Turning Beginners into Thinkers:

Thinking independently requires risk-taking. That is one reason why critical thinking is hard to foster in the classroom: how do we reconcile the need to anchor student learning in disciplinary knowledge, traditions and procedures with the equally strong need for students to question what they think they know?

This workshop models what we can do to bring students into “inquiry” processes, without ignoring valuable traditions of knowledge. Finding acceptable ways to “exploit error” and to “manage correctness” will be key. Workshop participants will unpack some assumptions of traditional “procedural” instruction, in order to construct a more effective framework for getting students to think.

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Electronic copies of the slides will be made available to participants after the workshop.
Goals for this session

- Identify structures and processes of learning that motivate students intellectually (curiosity) or that lead to intellectual de-motivation (boredom)

- Construct a paradigm for designing learning activities that promote curiosity through inquiry & reflective thinking
A definition that is essential to effective instructional design

An “academic discipline” is NOT a collection of concepts, theories and information--this is impossible, since these are always changing.

An “academic discipline” (biology, music, history, law, pharmacy, literature)...is a particular way of observing, thinking about, judging, creating, managing and acting upon a body of changing information.
Do you remember what's it like to be a beginner?

If you have a background in or recent familiarity with atmospheric sciences and/or chemistry, please take the role of silent observer in the next discussion.
The image below represents two separate drops of a liquid (one small; one large). The tiny circles represent individual molecules of this liquid at the surface of each drop.

Another view: two drops of liquid, with a depiction of some individual molecules at the surface
Under equal conditions (temperature, atmospheric pressure, etc.),
how will vaporization rates compare between these molecules of
liquid distributed over the two spheres? Why?

What just happened?

1. You were given a question intended to place you in the role of “naïve” learner (Rationale: force you to activate from memory and experience concepts that might be transferable to the situation) (note format: decision)

2. You and your peers were asked to make public your judgments (Rationale: induce comparisons that are the basis for critical reflection)

You are now...
You are now heading into a learning cycle that is dynamically interactive with your existing thought structures.
The shape of traditional “teaching”

Procedural
Deductive

“Let me show you exactly how things work... “

“ Now that you know, apply your new knowledge to some examples/cases/situations.”
The shape of teaching: “Let me show you exactly how things work...”

Compare: **The shape of learning**

Here is a situation that I cannot quite explain. I wonder what is happening. What’s this about? Could it be X? Could it be Y? Why?

Next steps:
What do we need to know in order to be certain? Where could we look to find it?
Our challenge:

*Procedural, deductive approaches do not develop in students the persistence and flexibility needed to explore real disciplinary problems, e.g....*

--What should students be able to do when they do not have enough information to solve a problem?

--What should students be able to do when there is too much information?
A “culture of instruction” assumes that disciplinary knowledge consists of transferable content chunks and procedures

Language professor “transfers” correct grammar to students

Chemistry professor “transfers” research procedure to students

Sociology professor “transfers” theories of social inequality to students

Math professor “transfers” formulas and algorithms to students

Literature professor “transfers” various “lenses” (gender; history; Marxism, etc.) through which to read

Business professor “transfers” management/accounting/finance models to students
Basic tenet of the "culture of instruction"

Learning ("transfer") is **simple and straightforward**.

*We (the professors) have already done all the heavy lifting to collect, sort and distill the best information, so all you have to do is take it and use it...*

"Just follow these directions and you’ll get a good result..." + "Why can’t my students follow simple instructions?!?!?"
The Inquiry Model = “Shape of Learning”

**Question**
How do individual molecules of a liquid bond?
How does the disposition of molecules affect the strength of the bond?

**Data**
We *imagine* the molecules evaporating—or not (in a lab we could collect data)

**Significance**
Extractable concepts, principles and models (whether we already know the terminology or not!!)
The learning cycle (David Kolb)

1. Concrete experience
2. Observation and reflection
3. Forming abstract concepts
4. Testing in new situations
How the brain works (diagram from Paul Zull)

Sensory cortex

Sense

Action
Motor cortex

Connections / meanings
Back integrative cortex

Ideas/Plans
Front integrative cortex
The **scientific method** =

knowledge-making based on the cycle of human learning and thinking

- **Question**  
  (Hypothesis)

- **Data**  
  (Analysis)

- **Significance**
Traditional teaching ("Procedural instruction")
short-circuits the learning cycle

Significance ← —— —— —— —— —— —— —— Significance

e.g.,
Plug and chug: “Here is a concept A that explains example X.
Now tell me how Concept A explains example Y.

Memorize and hope: “Here is a definition of X. Remember this for future use. You’ll need it, I promise!!!”
The human brain “seeks” to make its own significance (even when it’s something that is already “known”)

Our teaching and learning processes are most effective when we feed this desire (curiosity) to “make significance.”

How do we do this?
Start by **activating** the most common tools of the course

Textbooks, when used in a traditional course, are...

...extended (and expensive) answers to questions that students never asked.

Compare: example from atmospheric sciences
Undoing the textbook

- Identify the key concepts that the textbook addresses
- Identify the questions and data that are pre-supposed (imbedded) in the textbook’s presentation of a concept.
- Structure an activity where students are given a PIECE of the process or information, and are asked to construct the remainder
Start anywhere in the scientific method:

Question $\leftrightarrow$ data $\leftrightarrow$ significance

- What hypothesis can we construct to explore the question?
- What data will be generated by my hypothesis?
- What does this data signify?
- What question and hypothesis generated this data?
- What kinds of data might have been used to generate this significance?
- What new questions are generated by this significance?
An example of “staging” an inquiry using published research:

Part I: A Sociological Study on Gender and Math

- **Population**: Male and female students who scored well on the quantitative part of the SAT and reported that doing well in math was important to them.

- Both male and female high scorers were given a math test.

- Before the test, half the female students were told that women typically scored lower than men did. The other half of the female students were told that the test was one in which no gender differences had been found.

Spencer, S. J., & Steele, C.M. 1992
A Sociological Study on Gender and Math

Predict the results of this study.

What do you think happened? Why do you think so?
A Sociological Study on Gender and Math

Results of the study

The women who had been told that women typically did worse than men scored lower on the test than the male students who were taking the test at the same time.

The women who were told the test showed no gender differences scored the same as the male students.
Staging-Part 2: A Sociological Study on Mental Rotation

Mental rotation is a task that males typically perform much better on than females do.

Men and women were given a test requiring mental rotation of an object.

- Half of the participants (½ men, ½ women) were given “masculine” instructions which communicated that success on the test correlated well with achievement in tasks requiring good visualization abilities, such as "in-flight and carrier-based aviation engineering, in-flight fighter weapons and attack/approach tactics"

- Half of the participants (½ men, ½ women) were given “feminine” instructions which communicated that success on the test correlated well with success in "clothing and dress design, interior decoration and interior design" and related skills.

- Sharps, M. J., Price, J. L., & Williams, J. K. 1994
Predict the results of this study. What do you think happened? Why do you think so?

Express your prediction by ranking the performances of the 4 groups. (1 = best; 4 = worst)

_______Women receiving “feminine” instructions

_______Men receiving “masculine” instructions

_______Women receiving “masculine” instructions

_______Men receiving “feminine” instructions
Note: the format of the exercise is designed to clarify distinctions, judgments and reasoning by forcing a specific decision:

Ranking
Sorting
Multiple Choice
Prediction

“Best” answer given the information/experience I have
A Sociological Study: Mental Rotation

The results

- Under the feminine instructions, there were no differences in the performance of males and females.

- Under the masculine instructions the males significantly outperformed the females.

- The males who took the test with masculine instructions significantly outperformed the males who took the test with feminine instructions.

- Females' performance did not differ under the two types of instruction.
Staging continued: stating the idea

Compose a statement that draws a conclusion about what the data suggest (even if you don’t agree!!)

e.g.

What does the data suggest about how men vs. women respond to “prejudicial” instructions?
Staging continued: Critiquing the Study that generated the data

- What questions do you have for the researchers who set up this study?

- What would you do to “improve” this research?
Closing the loop
(or, what I just asked you to do…)

Question ◄ ——— ► Data ◄ ——— ► Significance

A. You were given the question and asked to predict the data.
B. You were asked to draw significance from the data (what does it mean?)
C. You were asked to consider reformulating the question for additional investigation
Closing the loop
(or what we just asked you to do...)

Question ← ———— ———— Data ← ———— ———— Significance

Question
Closing the loop
(or what we just asked you to do...)
Closing the loop
(or what we just asked you to do...)

Question ← ——— → Data ← ——— → Significance

Significance ← ——— → Data ← ——— → Question
This is a spiral
“Problematizing the content”

Requires no special design, no special research, no special preparation by the instructor.

Sociology example was lifted from published research, “results of study” were turned into a “prediction,” put on a slide, to become the exercise.

Previous example from atmospheric science: illustration was lifted from a textbook chapter on evaporation chemistry.
What I REALLY did:

I placed the information within its ORIGINAL context of MAKING KNOWLEDGE:

Question → Data → Significance → Question

Open to any chapter of any text you use and ask:

- How was this knowledge made?
- What was the Question? Hypothesis? Data? Significance?
- How can I put students on the path to RECREATE this thought process??
Learning through “inquiry” = “knowledge making…”

For experts: making new knowledge for the discipline

For beginners: (re)making knowledge for myself that others have already made

Common fallacy in traditional teaching:

Students don’t need to “make knowledge,” they just need to take it and use it.
The Scientific Method is the codified process of making knowledge by extracting value from error and failure.

1. Observe
2. Make a hypothesis or prediction
3. Collect data, test, observe more closely, study
4. Reflect, consider alternate theories, revise hypothesis/prediction
5. Repeat as needed

Error/Failure $\rightarrow$ valuable data has been collected
Error/Failure $\neq$ lack of success
Inquiry’s essential tool: ERROR

Manufactured error
(used by teachers to make grades)

Vs

Authentic error
(used by experts to make knowledge)
**Manufactured error** = failure to replicate pre-ordained correctness

- Learner’s information does not match the teacher’s
- Discrepancies in information have no intrinsic value to learner

**Student responses:**
- I gave the wrong answer, I’m dumb, I’ll never do well in this subject
- I gave the wrong answer, why did you trick me?
- You say my answer is not correct. What’s the right one, professor?

**Student’s Belief:** evaluation of his answer is solely professor’s responsibility; student has none.
**Authentic error** = resulting from a quest to understand

**Student:** my thinking on this question was not confirmed by observation, experiment, reading, analysis or calculation

**Questions emerging from authentic error:**
- What went wrong?
- I wonder why...?
- What might I try now?
- How will I “learn my way out” of this dead-end?
- Professor, I’m stuck...is there something I’m not seeing?

Student is responsible for evaluation of his answer.
Perceived type of **risk** is the intellectual *and* emotional key to learning to think in the discipline

Risk of Discovery (Joyful risk) associated with authentic trial and error:

*I’m taking a risk in order to know more; my errors are interesting, and lead me to more questions. If I’m wrong, let me try it again with new tools and more information.*

Risk of Incorrectness (Fearful risk) associated with error as “mistake” (manufactured error):

*I’m risking an answer because I am forced to, but my mistakes terrify me because I will feel inadequate or cheated if I’m not right.*
What advanced thinkers/risk-takers do well and often...

- Take the risk of “setting” the problem by formulating questions from an over-abundance of possible ways to proceed, and from information gaps

- Risk a prediction of data, given the research question and hypothesis (“thought experiments”)

- Risk “educated guesses” based on limited, minimal or even no information

- Risk speculations, estimations, “guesstimations” and imagining

- Risk improvised solutions when confronted with messy situations
As university instructors we are trying to “stage” the Scientific Method for students (NO MATTER THE DISCIPLINE)

This means:

We provide a framework (stage) in which students must struggle to make decisions BEFORE they are given sufficient information to “determine” correct answers.
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