Dep’t Earth and Ocean Sciences

EOS-SEI

Teaching, learning and assessing scientific skills early in an undergraduate degree

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Can proven pedagogy foster “generic” scientific thinking skills?

What are “science thinking” learning goals?

How to measure corresponding abilities?

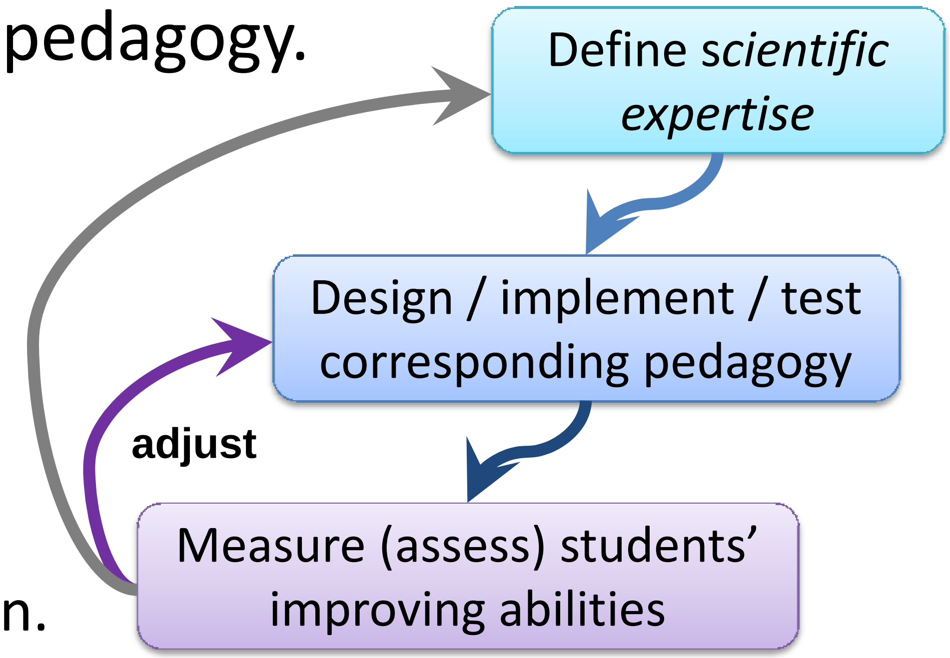
CWSEI

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

Outline

A. Contexts
B. Science expertise defines learning goals.
   – Five “expert” characteristics chosen
C. Relate characteristics to pedagogy.
D. Examples of results.
E. Lessons learned.



- Pedagogies not “new”, but focusing on generic science thinking is uncommon.

- Emphasis on measuring gains is also challenging.

A .Context: course and dep't

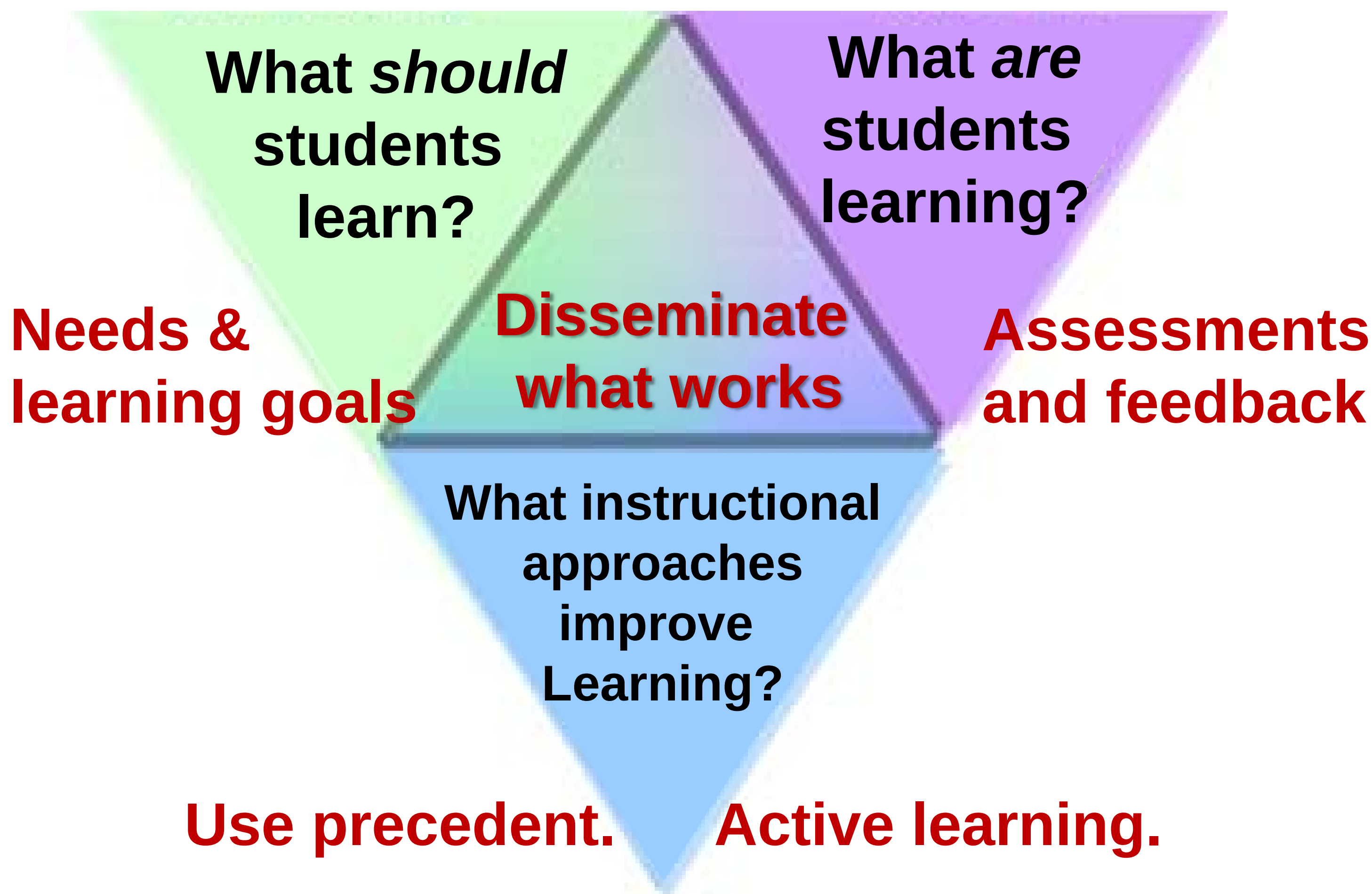
~2003: Desire to inspire 2nd year students in EOS:

- Morph an existing course to both
  - Showcase earth/ocean/atmospheric sciences
  - Expose students to reading, discussion & communication
- Developed by two professors – taught for 2 years
- 2007:
  CWSEI = opportunity to "transform" course;
  - use evidence based pedagogy
  - explore assessment of scientific thinking.

Context: Course development:

Framework: CWSEI **C**arl **W**ieman **S**cience **E**ducation **I**nitiative

http://www.cwsei.ubc.ca/



B. Science expertise defines learning goals

- Learning goals based on science expertise literature
  - First, ‘critical thinking’ &‘problem solving’ are a bit vague.
  - Therefore: examine “*what scientists do*” and “*what skills they use*” (Dunbar, Ericsson, Sandoval, etc.)

- Outline / details online
  - Course Learning Goals (Appendix 4)
  - Course components
  - Expertise, and other, references (42 and growing)

http://www.eos.ubc.ca/research/cwsei/scientificskills.html

Some Components of Scientific Expertise:

1. Domain knowledge
   - "Noticing" (consistent / inconsistent / relevant / …)
   - Follow up anomalies
   - Use of analogy

most courses focus here.

2. "Distributed reasoning"
   - Research teams
   - Peer support and assessment
3. Questioning: assumptions, methods, applicability …
4. Models, data, and how they relate.
5. Articulate, discuss, argue, communicate …

Modular course structure – 13 weeks

Intro (Module 1)
-First paper
-Reading / Questing workshops
-MBR

Module 2
- Reading, abstract, questions
- Team data-oriented activity

Module 3

Oral projects
- Peer assessment,
- Feedback

Module 4

(Module 5 – maybe)

Capstone (Module 6)
- MBR, reflections via. learning goals

Poster presentations

Archived at
www.sei.ubc.ca
(mostly public)

Activities / Assessments

- Readings
  - Topics with intrinsic interest in SciAm, Science, etc
- Abstracts / Questioning assignments
- Individual + team content quizzes
- Data analysis / interpretation exercises in teams
- Just-in-Time discussion-oriented lectures
  - Model Based Reasoning test
  - One / Two instructors + some guests
- Student-chosen projects
  - Oral and poster presentations with peer assessment

C. Relate characteristics to pedagogy:

Expertise	Activities / Assessments
1. Domain knowledge	A. Readings
2. Distributed reasoning	B. Individual / team quizzes
3. Questioning	C. MBR, & JiT Disc'n lectures
4. Models and data	D. Abstracts / Questioning
5. Articulate, discuss, argue, communicate	E. Team data analysis / interpretation exercises
	F. Student - chosen projects

Expertise

1. Domain knowledge
2. **Distributed reasoning**
3. Questioning
4. Models and data
5. Articulate, discuss, argue, communicate

Activities / Assessments

A. Readings
B. Individual / team quizzes
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Expertise

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Activities / Assessments

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B. Individual / team quizzes
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D. Abstracts / Questioning
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C. Examples of results
1. Domain knowledge

- "How to Read" workshop
- Topics (module) list:
  1. Basic skills (using Do Hotspots Move?)
  2. Crustal dynamics (GPS / InSAR)
  3. Mars / Venus: surface features and climate
  4. Climate variability & dynamics of ocean / cryosphere
  5. Volcanic eruption forecasting

  (Capstone: reflection on learning gains related to goals.)

  (Two projects with student-selected topics.)

- Example data analysis exercise in Appendix 1.

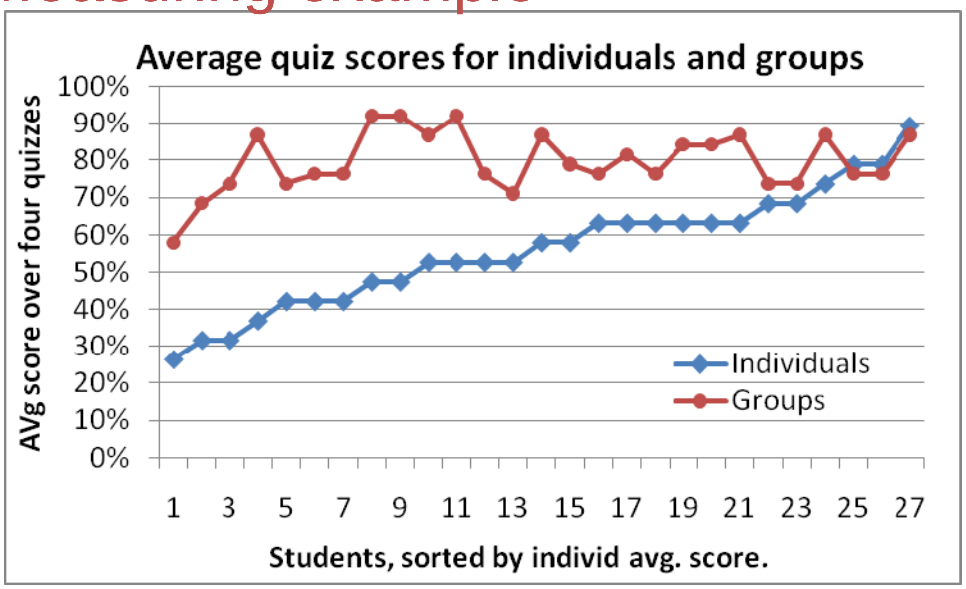
2. Distributed reasoning (solo / teams /partners)

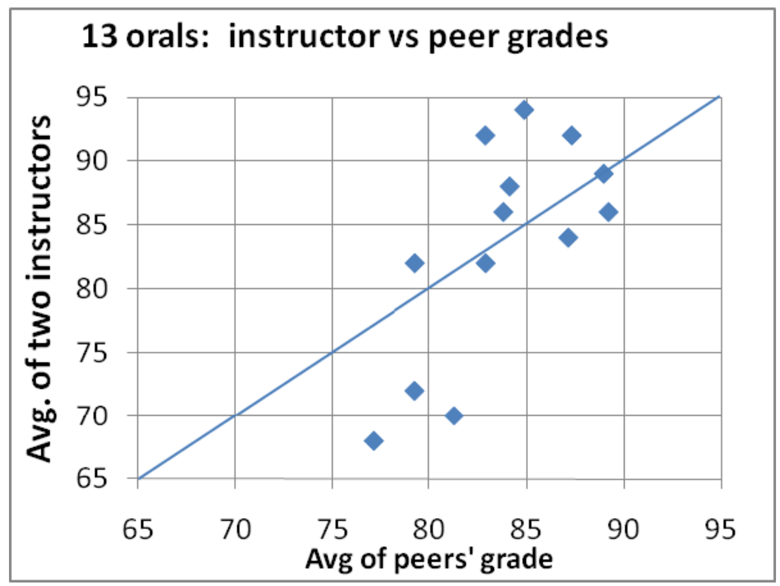
Doing

- TBL* strategies
- Data analysis in-class team activities
- Self-selected pairs for projects
- Peer assessments & feedback (abstracts & projects)

*Team Based Learning (Michaelsen, 2004)

Measuring example





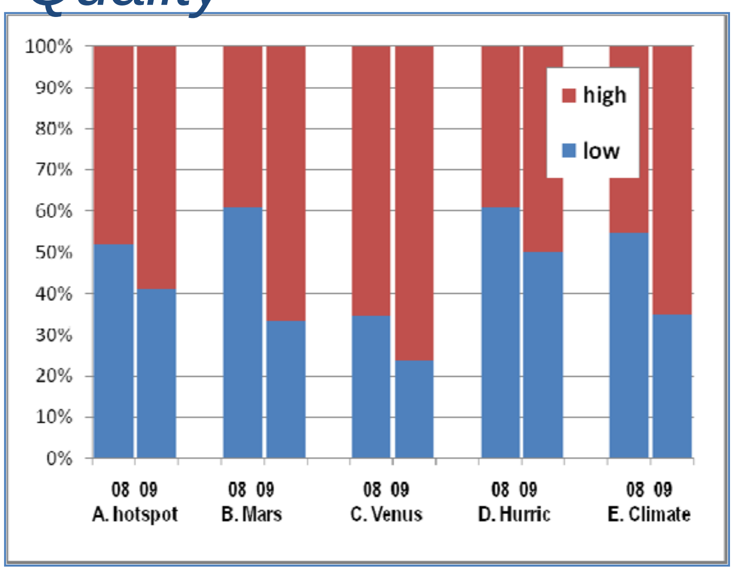
3. Question posing: first attempts

Doing

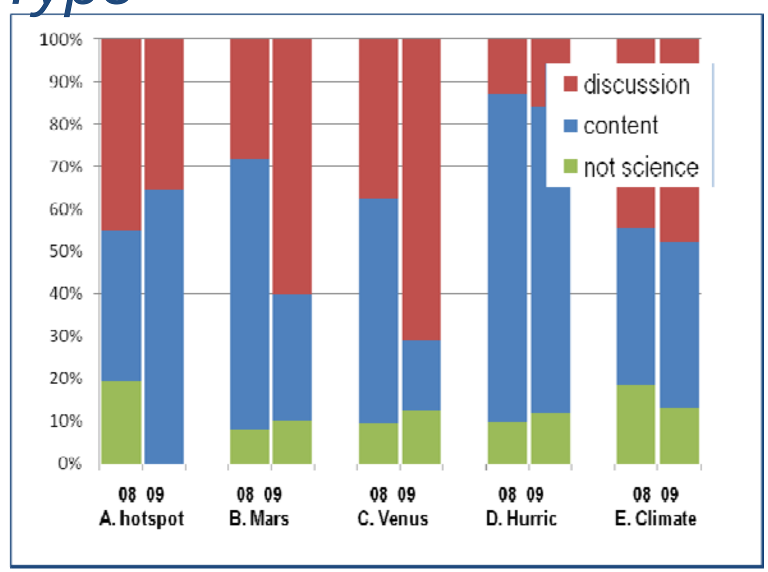
- Early attempts to gauge question quality and type
  - Challenging to find a useful coding scheme.
  - **Quality**: 2009 > 2008 but no change within the course.
  - **Type**: variable, and depends on topic *not* time.

Measuring

Quality



Type

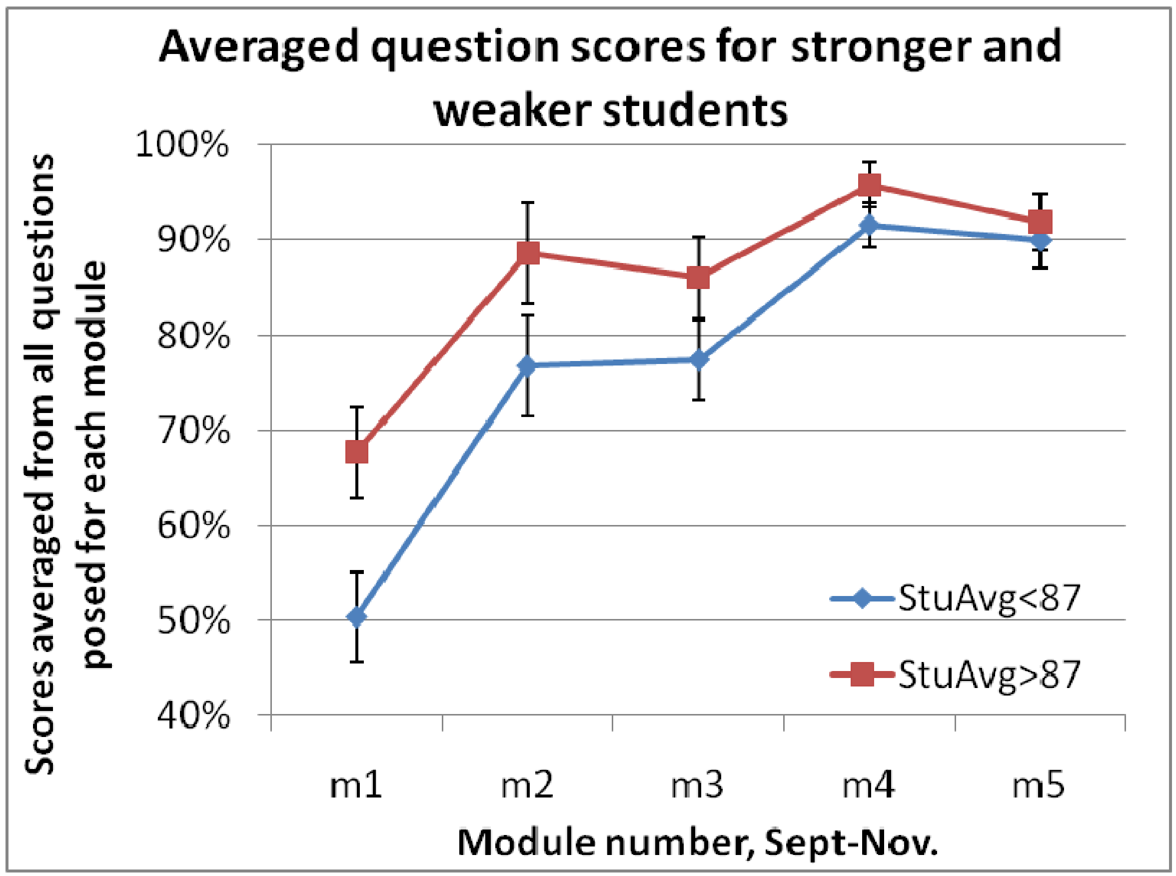


3. Question posing: subsequent strategies

Doing

- "Good questions" workshop
- Targeted question posing: What Why/How Philosophical
- Rubric (Appendix 2.)

Measuring

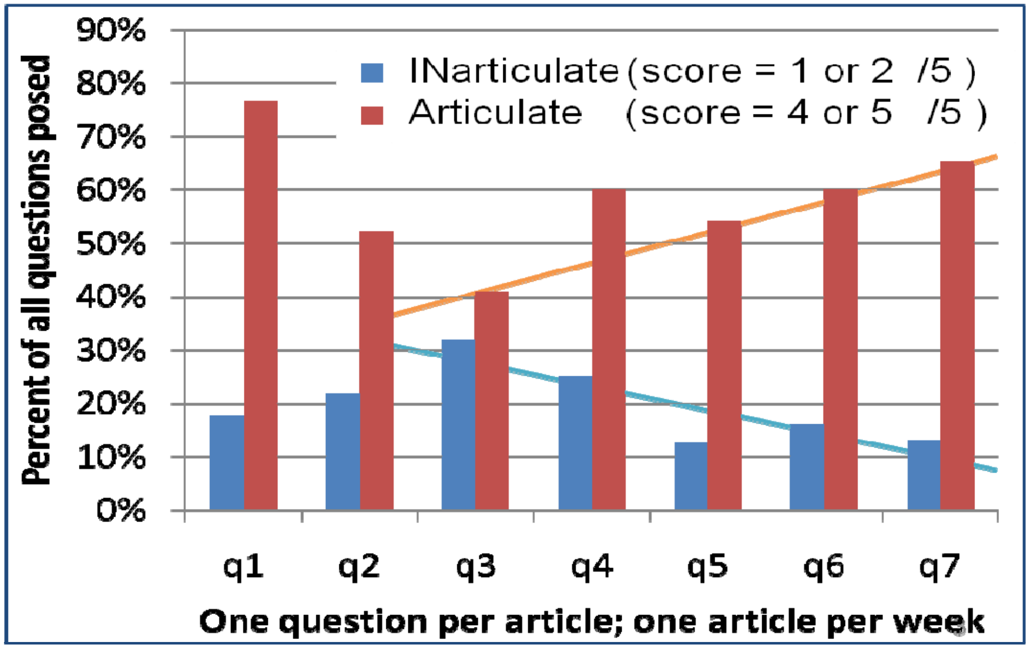


3. Question posing: gauging type/quality

Still challenging; criteria in literature depend on context.

	Criteria score on a scale of 1 to 4	
criteria	**1**	**4**
a	testable or answerable	philosophical
b	specific	broad
c	irrelevant to author's thesis	critical
d	trivial	highly insightful
e	detail oriented	focused beyond the article
f	incomprehensible	articulate

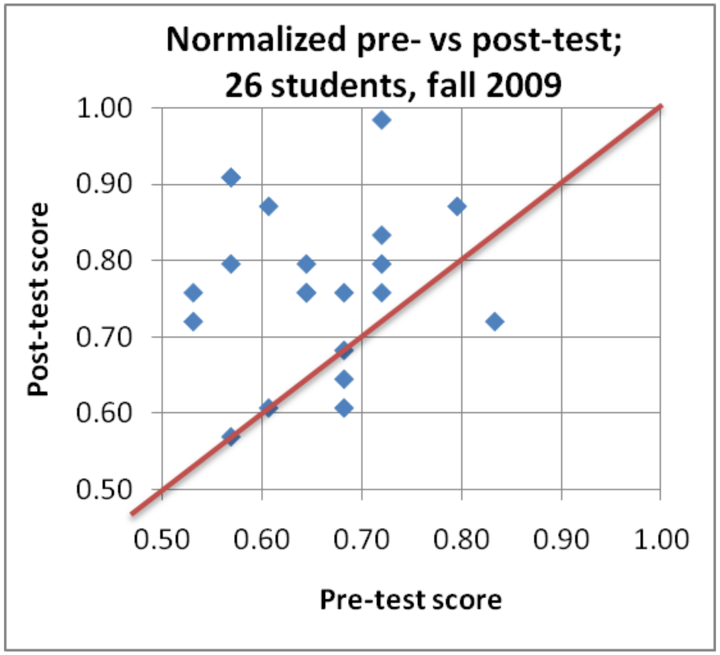
Measuring



4. Fluently use, and relate, models & data

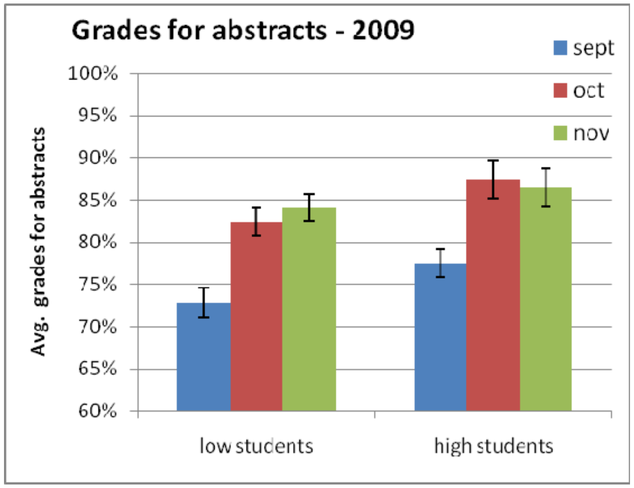
- Readings & discussions are measurement and observation oriented.
- Exercises involve relevance & quality of data
- Model Based Reasoning (MBR) pre–post test
  - Gains made for most students.
  - Test questions and results in Appendix 3.

Measuring

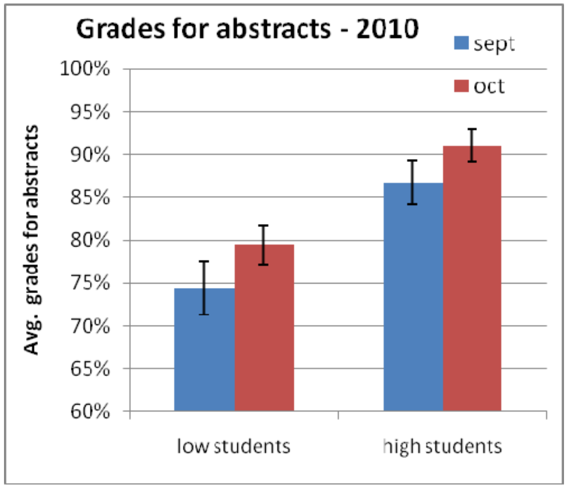


5. Articulate, discuss, argue

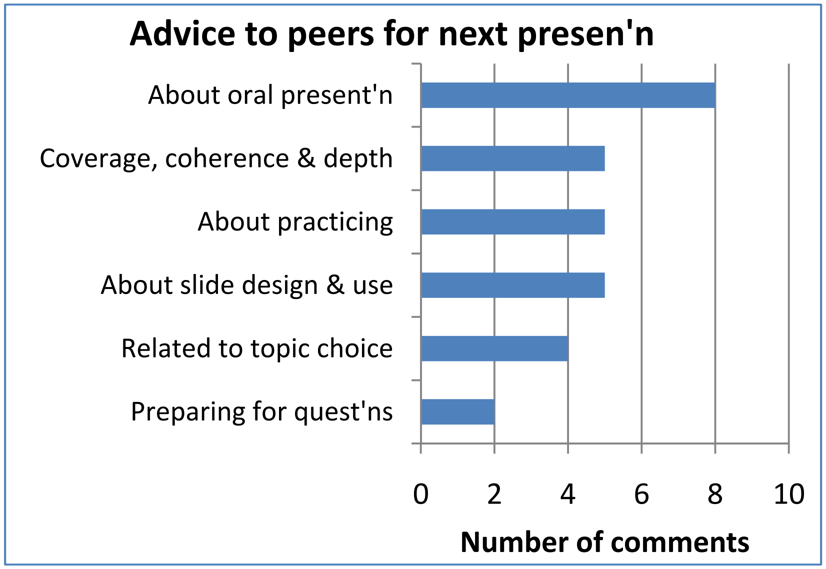
- "How to Read" workshop
- 8-sentence abstracts for Scientific American or Nature articles.
- Gains made by both lower and upper halves of the class.
- Gains level off late in the term.

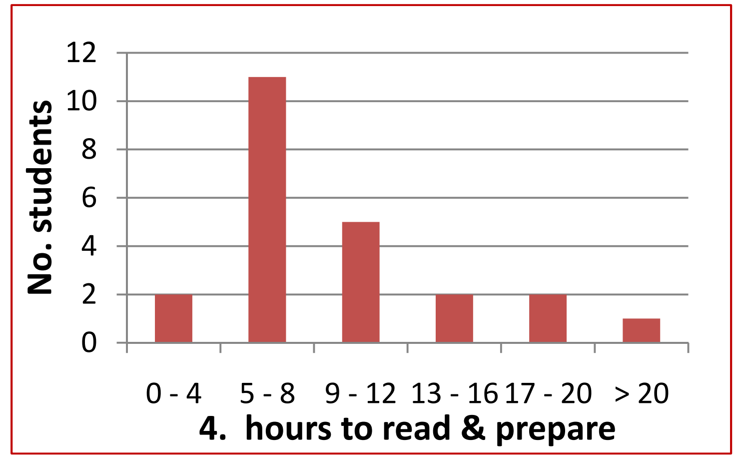


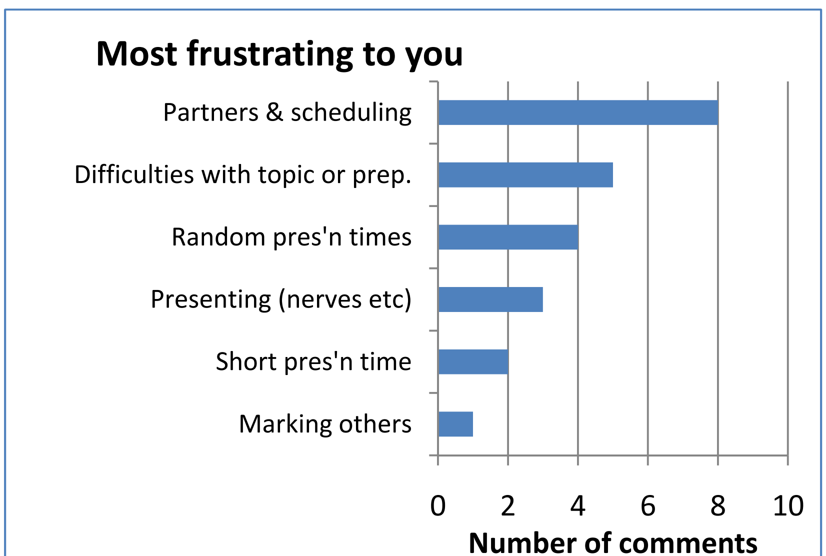
Gains happen early, therefore focus elsewhere



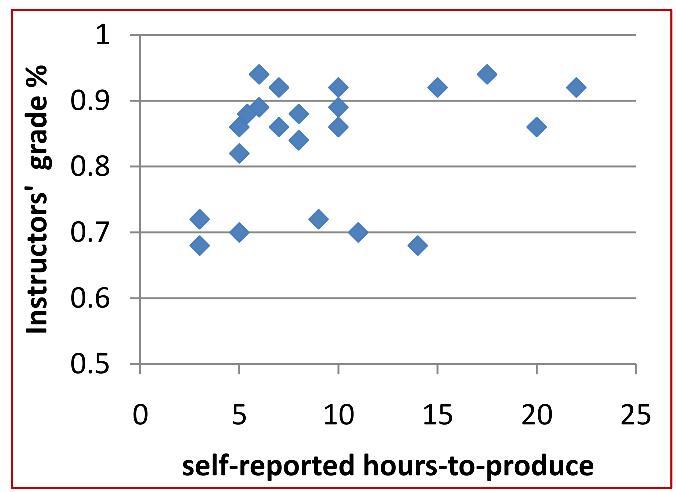
Reflection about presentations;
Questions to help *think about your thinking and your work*





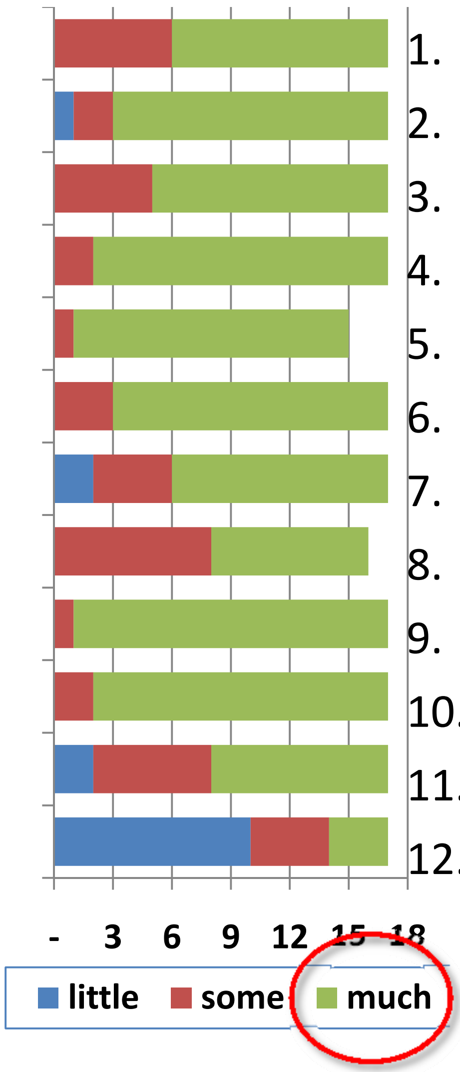


Self-reported hours is un-correlated with result



Student feedback about the *course*

"How much has this course helped you improve skills at … "



1. Recognizing what's learned, and what's missing in your understanding.
2. Asking insightful and precise questions about scientific ideas.
3. Making good judgments about the work of peers.
4. Identifying the principle question being addressed in scientific writing.
5. Recognizing distinctions and relationships among data & models.
6. Critically evaluating scientific literature.
7. Making inferences from incomplete data.
8. Formulating hypotheses.
9. Development of oral presentation skills.
10. Development of team working skills.
11. Development of writing skills.
12. Memorizing facts, ideas, or methods.

Lessons learned

- What worked well:
  - Interactive, discussion-oriented lessons, data/models focus, and a *true* teaching *team,* are fun for instructors & students.
  - Teams, workshops, readings, quizzes, abstracts, question posing, inclass worksheets, capstone, template so modules can change.
- Practical constraints
  - Quizzes, peer assessments are time consuming to manage
  - We have scaled *SOME* aspects for 70+ students.
- Improvements / research
  - Practice sessions to improve peer assessment.
  - Incorporation into larger classes, and wider variety of class types.
  - Questioning criteria.
  - More rigorous causes/effects, longitudinal effects, ...

Transfer to other settings

Can components be employed in other courses?

Worksheet and discussion …

Resolve:

- Common aspects of science expertise?
- Common settings where components can be explicitly targeted.

Discuss, share … (worksheet)

1. Think of a course you teach. Title? Department? Year or Level?
2. Choose ONE aspect of science expertise that you would MOST like to emphasize in that course:

   (a) Domain knowledge; (b) Distributed reasoning (teams); (c) Question posing; (d) Models and data; (e) Articulate, discuss, argue, communicate (f) Other ?? ________________________

3. How do students CURRENTLY practice this aspect in the course?
4. How are student abilities MEASURED – i.e, what is the evidence of learning (i.e. of meeting goals)?
5. What different approaches for helping students improve this aspect do you find intriguing? Why:
6. Other comments about options for, and challenges of, teaching generic science thinking skills:

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Conclusions:

1. Specific characteristics of Science Expertise can be targeted.

2. "Proven" pedagogy CAN improve abilities of 2nd yr science students.

3. Gains can be measured.

4. There are still challenges; cause/effect & longitudinal research needed.

Thanks to WCSE organizers !

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Thanks for participating !

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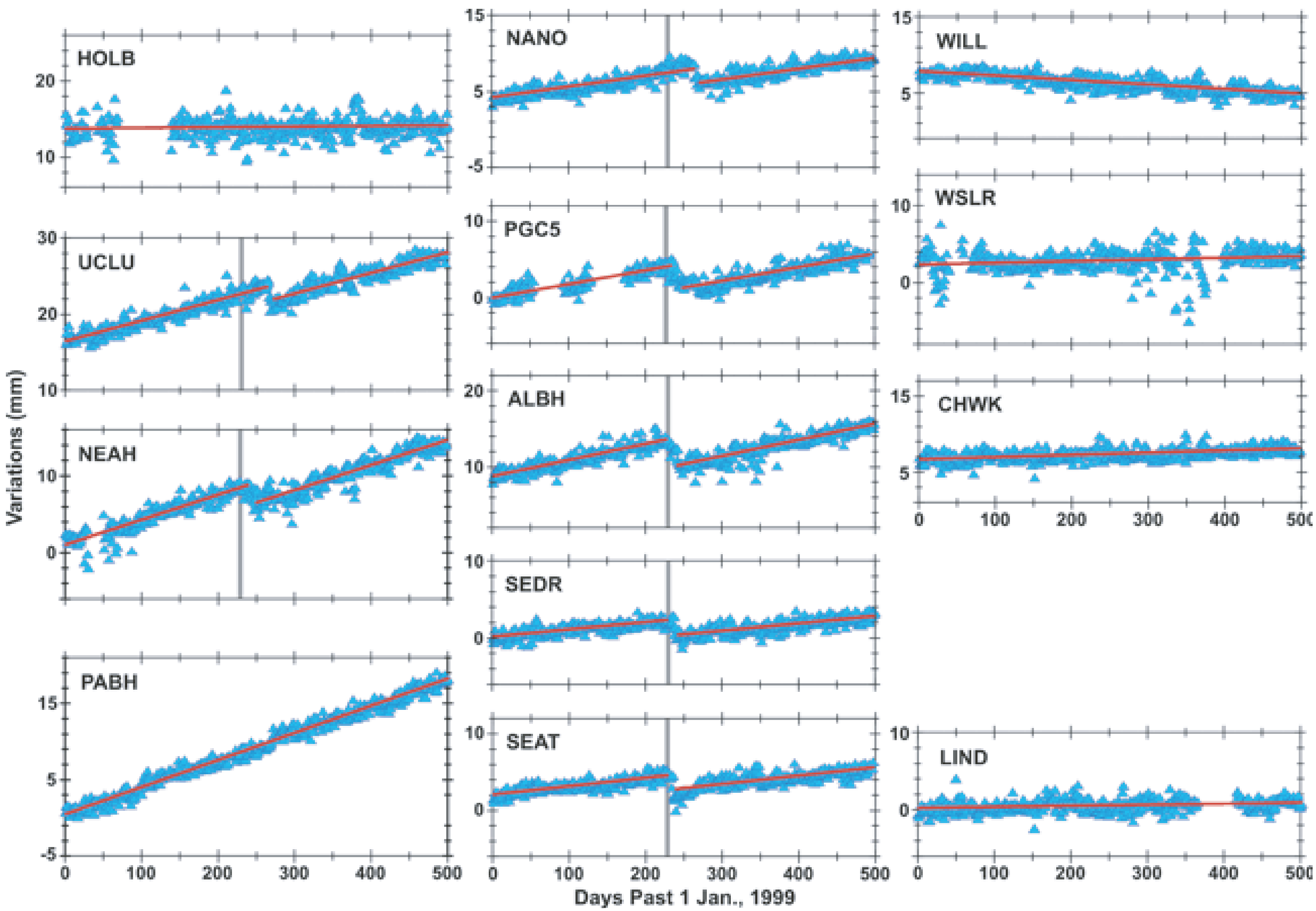
Appendix 1:
GPS exercise

1. Do filtered time series look ‘normal’ = show the steady buildup of strain?
2. How large are Earth motions in the horizontal plane
   - Outline your method(s) of determining values:
3. What is the most important thing that Figure 2 tells you about the “irregular” motion?
4. If “irregular motion” was an earthquake, where would you place its epicenter? (Mark the map.)
5. Could it be occurring in the locked zone?
   - Why or why not?
6. Do you think this irregular motion is an earthquake?
   - Why or why not?

Appendix 1:
GPS exercise data



Appendix 2:
Question posing rubric

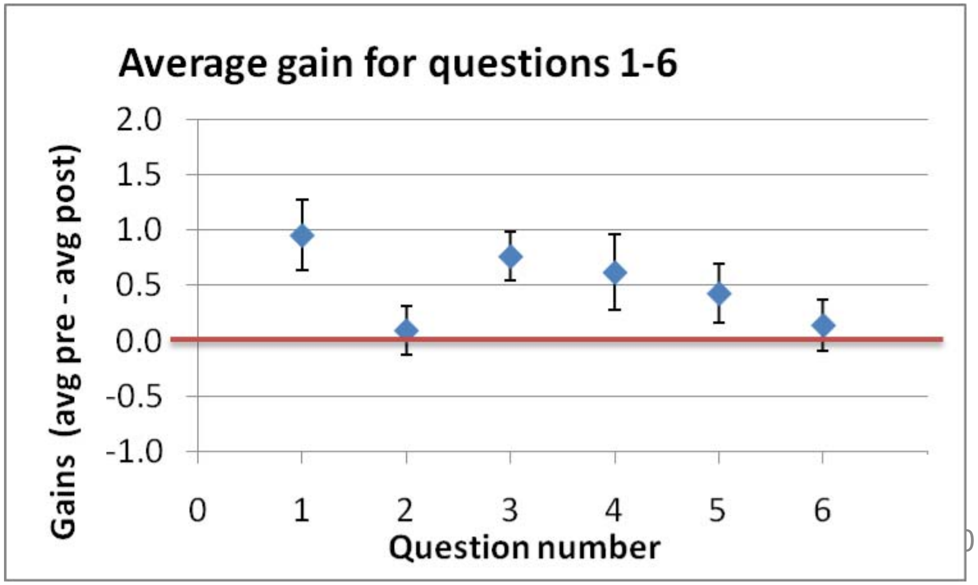
	Question Level			
Q'n Perspective (type)	**1**	**2**	**3**	**4**
A) Asking about article contents	about background, definitions, basic physics or geology	about processes, models, relationships that are in the article	probing assumptions, or not convinced of something & "why"	Beginnings of a new idea that needs testing.
B) Asking about followup to the article's thesis or discussion	A simple unqualified what if? or What's next?, etc.	Given xyz ... what if? What are implications of ... (something in the article)?	What about .... shows extended thought or synthesis of article contents; will likely be preceded by a summary, a paradox, or a puzzling result.	Beginnings of a hypothesis that can be tested.
C) Philosophical, socio-political or ethical questions				
D) Naïve: - not based on the article, or indicates basic misunderstanding or misconception; - OR irrelevant, does not make logical or grammatical sense				

Appendix 3: MBR pre-post test questions;
Average gains made for whole class, fall 2009

1. Briefly describe the primary model that is discussed in this article.
2. Provide two examples of data or observations that are related to this primary model.
3. Describe one process or phenomenon that this primary model is supposed to explain.
4. Identify one technical aspect of this primary model that you would need to learn more about, if you wanted to be more of an "expert" at using or discussing the model in its present form.
5. Identify one practical "what if" type of question that might test the limits of the model you identified.
6. Identify two other models used as part of this article's discussion of the model you identified.

Questions 2 and 6 seem “harder”.

(The same article was referenced for both the pre- and post-test.)



Appendix 4: EOS212 course learning goals

Goals related to working in Earth and Ocean Sciences

1. **Concepts and topics**: Describe the essential Earth science concepts that underlie each topic; Identify core concepts and elements of scientific controversy
2. **Models versus measurement**s: For each topic, characterize the relationship between measurements and models.
3. **Using skills to work with scientific information:** Use first-year math and analytic skills to analyze & interpret data sets similar to those encountered in readings.
4. **Enthusiasm for and knowledge of EOS:** Enthusiasm for all Earth and planetary sciences should grow, as well as awareness of research and expertise within the EOS Department.

Goals related to thinking as scientists do

5. **Using science articles:** Recognizing the principle questions, measurements, data sets, interpretations and uncertainties in assigned readings.
6. **Communicating:** Presenting, debating and asking insightful (and precise) questions about scientific ideas in assigned and self selected readings.
7. **Awareness of science learning:** Articulating both what has been learned and what is perceived as missing in your own understanding.

Context1: Desire to teach science thinking skills

- Nature of science courses (13 of 38 at EOS)
  - UBC-EOS course learning goals at http://www.eos.ubc.ca/courses/
    - Few have explicit Science Thinking goals
    - BUT there are "department goals" for service courses
  - Specialist courses rarely express Science Thinking goals.
- Unspoken "objectives"
  - We all have them ☺
- Assumed prior-abilities (read / write / synthesize, etc.)
  - Rarely clear … diagnostic tests can help here.

Examples of Science Thinking (ScTh) goals

By browsing SERC's Course Goals and Syllabi Examples at
http://serc.carleton.edu/NAGTWorkshops/coursedesign

1. Strong ScTh goals: Bio. Sciences: Organisms and Populations
   Students will be able to organize their knowledge by identifying the complex relationships among biological concepts and by creating conceptual frameworks that can used, expanded, and modified with new information.
   http://serc.carleton.edu/NAGTWorkshops/complexsystems/courses/42337.html

2. Weak or implied ScTh goals: Introduction to Earth History
   Students should be able to synthesize and evaluate the evidence used to determine rates and patterns of evolution.
   http://serc.carleton.edu/NAGTWorkshops/coursedesign/goalsdb/4303.html

3. No ScTh goals: Extinction & Evolution (entry level)
   Students will be able to describe a variety of ways in which life has affected the Earth, and how geologic events have affected life on the planet.
   http://serc.carleton.edu/NAGTWorkshops/intro/courses/28674.html