALUATION: VEE AND MEMORY LEARNING TASKS

8  18
13 26
21  3
  12
11  7
Ready, Set, Go
EVALUATION: VEE AND MEMORY LEARNING TASKS

C
Q
V
M
A
E
P
Y
T
O
EVALUATION: VEE AND MEMORY
LEARNING TASKS

How many did you remember?

Write them down now!
EVALUATION: VEE AND MEMORY LEARNING TASKS

C E
Q P
V Y
M T
A O
Ready, Set, Go
<table>
<thead>
<tr>
<th>pet</th>
<th>turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td>dog</td>
<td>animal</td>
</tr>
<tr>
<td>cat</td>
<td>house</td>
</tr>
<tr>
<td>mouse</td>
<td>door</td>
</tr>
<tr>
<td>rabbit</td>
<td>toy</td>
</tr>
</tbody>
</table>
EVALUATION: VEE AND MEMORY LEARNING TASKS

How many did you remember?

Write them down now!
<table>
<thead>
<tr>
<th>pet</th>
<th>turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td>dog</td>
<td>animal</td>
</tr>
<tr>
<td>cat</td>
<td>house</td>
</tr>
<tr>
<td>mouse</td>
<td>door</td>
</tr>
<tr>
<td>rabbit</td>
<td>toy</td>
</tr>
</tbody>
</table>
Ready, Set, Go
EVALUATION: VEE AND MEMORY LEARNING TASKS

petunia  sunflower

gardenia  maple

marigold  sycamore

zinnia  cottonwood

goldenrod  walnut
EVALUATION: VEE AND MEMORY LEARNING TASKS

How many did you remember?

Write them down now!
EVALUATION: VEE AND MEMORY
LEARNING TASKS

petunia  sunflower

gardenia  maple

marigold  sycamore

zinnia  cottonwood

goldenrod  walnut
Ready, Set, Go
EVALUATION: VEE AND MEMORY LEARNING TASKS

- tracheid
- xylem
- cambium
- phloem
- epidermis
- palisade
- mesophyll
- stomate
- aperature
- plastid
How many did you remember?

Write them down now!
EVALUATION: VEE AND MEMORY
LEARNING TASKS

tracheid  palisade
xylem     mesophyll
cambium   stomate
phloem    aperature
epidermis plastid
CONCLUSIONS/DISCUSSION

- Concept maps allow the teacher to
  - Expose/change learner’s knowledge structure
  - Identify and remediate misconceptions
  - Help student move from rote learner to meaningful learner
  - Help student move from algorithm memorization to problem solving
- The quantitative analyses support the use of concept mapping as a metacognitive learning strategy suitable for use by both resident and distance learning students in the Nuclear Medicine Technology program.
- Meaningful learners are more adept problem solvers/critical thinkers and should be more adaptive technologists
In Closing…Questions?