How to Teach Students to Design Their Own Laboratory Investigations

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My History with Inquiry

My Transition

- Undergrad science methods courses
- The first few years:
  - Painful and infrequent inquiry
- Why isn't it working?
- Because it's overloading my students!
- Now:
  - At least once per chapter…and far less pain!
  - 2006 NSTA HS Awardee for Excellence in Science Teaching

General Inquiry Background

What I knew before "my transition"

Inquiry

- More than just hands-on
  - Students designing labs or lab components
- Doesn't have to be hands-on
  - Debates, discussions, literature review & analysis, etc.
- **It's all about the questions**—asking them and trying to answer them

Guided inquiry

Open-Ended Inquiry

Benefits of Inquiry

- **Students** doing science
- Applying acquired techniques and skills to new situations
- Understanding of "why"
- Student interest/motivation
- Students taking part in their learning
- Students learning they have valuable thoughts and ideas

Roadblocks to Using Inquiry

- Takes more time
- Student complaints
- Loss of control
- Safety concerns
- Lack of knowledge of how to support classroom inquiry
- Lack of available inquiry resources

When **not** to use Inquiry

- When it's not safe
- When students don't know the underlying techniques
- When it's "copycat" inquiry

Begin by looking at Traditional Labs

- Problem/purpose
- Hypothesis/prediction (appropriate versus not)
- Variable (appropriate versus not)
- Materials (what is/isn't commonly included)
- Safety (common concerns)
- Procedures (what is/isn't commonly included)
- Data (direct/indirect measurement)
- Calculations/Results (done in this section—not in data)
- Conclusion (what's usually asked for)

Bring specific attention to these things that usually aren't talked about!

Then Look at Previous Student Labs

- Use old student labs (or fake them)
  - Use common mistakes: Not enough information, too much information, illogical order, etc.
- Have groups analyze different procedure options & discuss

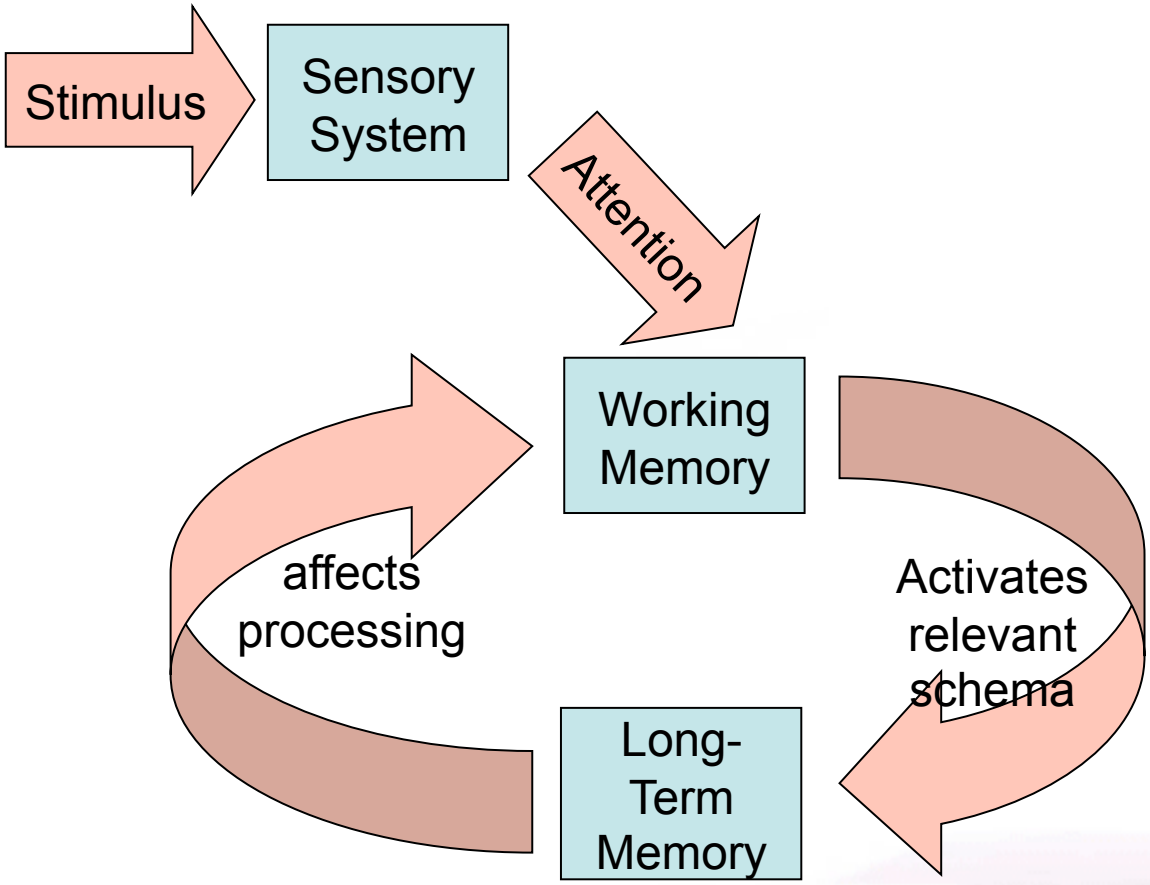
Cognitive Theory Background

What explains why "my transition" worked

Cognitive Processing Components

Sensory System	Receives stimulus Very limited in capacity & duration
Working Memory	The processing center (“thinking”) Capacity of 5-9 pieces of information
Long-Term Memory	Essentially limitless capacity Storage only—no processing Information stored in schema

Cognitive Processing of Stimulus



What's the "Big Idea"?

- Processing only in working memory
  - Limited to 7 +/- 2 "chunks" of information
- Prior knowledge (schema in LTM) affects how information is processed

Working Memory & Teenagers

- 5-9 working memory slots available…
- But what other things are they using their slots for during your class?

What about 7 +/- 2 and complex tasks?

Concept 1

Concept 2

Procedure 1

Interconnected network (schema) of understanding relating all these together

Now instead of 3 slots, the same “task” requires only 1

When new, each piece of information takes up a slot

Through:
Worked Examples
Varied Scenarios
Practice

This is “chunking” information

Cognitive Load Theory

Why I needed to scaffold my students

History of Cognitive Load Theory

- Begin in the 1980's
- John Sweller (in Australia) is one of the "founding fathers"
- Developed and expanded in 1990's
- Major theory for investigation into cognitive processes & Instructional design

Types of Cognitive Load

- Cognitive load = demand on working memory processing capacity
  - Intrinsic Cognitive Load
  - Extraneous Cognitive Load
  - Germane Cognitive Load

Intrinsic Cognitive Load

- Intrinsic to the material
  - How "hard" the material is
  - Reduced with chunking and schema acquisition
    - This is why the same stoichiometry problem has a much lower cognitive load for us than for our students

Extraneous Cognitive Load

- From instructional design
  - Not intrinsic to the task/ concept
  - Can be controlled
- Major focus of cognitive science: how to reduce extraneous load

Germane Cognitive Load

- From instructional design
  - Not intrinsic to the task/ concept
  - Can be controlled
- Rather than interfering with learning (extraneous load), it **enhances learning**.
  - By allocating working memory resources to schema acquisition and automation

Additive Loads

- Intrinsic

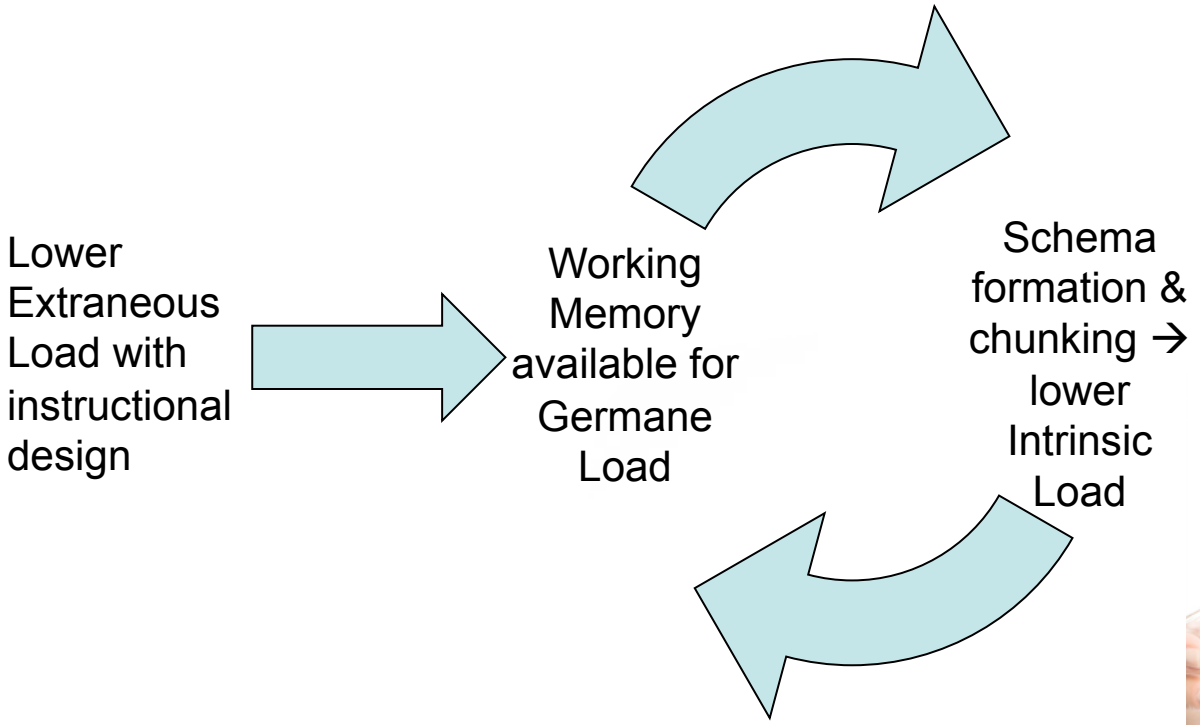
  + Extraneous

  + Germane

  = total working memory slots available (5-9)

- Ever have a student go through a process but not learn it?
- We must balance the types of load so that students can manage all 3 at a time

How we learn effectively



We can help students into this efficient learning cycle by providing the first step—lower Extraneous Load

Why Minimal Guidance Doesn't Work

Do your students do these things?

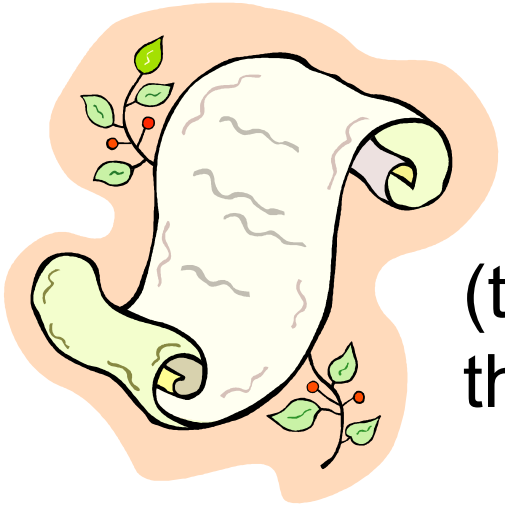
- Stare at a blank paper
- Ignore the assignment
- Ask you how to do it
- Write a lab and then ask you what to do
- Whine and complain
- Don't know where to begin

Novices versus Experts

- My mistake for years:
  - Assuming students were relative "experts" at labs
  - But "expert" in performing ≠ "expert" in design

In other words…

They think that labs are handed down from on high



(that means from the teacher)

And they don't know how to write one

Implications for Cognitive Load

- High demand on Working Memory for design process for design novices

+ intrinsic load associated with the specific lab

= no working memory slots left over for Germane Load

- They're not building schema…not learning!

Why students are clueless

- Trying to hold too much in Working Memory at one time
- We can remove Extraneous Load by giving a roadmap (**Scaffolding**)
  - Allows focus on Intrinsic and Germane Load!
- As they chunk aspects of designing the lab (build schema), we scale back the scaffolding.

Teachers and scientists design labs backwards!

And most of us don't even know it!

Order as handed to the student:

Purpose

Background info

Material

Safety

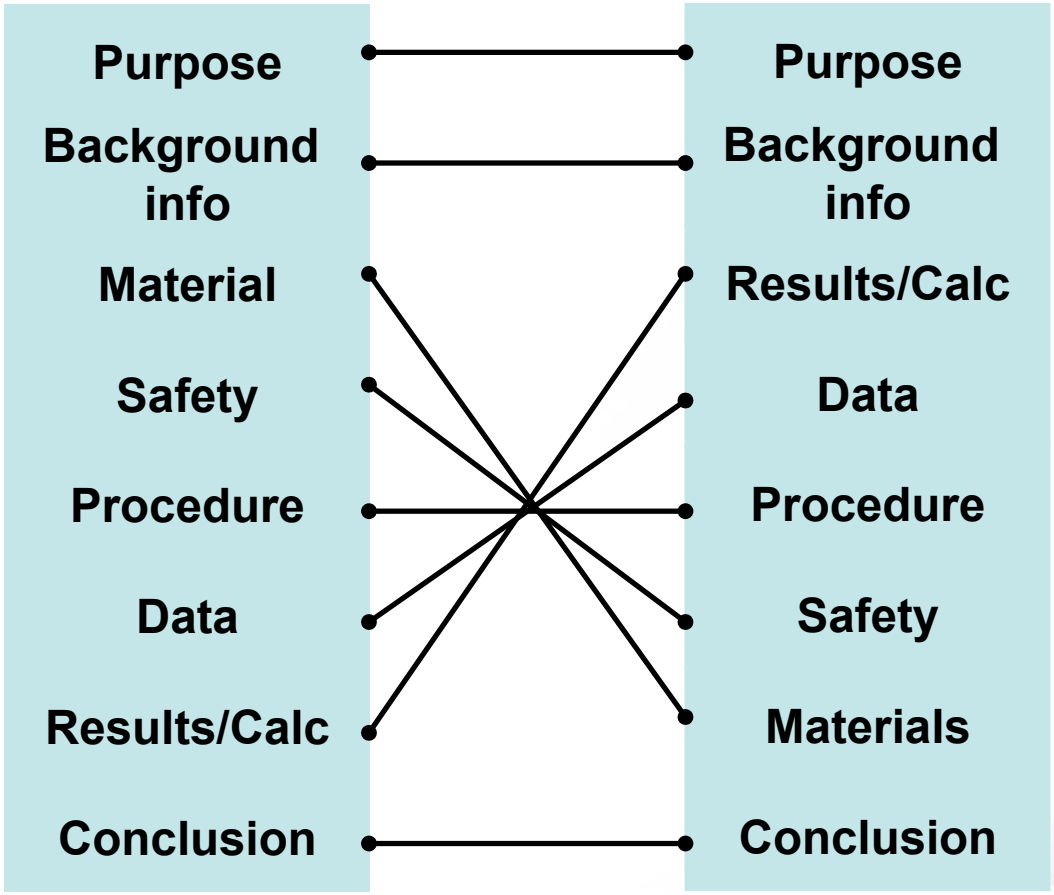
Procedure

Data

Results/Calc

Conclusion

Order the lab was designed in:



It's probably all done in your head…but remember, you're an "expert"—you can hold all that in your working memory!

Additional tips for Inquiry

Things **Students** need to know

- OK to leave paper in the "backwards order" (if that's OK with you)
- OK to change your procedure mid-stream…just make sure that your final written paper reflects what you ACTUALLY did in the lab.
- There's often more than one correct way

Things **Teachers** need to know

- You're going to get backlash
  - Once you get past the #1, 2 or 3, it gets easier!!!
- You may need to lead them through one (or more) as a class
- Scaffold appropriately for the group of students!

The Technology Tool

Computerized Scaffolding

- Providing a work space for what's required
- Providing progress displays
- Display only relevant information and each time its relevant
- Make the task structure visible

SDL-SAT

- Student Designed Labs Scaffolding and Assessment Tool
- Basis of my dissertation study
- Improved student lab report scores
- Windows & Mac Version

www.reallifechemistry.net/SDLApplication.htm

- Play with the "test" account
  - Teacher login
  - School "test"
  - Teacher "test"
  - Password "test"
- Email kellymdeters@gmail.com to set up a real account.
  - Send your desired username, password and school name.