Can “generic” scientific thinking skills be promoted & measured?

Work in progress

~

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EOS-SEI

CWSEI Carl Wieman Science Education Initiative at the University of British Columbia

Abstract

EOSC 212, “Topics in Earth and Planetary Science” is a second year course offered at UBC in the Department of Earth and Ocean Sciences (EOS). It’s original objectives were to (a) help 2^{nd} year EOS students decide about preferred program streams by exposing them to a range of exciting topics in Earth, ocean, atmospheric and planetary sciences, and (b) foster, at the second year level, skills that are associated with critical scientific thinking, presentation and framing of scientific arguments/questions. An interesting question is whether these types of “higher level” learning goals can be addressed without significant discipline-specific background. The CWSEI-sponsored Science Education Initiative in EOS has allowed us to refine existing components, implement new ideas, and explore which aspects support development of these desired outcomes

This poster summarizes results of several components. First, following a guided article reading activity, assessment of written abstracts of seven Scientific American articles showed that for all students, improvement leveled off after roughly two thirds of the course. Second, following a guided science question-asking activity, types and qualities of questions students posed about the articles were assessed. Improvement is demonstrated, and some challenges associated with measuring question-asking skills are uncovered. Third, pre-post testing showed that students improved their abilities to recognize and think about the “models” and “data” being discussed in articles. Fourth, some observations are made about successes and challenges of presentation and poster projects. In conclusion, students do improve at the learning goals of this unusual course, and aspects which deserve further research were identified for several components of the course.

- How to **measure** generic science thinking abilities?
- Can scientific thinking skills be **promoted** with minimal content knowledge in 2^{nd} yr?

Efforts outlined here:

1. Correlating course learning goals to activities
2. Abstract writing
3. Question posing
4. Model Based Reasoning pre-post test
5. Communication Projects

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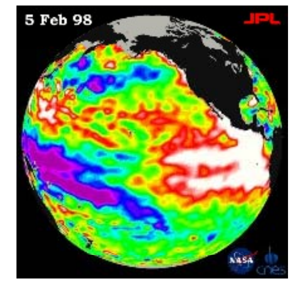
- Eosc212 “Topics in Earth & Planetary Science”
- 2-wk modules based on Scientific American articles

	2008	2009
Content modules		4
Articles read	8	7
Reading workshop	Y	Y
Abstracts written	5	7
Questions workshop	N	Y
Questions posed	7	7
Projects	2	2
Model based reasoning	-	Pre-post
Capstone module	N	Y



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Course level learning goals

1. Based upon this term's assigned readings and class work, you will ...
   a) Describe the essential Earth science concepts that underlie each topic; Identify core concepts and elements of scientific controversy.
   b) For each topic, characterize the relationship between measurements & models;
   c) Use first-year math and analytic skills to analyze & interpret data sets similar to those encountered in readings.
2. Scientific skills you will develop include ...
   a) Recognizing the principle questions, measurements, data sets, interpretations and uncertainties in assigned readings.
   b) Presenting, debating and asking insightful (and precise) questions about scientific ideas in assigned and self selected readings.
   c) Articulating both what has been learned and what is perceived as missing in your own understanding.
3. Enthusiasm for all Earth and planetary sciences should grow, as well as awareness of research and expertise within the EOS Department.

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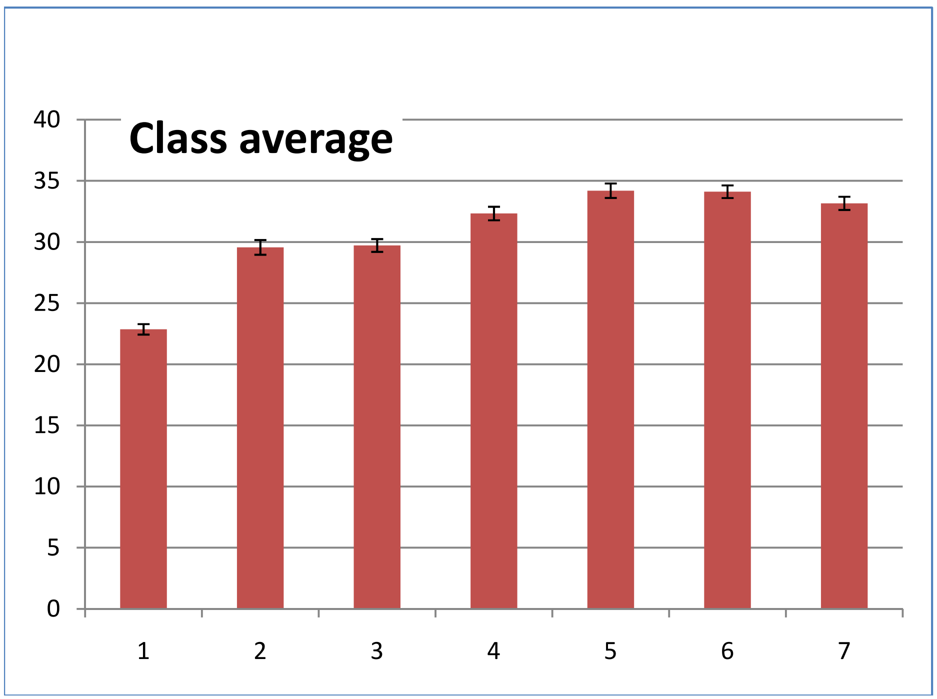
Goals - Activities matrix; *Perceptions of 2 instructors*

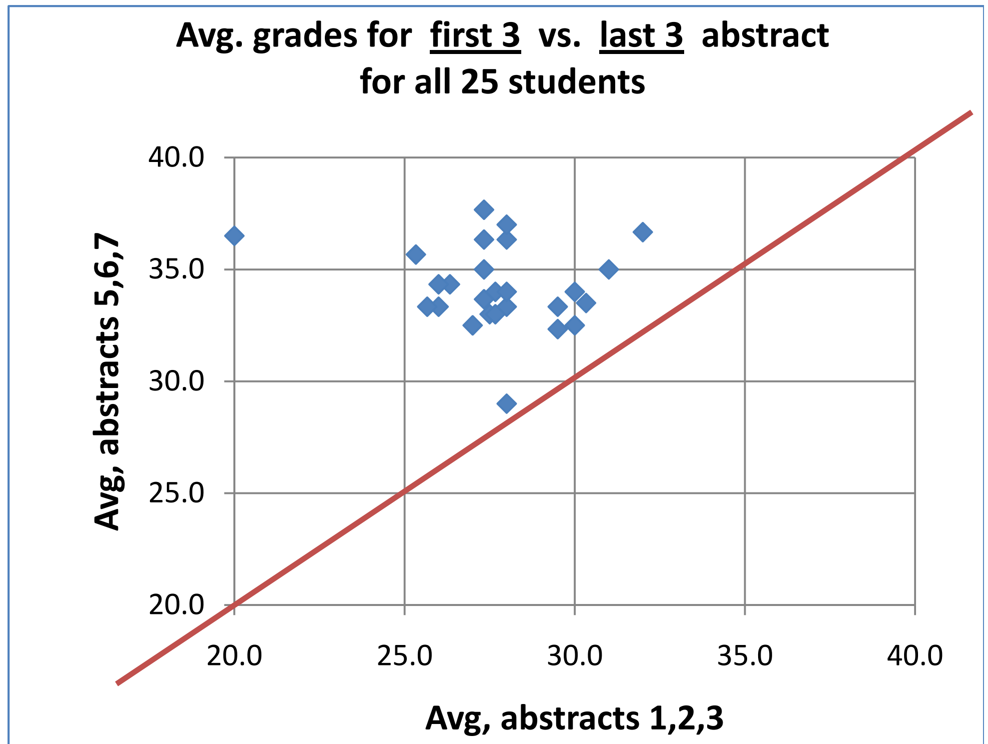
✓ = MB ✓ = MJ ✓ = STLF

Full agreement in [ ] = both instructors [ ] = one instruct + STLF

Course level goals: / Learning activities:	1. structure of scientific commun's	2. dissection of others' scientific work	3. construction of their own work	4. key attributes of good scientific quest's	5. awareness of fore-front research areas	?? Team working goal	?? Practice working with data / concepts	Instrs.	Agree
Primary SciAm readings & quizzes	✓✓✓	✓		✓	✓✓✓	✓		4	57%
Secondary readings	✓✓	✓			✓✓✓			5	71%
Abstract writing	✓✓	✓✓	✓✓✓			✓		5	71%
Question posing		✓✓✓	✓✓✓	✓✓✓	✓	✓		5	71%
In-class activities (group & individual)		✓	✓✓		✓✓	✓✓✓	✓✓✓	6	86%
In-class instructor-lead discussion		✓✓✓		✓✓	✓✓✓	✓	✓	4	57%
Instructor's lectures (readings follow up)		✓✓✓		✓	✓✓			5	71%
Instructor's lectures (new-content)		✓✓		✓✓✓	✓✓			6	86%
Guest speakers	✓✓	✓✓		✓	✓✓✓	✓		4	57%
Oral presentation (and peer assessment)	✓✓	✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓	4	57%
Posters (and peer assessment)	✓✓	✓✓	✓✓✓	✓	✓✓	✓✓✓	✓	4	57%
Peer assessment	✓	✓✓	✓		✓	✓✓	✓	1	14%
								53	
Instructors agreement	**9**	**7**	**11**	**6**	**6**	**6**	**8**	**53**	
	75%	58%	92%	50%	50%	50%	67%		

- **Science article reading workshop in week 2 → rubric.**
- Abstracts for 7 SciAm articles, targeting the rubric.
- Class average improved
  - Improvement seems to saturate by #5 of 7.
- All individuals improved.
- Peer assessments of 2.





Workshop:

What constitutes a 'good' question? → rubric.

For each article:

Students asked to *"Pose one 'good' scientific question".*

"Try to decide what 'good' means for you".

How to measure abilities or quality?

- Define: 10 "*types*" – 3 "*levels*" – 4 "*qualities*"
  - – 2008 first attempts
  - – 2009 modified, standardized codes
  - – 2010 still fine tuning …
- All questions for 5 articles coded from '08 & '09.

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Question *type* – results of analysis

Does ***type*** depend on article or year?

Observations:

- *Type* of questions asked seems to depend on article.
- More discussion-oriented questions in 2009.
- Number of *"non-science"* questions is constant.

- Specifics: D / E

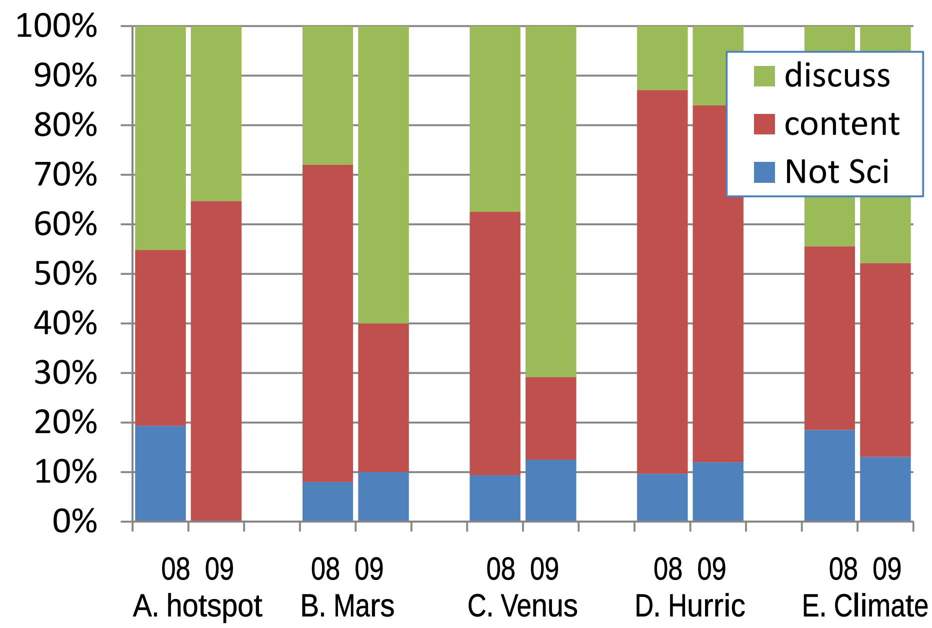
  Depends more on article than yr;

  > D more content related than E.

- Specifics: B / C

  Depends more on yr than article;

  > '09 is more discussion oriented.

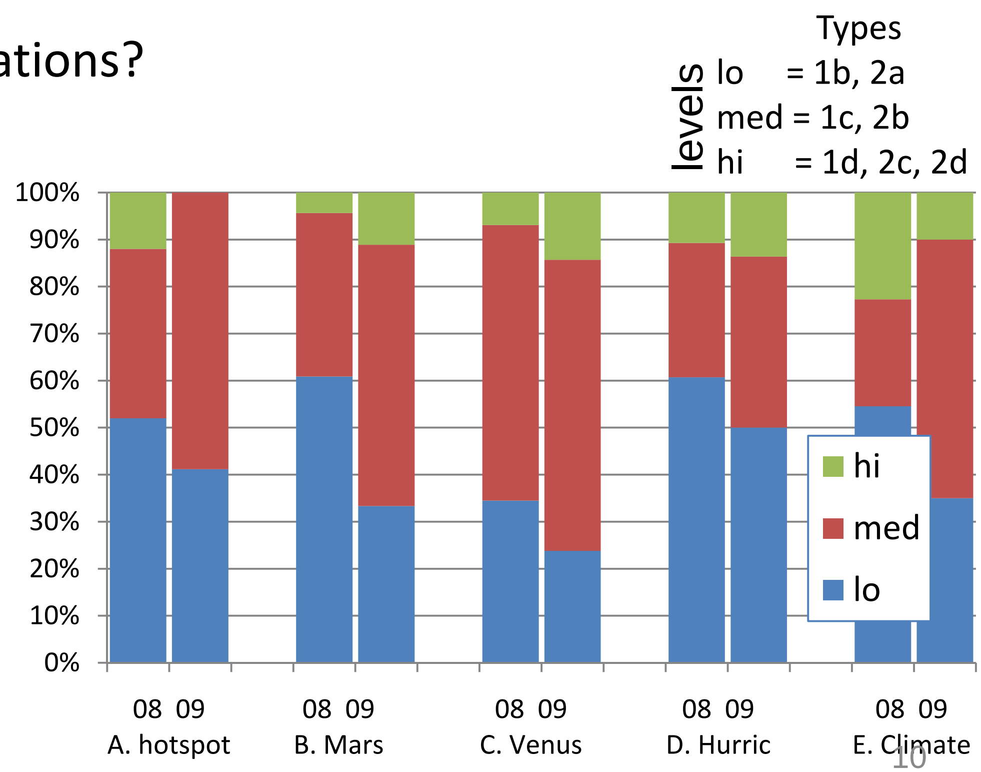


Question *level*

Does ***level*** depend on article or year ?

Observations & questions:

- Fewer lo's for all '09 ("Better" students? or pedagogy?)
- Does fewer "low level" from suggest students understood better?
- Are there "type" vs "level" correlations?
- Should we code for only 2 levels?



Question *quality*: 4 characteristics are …

1. Is the question practical to answer or pursue?
2. Is it succinct and well articulated?
3. Does it reflect careful reading, or could it be asked without reading?
4. Is it relevant; *i.e.* pertain to superfluous details or to broad implications?
5. Does it probe a precisely targeted scientific issue related to the article?

Comments:

- Coding questions for 1, 3, 4, 5 was “problematic”.
- Perhaps better codes are needed:

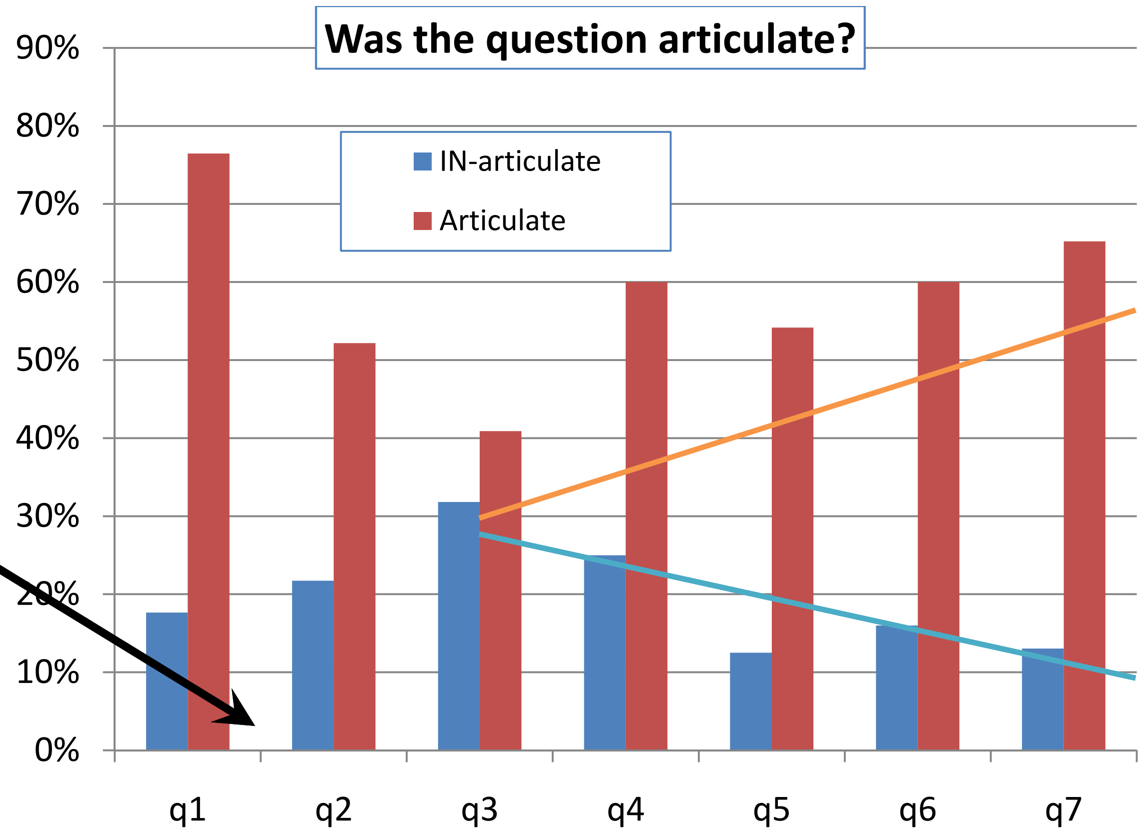
  e.g., apply scales of 1-5 to characteristics:

  - *specific detail* ***vs*** *broad implication;*
  - *irrelevant* ***vs*** *critical to the author's thesis;*
  - *testable/answerable* ***vs*** *philosophical;*
  - *incomprehensible* ***vs*** *articulate;*
  - *Others???*

In progress June 2010
with UnderGrad help

Coding for quality #2, "articulate"

- Q1 were "articulate" because they were very simple.
- Are Q3-7 targeting the rubric?
- Questioning workshop after Q1

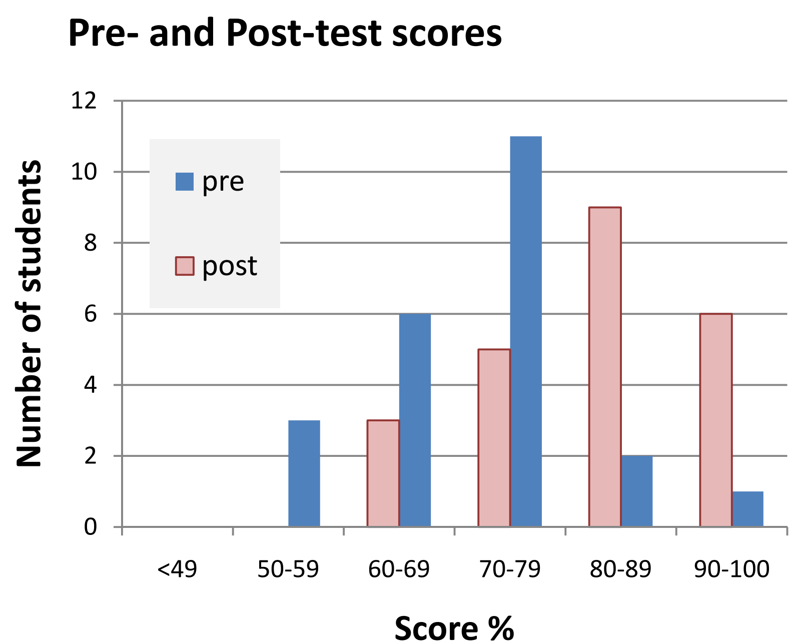


- Pre-test: 6 questions on use of models & data in 1 article.
  - Article discussed in class following the pre-test (week 2).

- Post-test: (students were reminded to re-read the article)
  - Same questions, same article.
  - Done in last week of class.

- Questions or ‘issues’:
  - “Teaching to the test”?
  - New article for post-test?
  - Avoid discussion of this article?

- *Conl’n:* still experimenting.

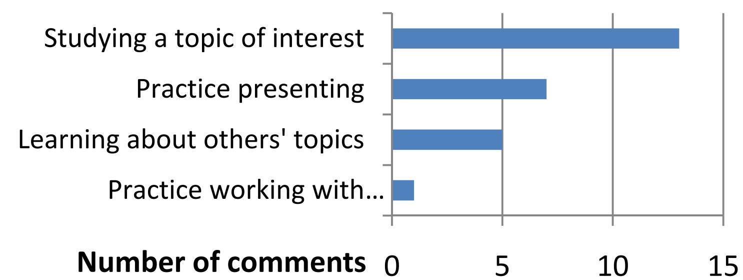


Model based reasoning QUESTIONS

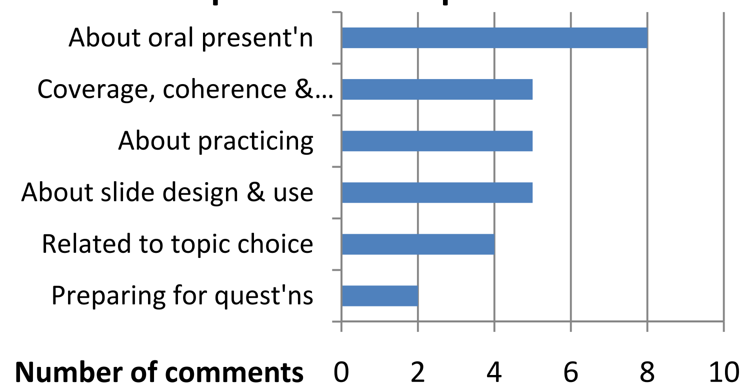
1. Briefly describe the primary model discussed in this article.
2. Provide two examples of data or observations that are related to this primary model.
3. Describe one process or phenomenon that this primary model is supposed to explain.
4. Identify one technical aspect of this primary model that you 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.

Reflections from students

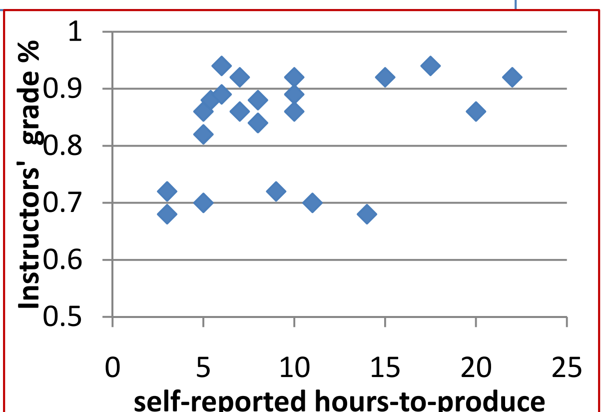
1. What YOU got out of it



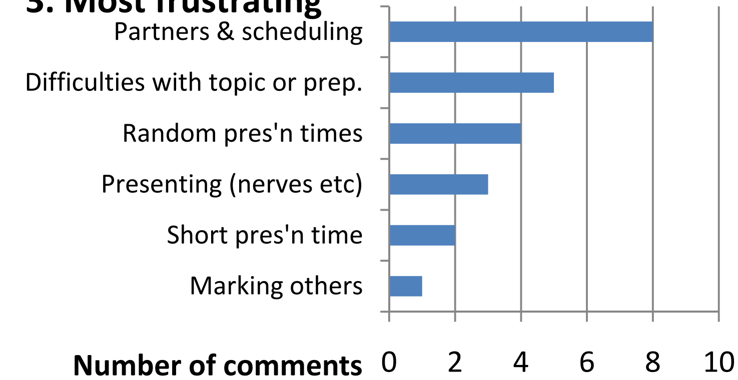
2. Advice to peers for next presen'n



Self-reported hours is un-correlated with result.

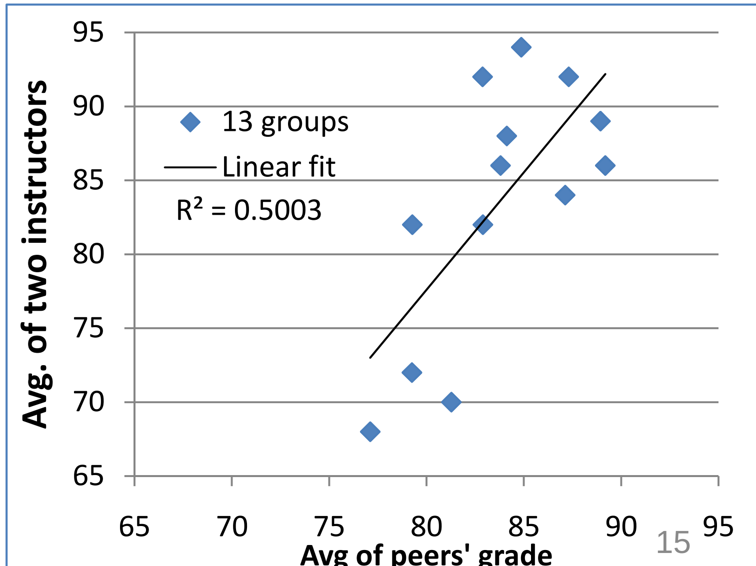


3. Most frustrating



Grading from peers vs. instructors

- Do students need better guidance for peer assessment?



Poster results

- Rubric for peer assessment
  - Simplified after *Presentation* rubric was too complex.
  - Students enter peer assessment data into a Vista "quiz".
- Criteria:
  - Content 1: "model, data & their relationships".
  - Content 2: coherence, clarity of question, abstract & conclusion.
  - Content 3: well researched and well understood .
  - Presentation 1: Quality and utilization of graphics & text.
  - Presentation2: "Stage" presence and question answering.
- Results are rather uniform.

Peer assessment results

	c1	c2	c3	p1	p2	avg
min	6.8	6.3	6.7	6.1	5.9	**6.4**
max	7.6	7.6	7.6	7.3	7.6	**7.4**
avg	7.2	7.1	7.2	6.9	7.1	**7.1**
stdev	0.2	0.4	0.3	0.4	0.4	**0.3**

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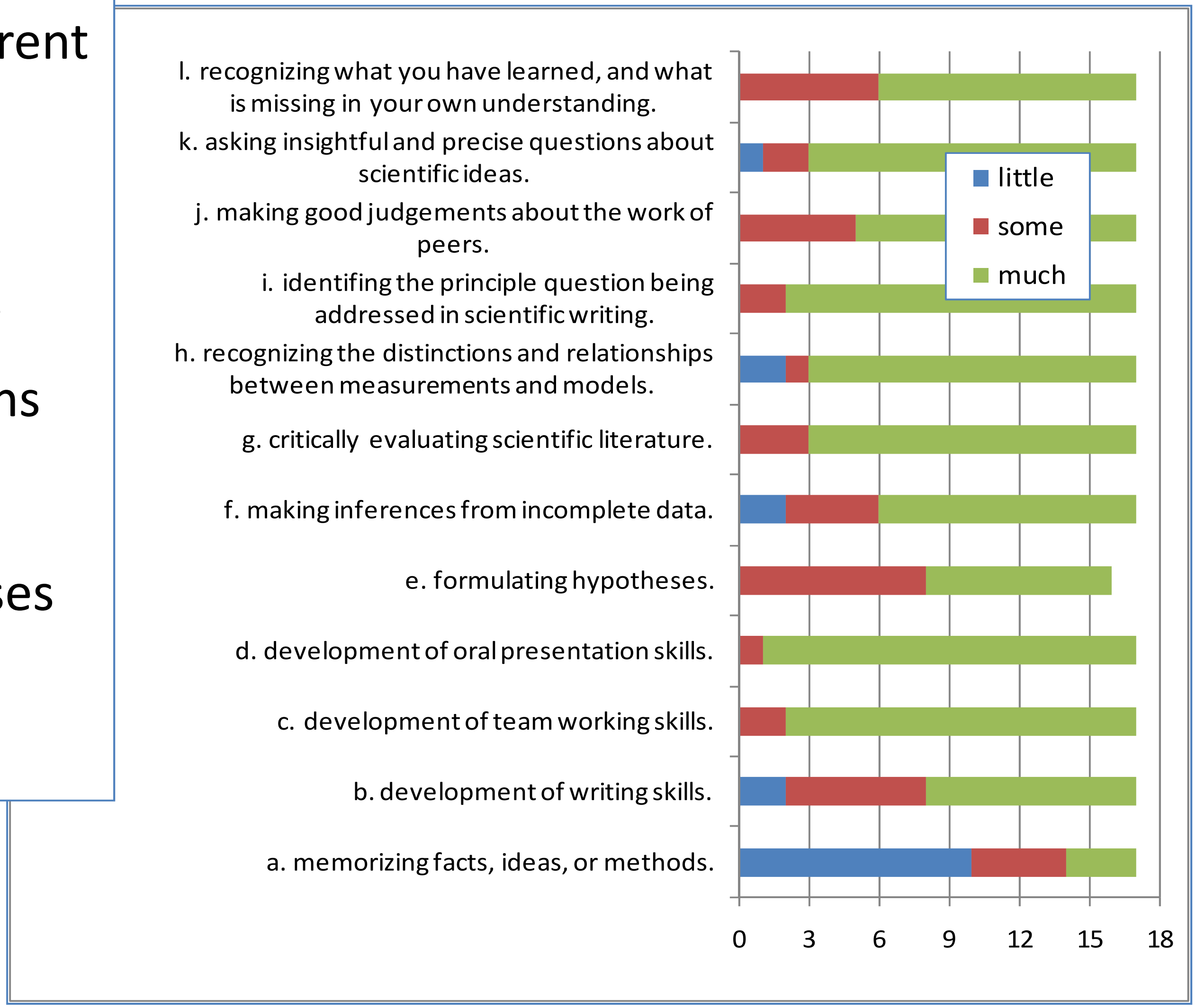
Student feedback: End of term survey

- Why take this course
- Comfort level in different discussion settings
- Interest in the topics
- Article reading habits
- Workload comparisons
- Multiple instructors
- Comments on exercises
  - Abstract writing
  - Question posing

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



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Work in progress:

1. **Refine and utilize learning goals** (especially module level)
2. **Content, activities & assessment**:
   - Quizzing on content is "saturated" – needs refining.
   - Team worksheets need to be assessed. Consider assessing team skills?
3. **Question posing**:
   - Criteria need refining.
   - Student effort needs to be more focused and purposeful.
4. **Model Based Reasoning** (MBR):
   - This was an initial experiment. It can be done better.
   - Consistency of emphasis on aspects of MBR could be improved.
5. **Teams, Peers, Communications**
   - Improve assessment of peers and team behavior.

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Purpose and context

Learning Goals

Abstract Writing

Question Posing

Model Based Reasoning

Communicating & Feedback