

Title: Memory and Learning: a practical guide for students

- Intro to course and workshop

- Welcome....

- I am a Professor of Biology at the College of William and Mary and PI of our Noyce Phase I and Phase II grants
- My research area is in neuroscience (on brain regulation of fertility and infertility)
- The material in this talk is from a one-credit add-on course required for our Noyce Scholars (and open to others)
 - This content is (mostly) part of a textbook (free) that is one of the readings for the class.
 - Many Noyce students told me, "I wish I had known this when I was a freshman"
 - Beginning in 2011, I have taught a freshman version of the class based on understanding learning and acquiring new learning and study skills
 - The textbook has the same title as this workshop
 - Textbook is intended to be readable by college freshmen and high school seniors; Noyce students have additional readings
 - Additional course materials and guidelines for other instructors will be posted later this summer
 - All materials will be posted on the web for free (with support from a Jessie Ball DuPont Fund grant)

- **(Slide 2 – slide numbers at lower right)**

- Outline

- I. - Introduction – two courses and material
 - a) 'How Students Learn' (Noyce Scholars)
 - b) 'Memory and Learning: a practical guide for students' (Freshmen)
 - Textbook * and other materials (* beta version free on website)
 - Sample illustrations
- II. Learning methods
- III. Chunking & working memory
- IV. Student experiments on their own
- V. Noyce class experiment: drawing-to-learn
- VI. Assessment
 - Enduring change?

SLIDES 3-5. Some sample illustrations – textbook illustrations by line drawings (mainly)

- (a) Two illustrations related to chunks and chunking
- (b) illustration showing difficulties in interpreting words without sketches
- (c) Neural circuits as dominoes, and neural circuits for learning a letter

EXPLAIN THESE THREE SLIDES ONLY BRIEFLY during the workshop

– just present for a sense of what the illustrations look like!

SLIDES 6-11. (S6-11) Exercise 1: How do students learn, when given a choice? (How do they choose to study?) *NOTE: I've done modified versions of this exercise with my Noyce Class & my Freshman Class (and with College Professors). It can be useful as an exercise and discussion for any of these groups.*

(S6) Choose up to two

- Record results
- PDH students: Rereading and Highlighting (then cramming)

(S7) Which of these strategies do you feel are most effective? (Rank as many as you wish)

- Record results

(S8 & S9) Research findings.

See Dunlosky et al 2013

- Discuss results of workshop survey – *never quite the same with each group!*

(S10) What do your students know about evidence for effectiveness of study methods? [*In most workshops I do with students or Noyce Scholars, the great majority of students do not have this information. Most teachers & professors seem to be aware that their students don't know it.*]

- When should we tell them?
- Middle school? High School? College? Never?

(S11) Probably multiple times [*my opinion: we could start on this in middle school*]

S12-14. (This can be a good exercise for students [because their definition often differs from mine] or for teachers and professors; It was not an exercise in this workshop because there wasn't time for it)

(S12)- What does it mean to 'learn' something?

- WATER CYCLE
- My students tend to say: **Memorize** it (often they add '& understand it')

(S13) - I mean more than this; I mean, "Fluent Recall with Understanding Connections, and Organization" (acronym FRUCO is used in the textbook)

- What do I mean by connections & organization?
- ILLUSTRATION from textbook (To be useful, knowledge needs both connections and organization; "Tubig" is the word for water in the Central Philippine language of Cebuano.)

- Problem solving is also important (if we alter one thing, such as to lower the temperature or increase impervious cover, what should happen to the water cycle and why)?

- We often want them to learn complex things, such as the ...

(S14) - CARBON CYCLE

- Think a bit about 'learning' this diagram.
- We will come back to it later

S15-17. Exercise 2. Chunking and Working Memory Capacity

(S15) Learn this figure by looking at it, and redraw it from memory

- You have 30 seconds to look at it; then
 - I'll distract you briefly by saying something, and
 - Then you'll try to sketch it as accurately as you can

(S16) - After 30 seconds, change to blank slide (S16) and

Say – “Wait, don't start yet! I have to distract you just briefly.
So, listen to me for a moment. NOW, go ahead.

- “Look up at me and catch my eye when you've sketched what you can” [*usually a minute is enough time for this*]

(S17) Back to another copy of the figure.

- Count how many parts you got correct.
 - Give yourself a score of one for each “thing” you thought of as a unit
 - one line, a box, a triangle, etc.
 - Each of these is known as a “Chunk”, one thing you can hold in working memory
 - Typical for humans in an exercise like this might be 5-7 chunks – numbers vary, but the exact amount doesn't matter to us.
 - In this exercise, whether I give it to College Professors, Teachers, or Students, the numbers typically range from about 3-7 ‘chunks’ that people get right

(S18-19) Working Memory and overloading working memory

(S18) An illustration of working memory with about 7 spaces, each able to hold one chunk

(S19) The figure as you might have held it in working memory, as about 7 chunks.

- Some chunks: individual lines
- Others might be a line with a dot at one end, a triangle with a couple of the lines extended, or any other figure (square, etc) that you found in the sketch
 - Each thing in one of the spaces is a ‘chunk’, and you have room for only about seven
 - Oversimplifying a bit: chunks that are more complex are made from combinations of the simpler chunks you've already learned (*This specific point, that “complex chunks can be made from simpler chunks”, is not accurate from the cognitive psychology literature, but I think it is a useful way of thinking for students, teachers, & professors; my own suspicion is that the statement ‘complex*

chunks are made from a combination of simpler chunks' might be a correct way of interpreting some neuroscience research, particularly on learning by the visual system.)

- Down at the bottom of the slide are the lines you couldn't remember:
 - Excess cognitive load;
 - We've overloaded working memory
- Importantly, it isn't the number of lines & connections that makes it hard to remember and redraw the sketch.
 - It's the fact that you've never chunked the different pieces of that diagram
- It isn't the number of lines or their connections that's the problem.
 - The problem is the number of chunks you have to recall
 - We learn things as chunks;
 - Each chunk is one thing you know
 - The diagram I gave you has almost no chunks you already know.
 - You have to try to remember each piece
 - Working memory has about 7 spaces, and
 - This task overloads working memory
- I can show you exactly the same set of lines, but rearranged into a different pattern, and then the problem becomes very easy.

(S20-23) Exercise 3. Let's try the same exercise again, with the same lines, but rearranged into something you've chunked and practiced many times.

- For this one, usually 5 seconds is enough time to look at it...
- When I give you the same lines, rearranged, & you,
 - Try again, this should be easy

- The difference is that this figure you've already chunked
 - Roof, walls, floor, window, door

(S21) Blank slide – I won't have you do this exercise today, because other workshop attendees have done it for me many times;

- You might want to close your eyes and see if you have it (pause for this)
- Done on paper, everyone is either perfect, or they put the doorknob on the wrong side of the door.

(S22) The sketch again, to check for errors

(S23) This slide has the two sketches, with the same lines

- One that you've chunked many times, and is easy; the other has almost nothing you've ever chunked, and is hard

(S24) Can we make this understanding of chunks and chunking useful?

- My experience is that professors, teachers, and students who know this information don't tend to use it.
 - Some of my freshman students are also aware of the concept
 - Is there a way to use this information to suggest to students better learning and/or studying strategies?

(S25-31) Exercise 4: A new task – learn another figure, but with a different strategy

(S25) - This time, I'll give you a strategy

- a learning tool
- Break the structure into chunks you can hold in working memory
 - None should overload working memory
 - Then try to combine them into the more complex figure

(S26) Color version: several parts, with names

- The backward S, the claw...

(S27) The same colors and parts, adding 'the lollipop Y'

(S28) And in an exploded view adding the recliner (someone leaning back in a chair with a leg out forward) and the smile and mustache)

- I'll give you 20 more seconds, because you've already looked at some parts

(S29) Now redraw the figure ...

(S30) – Let's discuss the results – compare to the original

[In this workshop with 30 attendees, I watched some of the sketches being made, and I took a poll after the sketches were made. The sketches I saw had almost all parts correct (though no one was perfect). All or nearly all attendees raised their hand to say that they did better than on the first figure (I had everyone close their eyes to reduce the effects of peer pressure/potential embarrassment).]

- What was different?
 - Not the complexity of the sketch.
 - In various workshops, I've used both this sketch and my previous sketch in my first exercise, and people are equally poor at reproducing either one.
 - The difference was in your strategy

(S31) This shows the same figure rearranged to something that, again, everyone can reproduce it nearly perfectly: a stick figure human, something you've all chunked many times.

- It's not the number of lines & connections,
- it's whether we can chunk them well

- So this was an interesting exercise, but can we use it in studying?

- Yes
- My students can learn to take a complex figure,

- Recognize when they are overloading working memory
- And break it into smaller chunks to learn. Then,
- Combine the smaller groups of chunks into the full figure only as each group starts becoming a chunk (like 'the claw', 'smile and mustache', and 'lollipop Y'.
- Whenever you forget each chunk, practice it again for FRUCO

- If you think about it, this might be considered self-directed 'scaffolding'
- Building more complex knowledge from simpler chunks

S32-37 - Exercise 5: Let's apply this to the complex figure I showed you earlier for the carbon cycle

(S32) This figure is much too complex for my students,

- even though they feel like they ought to be able to learn it just by looking at it for a long time.
- Textbook figures like this overload working memory in the same way my earlier figures do
 - This may not be true for the teacher!
 - For those who have built all the simple and the complex chunks for the carbon cycle, this figure may be like the house or stick figure I showed earlier – fairly easy to understand
 - But for those new to the carbon cycle, this figure is like the rearranged versions -- impossible

- So what can students do, once they realize this?

(S33) Chunk it in smaller pieces to learn it well

- I call this "Information reduction", just so that I have a term for it
 - Reduce something into just the essentials – just the parts that are truly necessary –
 - And then learn those as a new chunk

- In this exercise, that's what you're going to do: take part of this carbon cycle diagram and,

- Create a sketch (or diagram or flow chart) that has ONLY the parts that are necessary.

(S34) Here is the one piece I chose for you: in side the box in red

(I could have put the box around ANY part; to learn the full carbon cycle, I would have you do a new box for each part, and I could let you choose which parts.)

(S35) So let's look at that piece separately,

(S36) And the same piece – shown larger ...

- First, you (and students) need to get a sense of what this piece is about.

- Now, spend a few minutes making a sketch/diagram/flow chart that captures at least part of this.

(I gave about 5 minutes for this sketching/diagramming task;

- *For a challenging new chunk, students may need up to 20-30 minutes, especially when they are new to this method and still learning it.*
- *Later, with some coaching and practice, they get much, much faster.)*

(In the workshop, I wandered and watched the sketches being made. If these had been students, I would have been asking questions and making suggestions about their sketches – getting individual students to think about what they were doing and coaching them on the process. It can also work to add in a think-pair-share exercise – once they have a sketch at least partly done, to compare and talk with their neighbor about their sketch.)

- Once you have a sketch, compare back to the original
 - I am sure you left out many non-essential parts (the colors, the big white box, maybe some of the numbers, depending upon what you decided was essential for just this piece)
 - Is there anything essential missing?
 - ALSO, is there anything that really isn't essential, but you included it. If so, you can take it out.

(S37) Now, here's my sketch, to compare with yours

- I left out the numbers in brown (because I didn't know what they were – a useful sketch can only have the things the maker understands) (*I hope they were non-essential for this part of the carbon cycle. If I'm wrong, I could check later.*)
 - On my sketch, I included only essential pieces, including one (and only one) tree with some soil to remind myself that there are 2300 Gigatons of carbon held in vegetation & soil
 - I decided the term "detritus" wasn't necessary, because that's just dead parts of organisms, such as fallen leaves and branches

- Now, close your eyes (or look away), and think about this part of the sketch
 - Think through this part of the carbon cycle

(After about 30 seconds for people to do this, I asked a question.)

"Stop. What's in your mind right now? Do you see anything? Are you imagining anything?"

- I got feedback from the audience (or my students, when I do this with them either in a group or one-on-one). Feedback usually includes the following:
 - Most common answers: "I saw my sketch," or "I saw your sketch".
 - Sometimes: "I was picturing the events in the real world."

- I can't remember anyone ever saying, "I saw the figure from the book [the figure they were sketching from]."
- Maybe some people do recall and picture the original figure, but it is NOT common.
- Even though you probably spent as much or more time looking at the original figure as looking at your sketch, it's your sketch you tend to recall.

SAME SLIDE (S37)

- We're going to use this sketch with terms for the NEXT exercise.
 - My sketch is in the form of what I call a "minute sketch" (because it takes a minute or less to redraw it)
 - Definition: a minute sketch is a sketch of a structure, process, events, or concept that is easily RE-drawn in about 30-60 seconds.
 - In my experience, any sketch that a student can redraw in about 30 seconds (and maybe up to a minute) they can close their eyes and see – in other words, they can hold it in working memory and think through it.
 - There is no written explanation of a minute sketch – a good sketch is the explanation – a good sketch tells/shows the student the events. (If they need an explanation plus the sketch, then they don't have a good enough sketch.)
- **Important rule:** All of the essential terms are to one side (on the left, in this case, but it doesn't matter which side).
 - Trust me that this is important, but I don't have time to explain why during this workshop – this is covered in the course textbook.

(For those reading these notes, why is it so important that students and you follow this rule?)

- *Because if we put words on the sketch, they distract us from the content of the sketch*
- *Experiments show that humans can either read or process an image, but we cannot do both at the same time.*
 - *Words ON the sketch make it more confusing for most people to process whatever the sketch is about.*
 - *In my experience with myself and with students, words to the side make it less confusing*
- *This topic is easy for students to test for themselves, or for me to test with them.*
 - *I just have them take the same sketch (usually one of theirs), and make two versions: one version in which the words are on the sketch, and another version in which all the words are off to one side.*

- *Then I have them time themselves thinking through each version of the sketch while looking at it.*
 - *I say, "think through this as if you were studying it for an exam, and look up at me when you're done. Start now."*
- *Reasonably consistently, students tend to take longer when there are words on the sketch (numbers might be 25 seconds vs 35 seconds) When I ask them which feels easier to think through, it's the version with words on the side. Try it for yourself, if you are even the slightest bit skeptical! (And you should be skeptical of new claims like this one!)*
- One more important piece of information for teachers and students:
 - Textbook figures must have words on the figure, because we need them in order to understand the parts of a figure. (We have to put up with the confusion.)
 - However, when we make our own minute sketches, all the terms can be placed to the side, where they serve as reminders and ways to practice the terms.

(S38-S44) Exercise 6:

To get students to actually change their learning methods,

(S38) I've learned I have to get them to try and test different methods

- I have them do experiments on themselves that test how they learn
- Metacognition Experiments

(S39) In the freshman class, each student has to do a portfolio of 10 experiments

One real example: Rereading vs. practice testing

(S40) Details of the experiment

- Study two chapters,
 - matched for time spent studying (20 minutes, in this case)
 - & some decision rule
(how well I do on the end-of-chapter questions)

(S41) Another experiment (highlighting)

(S42) Three more – minute sketching & mind mapping (shown earlier – "Tubig")

- The important point is that students are thinking about their study methods
 - They are getting experience, with some instructor and peer coaching, on how to compare two study methods
 - They learn to think about experimental design, controls, and bias (a good thing in itself!)

(S43) – My freshman students conduct ten experiments, and they discuss their classmates' experiments -- This becomes their "metacognition portfolio"

- In the process, they test out new study methods, some of which are likely to be better (*better may be defined as faster, more accurately, longer enduring recall, more accurate problem solving, and in other ways*)

- As an instructor, I have a chance to notice that they are applying a method incorrectly, and coach them to improve.

- My Noyce class of future science or math teachers do a collaborative class experiment (beginning with my Noyce Scholars in fall 2012)

- It has to be an experiment a teacher could do with their own students,

- that would help students understand learning and studying & metacognition experiments

(S44) MY goal is that students and teachers (1) know how to do their own experiments, and

(2) Continue to do experiments on their learning after the course

S45-49 Exercise 6: A metacognition experiment on sleep

(S45) Do you solve problems better on 6 h of sleep or 8 h of sleep

NOTE: This exercise didn't work in this workshop. A main problem was that only about 3 people had 8 hours or more of sleep. Nearly everyone was sleep deprived! I had to adjust the experiment to compare people with less than 6 h versus more than 6 h – not much of a difference in sleep. The results were that there were no differences.

I should add: the important comparison for any of us (and students) is to compare same person, comparing themselves on different days – at least one day with 8 or more of sleep, and another on 6 h or less of sleep.

Note that this experiment is only worth doing by people who sometimes (or often) get 6 h or less of sleep, especially before an exam.

In this circulated version of the workshop, I'm replacing the sleep exercise section of with results of some real metacognition experiments done by students (shortened for brevity)

(S46 – S49 have been replaced from the actual workshop)

(S50-57): The Noyce class metacognition experiment on Minute Sketches with Folded Lists

- In fall 2013, my Noyce class did their experiment on studying using Minute sketching with folded lists vs. 'staring' (repeated viewing to review – roughly equivalent to rereading).

- Staring – looking at something over and over or for a long time – was a method they felt most of their students used all the time.

- The question was whether minute sketches in folded lists might be better than this common study method, as measured in some simple way.
- Some of them were quite skeptical of the method, which made it particularly interesting to test on themselves

(S51) I need to explain minute sketches & folded lists

- Tool to associate terms with events and/or structures
 - in a way that is fast to learn and easy/fast to review & relearn

- Terms column

- Sketch column

- The sketch is the explanation

- Once a good sketch is made, must be able to redraw it in 30-60 seconds

- It's a minute sketch

- Minute sketches can be fast and easy to create, but for a challenging concept, it might take 20 or 30 minutes for a person to develop a new a minute sketch

- Here, I'm showing the water cycle, with important terms

(S52) To use these for studying and learning, start by hiding one column (here, the words column, but the order doesn't seem to matter).

- You can fold that column under, so it can't be seen

(S53) Now rewrite the terms from memory, in an order that makes sense to you

- While thinking about how the terms relate to parts of the sketch

- Never guess – if you're not sure, just flip the paper to check, and try to do it from memory next time

(S54) This is a form of practice testing – a “highly” effective study method in the review of study methods

(S55) Next, hide the sketch column (fold it under), and redraw the sketch from memory

- While thinking about how the terms relate the parts of the sketch being drawn

- Never guess (there is research suggesting that guessing tends to reinforce the guessed answer, and if that answer is wrong, that's bad)

(S56) Again, this is a form of practice testing

(S57) Repeat on about three different days (doesn't matter if they are consecutive or not), and

- Do two word columns and two sketch columns each day

(takes about 2-5 minutes each time – more time on the first day, but much less on the third)

- My students easily recall it,
 - can explain it (with the terms), &
 - can solve problems about it
- Using their sketch, they can get much better at solving problems such as, what would happen if there was more impervious cover? (Or if the temperature rose?)

(S58) The Noyce class chose to do an experiment using something very simple, clear, and easy to test

- They chose a novel task, in which everyone could try to learn something they didn't know at all
 - Arabic or Korean alphabet, which have symbols for the letters and sounds that go with the letter shape (& the sounds can be written and recopied as English letters)
 - Symbols for letters were the sketch column; the sounds were the word column
 - Four students did the experiment with Arabic, and four did it with Korean

(S59) They chose 24 letters total from one of these alphabets, and studied 12 by each method, matching the letters for complexity

- On each of three days, they studied for 5 minutes with each method
 - 'Staring' – looking at it (12 of the letters)
 - Minute sketches with folded list (the other 12 letters)
- They studied on 3 different days (with no review on the test day)

(S60) Results: (N = 7 – one student didn't make it through the full set of instructions during that week)

- Avg 10.5 correct with folded list
 - 5.8 correct with 'staring'
- Statistically significant ($P < 0.01$)
 - & Every individual did better with the folded list

(S61) How well is the knowledge retained (without practice)?

- Poorly
- After 3 weeks without practice, all did poorly (declined to average about 3 correct, and no difference between groups)

(S62) Could they recover with light review?

- After another 4 weeks w/out practice, they did one more practice session with each method (5 minutes each method, & again no review on the day of the test)

- Nearly recovered in the folded list treatment, while staring for a single session did little or nothing ($P < 0.01$)

- Their conclusions:

- For this kind of simple learning task, this study method seems to be effective for them.
 - Both better initial recall, and
 - Faster recovery of recall with brief review.
- Finding a way to teach and coach their students in this method might be useful

(S63-S66) - Effective learning methods are only going to be helpful if students use them.

- Teaching the best method in the world is a waste of time if students won't adopt it and continue to use the method
- Is there reason to believe that students in the class (one credit in fall of freshman year) actually change?
 - Do they adopt more active learning methods (such as general methods of chunking, practice testing, or specific study methods such as 'Drawing To Learn' methods)?
 - Do they continue to think about their own thinking and learning (metacognition), and do they continue to experiment on their own learning?

(S63) – Survey in April 2014 (~ 70% response rate)

- Do students in the class change as learners, and
 - Do the changes endure?
- Survey (ONLY for the freshman course – still need data for Noyce course)
 - Responses from 64 of the 89 students in the 7 sections of the course
 - Taken 5 months to 35 months after the course

(S64) Most students stated that they continued to experiment on their own learning

- 70% at least one experiment, 20% three or more
- This was 5-35 months after the course: most students said they continued to explore their own learning.

(S65) Students felt that they were different as learners and studiers

- Nearly all felt they were at least a little different
- 40% very different or completely different

(S66) What kinds of methods were they using (and how often)?

- Forty-eight responded that they were using at least one method before **“most exams or in most weeks”**
 - Most common response: some kind of drawing-to-learn method
 - Next most common: mind mapping or a related method

- “Chunking” was also listed in the narrative responses of a large number of students in response to another question
- Many other methods were listed – students had adopted different methods

(S68-S71) Workshop Summary

1. We’ve gone through just some course concepts, exercises, & materials.
2. Textbook is available (Beta version on the web site;
final version soon)
3. Course materials will be posted (& can send by request now)
4. Survey results suggest that more than half of the students
 - (a) adopt more active learning methods
 - (b) continue to experiment on better ways of learning

(& 40% felt very different or completely different as learners)

(S72) Acknowledgments

- Funding sources

(S73) Workshop Abstract