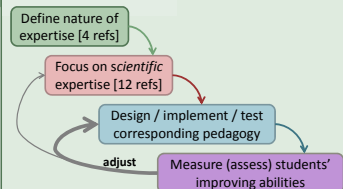


Promoting & Measuring Scientific Reasoning Expertise of 2nd Year Students

F. M. Jones*, M. Jellinek, M. G. Bostock, Dep't of Earth and Ocean Sciences (EOS), University of British Columbia (UBC), Vancouver, BC, Canada. (*fjones@eos.ubc.ca)

Project outline



The Course: EOOSC212
Topics in Earth and planetary sciences
 13-week, 2nd year course designed to:
 • Foster generic scientific skills while exploring 3-4 Earth and planetary science topics.
 • Pedagogy and assessment based on experience and literature on expertise & science expertise.

Classroom practices:
 • team-based learning strategies,
 • replace exams with quizzes and projects,
 • mix team-teaching with solo-teaching,
 • discursive rather than didactic instruction,
 • use of diverse, Department-specific topics.

Assessment practices:
 • individual / team quizzes
 • weekly abstract writing
 • weekly assessed questioning
 • team-based data analysis exercises
 • pre-post testing of model based reasoning
 • Poster & presentations (students choose topics)
 • Peer assessment of posters & presentations

Data & results of using strategies (3 terms):
 • Abstract writing skills improved then plateaued.
 • Thinking with (& about) models/data improves.
 • Questions posed ...
 o depend on article type.
 o become more articulate.
 o become more insightful, less about content.
 • Surveys showed students appreciate
 o topics
 o team work
 o practicing communication & peer assessment
 o the discussion orientation

Continuing challenges:
 • Assessment of question type and quality
 • Use of question-posing as a measure of expertise

Conclusion: (Lessons Learned)
Improving science thinking expertise involves explicit guidance in aspects involving judgments and metacognition. For EOOSC212 these are:
 • Synthesis of new knowledge (abstract writing);
 • Posing questions of various (& relevant) types;
 • Appropriate use of 'models' & 'data' in discussion;
 • Communication (written, oral and poster);
 • Assessment of peers' work & thinking.

Experts Have . . .

- Concept (content) knowledge [2][6][14]
- Strategic knowledge [2][6][14]
- Procedural knowledge [1]

- Frameworking (uses schemas) [2][6]
 - Flexible retrieval
 - Noticing patterns
 - Integrate new info. into schema
 - Adaptable (transfer)

- Metacognitive habits [2][6]
 - Learning is "deliberate"
 - Actions are planned & monitored
 - Making judgments is multifaceted

- Affective characteristics: [1]
 - Beliefs: relevance / irrelevance
 - Motivated to apply expertise
 - Expectations of what's achievable

- Pedagogic domain knowledge [2]

Expert Scientists . . .

- Have significant domain knowledge [2][6][12]

- Use analogic thinking [5]
- Use distributed reasoning (team player) [5]
- Identify & follow up anomalies [5]

- Frequently questions work & assumptions and generates hypotheses [4][7][10][11]
- Can design & execute experiments [14]
- Are measurement and/or observation oriented [3][14]
- Evaluate relevance & quality of data [12][14]
- Fluently use and relate models & data (including math and others) [4][8]

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- Use evidence & rhetoric in argumentation [12]
- Use graphical representations both for making sense and arguing. [2][12][9]

Readers ... Did we forget any aspects of "scientific expertise"?

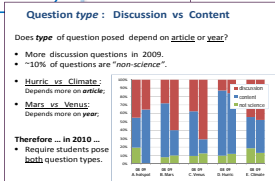
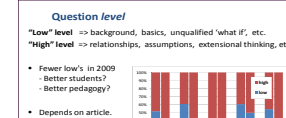
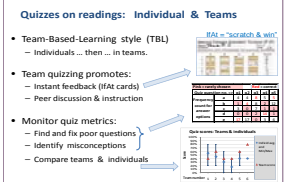
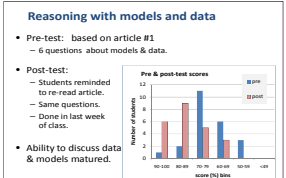
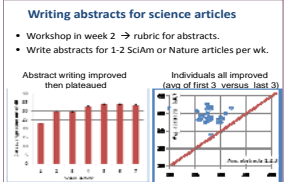
Use *post-its* to contribute below .

EOOSC212: Topics in Earth & Planetary Sciences

Features of this course:

- 2-3 readings per module
- Solid Earth physics
- Planetary science
- Atmospheric/oceanography
- Individual and team quizzes
- Model based reasoning Pre-Post
- Abstracts / questioning workshops
- Abstracts written for each article
- Questions posed for each article
- Team exercises with data & models
- Discussion oriented lectures lead by
 - Dual instructors
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 - Guests
- Student - chosen projects
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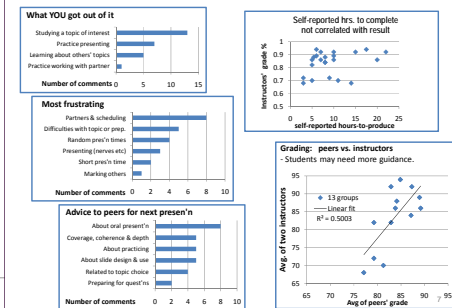
Data demonstrating learning



Guided question posing - 2010

- Assignment: pose 3 types of questions (27 students)
 - Preliminary results:
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 - 2 articles in Sept.
 - 1 article in Nov.
 - Questions get better.
 - Class consistency improves (not error).
-

Feedback about presentations ; self-selected topics & peer assessed



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Continuing challenges:

- Assessment of question type and quality
- Use of question-posing as a measure of expertise

Conclusion: (Lessons Learned)

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EOSC212: Topics in Earth & Planetary Sciences

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- Workshop in week 2 → rubric for abstracts.
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Reasoning with models and data

- Pre-test: based on article #1 - 6 questions about models & data.
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 - Done in last week of class.
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- Team-Based-Learning style (TBL) - Individuals ... then ... in teams.
- Team quizzing promotes:
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 - Peer discussion & instruction
- Monitor quiz metrics:
 - Find and fix poor questions
 - Identify misconceptions
 - Compare teams & individuals

Question level

- "Low" level => background, basics, unqualified 'what if', etc.
- "High" level => relationships, assumptions, extensional thinking, etc.
- Fewer low's in 2009 - Better students? - Better pedagogy?
- Depends on article.

Readers ... Did we forget any aspects of "scientific expertise"?

Use *post-its* to contribute below .

Feedback about presentations; self-selected topics & peer assessed

Question type: Discussion vs Content

Does type of question posed depend on article or year?

- More discussion questions in 2009.
- "10% of questions are 'non-science'".
- Harris vs. Climate: Depends more on article.
- Mars vs. Venus: Depends more on year.
- Therefore ... in 2010 ... Require students pose better question types.

Is the question succinct and well articulated?

- "Pose one good question ..." (with abstract writing assignment)
 - Scored using 1 = NOT articulate ... 5 = VERY articulate
 - Questions posing workshop after Q1.
- Q1: generally articulate, but simple.
- Q3-Q7: decline followed by improvement

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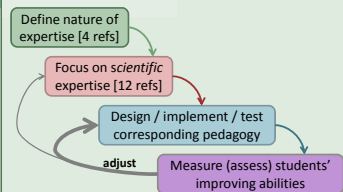
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o topics
o team work
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o the discussion orientation

Continuing challenges:
• Assessment of question type and quality
• Use of question-posing as a measure of expertise

Conclusion: (Lessons Learned)
Improving science thinking expertise involves explicit guidance in aspects involving judgments and metacognition. For EOSC212 these are:
• Synthesis of new knowledge (abstract writing);
• Posing questions of various (& relevant) types;
• Appropriate use of 'models' & 'data' in discussion;
• Communication (written, oral and poster);
• Assessment of peers' work & thinking.

Experts Have . . .

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- Have significant domain knowledge [2][6][12]

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EOSC212: Topics in Earth & Planetary Sciences

Features of this course:

- 2-3 readings per module
- Solid Earth physics
- Planetary science
- Atmospheric/oceanography
- Individual and team quizzes

- Model based reasoning Pre-Post

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- Abstracts written for each article
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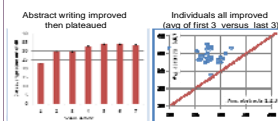
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Data demonstrating learning

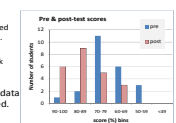
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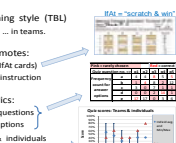
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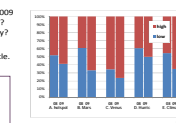
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Question level

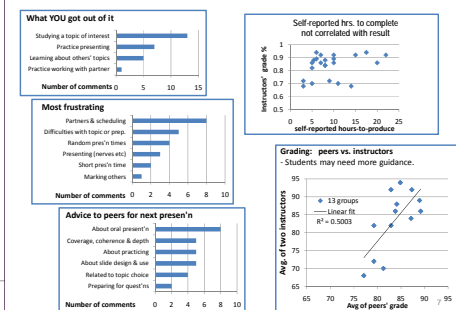
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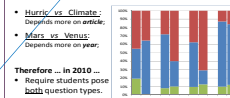
Feedback about presentations ; self-selected topics & peer assessed



Question type : Discussion vs Content

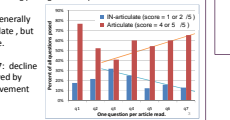
Does type of question posed depend on article or year?

- More discussion questions in 2009.
- "10% of questions are "non-science".
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- Therefore ... in 2010 ...
 - Require students pose **basic** question types.



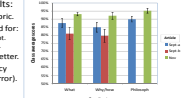
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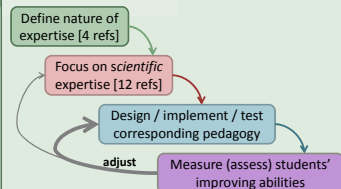
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 • Questions posed ...
 o depend on article type.
 o become more articulate.
 o become more insightful, less about content.
 • Surveys showed students appreciate
 o topics
 o team work
 o practicing communication & peer assessment
 o the discussion orientation

Continuing challenges:
 • Assessment of question type and quality
 • Use of question-posing as a measure of expertise

Conclusion: (Lessons Learned)
Improving science thinking expertise involves explicit guidance in aspects involving judgments and metacognition. For EOOSC212 these are:
 • Synthesis of new knowledge (abstract writing);
 • Posing questions of various (& relevant) types;
 • Appropriate use of 'models' & 'data' in discussion;
 • Communication (written, oral and poster);
 • Assessment of peers' work & thinking.

Experts Have . . .

- Concept (content) knowledge [2][6][14]
- Strategic knowledge [2][6][14]
- Procedural knowledge [1]

- Frameworking (uses schemas) [2][6]
 - Flexible retrieval
 - Noticing patterns
 - Integrate new info. into schema
 - Adaptable (transfer)

- Metacognitive habits [2][6]
 - Learning is "deliberate"
 - Actions are planned & monitored
 - Making judgments is multifaceted

- Affective characteristics: [1]
 - Beliefs: relevance / irrelevance
 - Motivated to apply expertise
 - Expectations of what's achievable

- Pedagogic domain knowledge [2]

Expert Scientists . . .

- Have significant domain knowledge [2][6][12]

- Use analogic thinking [5]
- Use distributed reasoning (team player) [5]
- Identify & follow up anomalies [5]

- Frequently questions work & assumptions and generates hypotheses [4][7][10][11]
- Can design & execute experiments [14]
- Are measurement and/or observation oriented [3][14]
- Evaluate relevance & quality of data [12][14]
- Fluently use and relate models & data (including math and others) [4][8]

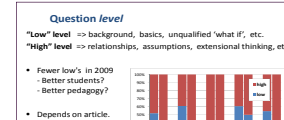
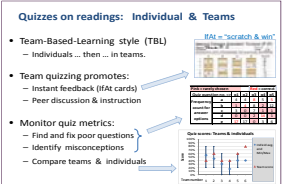
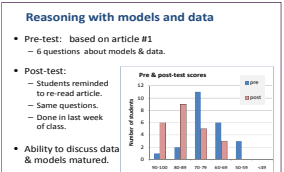
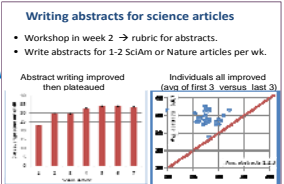
- Can articulate explanations & syntheses [12]
- Use evidence & rhetoric in argumentation [12]
- Use graphical representations both for making sense and arguing. [2][12][9]

EOOSC212: Topics in Earth & Planetary Sciences

Features of this course:

- 2-3 readings per module
- Solid Earth physics
- Planetary science
- Atmospheric/oceanography
- Individual and team quizzes
- Model based reasoning Pre-Post
- Abstracts / questioning workshops
- Abstracts written for each article
- Questions posed for each article
- Team exercises with data & models
- Discussion oriented lectures lead by
- Dual instructors
- Single instructors
- Guests
- Student - chosen projects
- Oral presentation
- Poster presentation
- Peer assessments

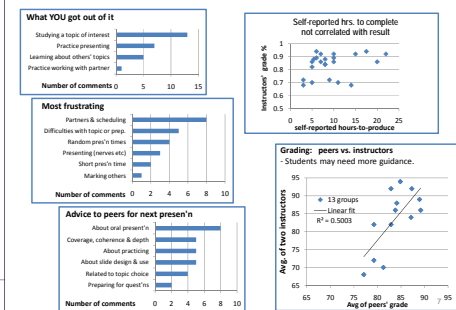
Data demonstrating learning



Readers ... Did we forget any aspects of "scientific expertise"?

Use **post-its** to contribute below .

Feedback about presentations; self-selected topics & peer assessed



Question type : Discussion vs Content

Does type of question posed depend on article or year?

- More discussion questions in 2009.
- "10% of questions are "non-science".
- **Harris vs. Climate:** Depends more on article.
- **Mars vs. Venus:** Depends more on year.
- Therefore ... in 2010 ...
- Require students pose **both** question types.

Is the question succinct and well articulated?

- "Pose one good question ..." (with abstract writing assignment)
 - Scored using 1 = NOT articulate ... 5 = VERY articulate
 - Questioning posing workshop after Q1.
- Q1: generally articulate, but simple.
- Q3-Q7: decline followed by improvement

Guided question posing - 2010

- Assignment: pose 3 types of questions (27 students)
- Preliminary results:
 - "Grading" via rubric:
 - Questions posed for:
 - 2 articles in Sept.
 - 1 article in Nov.
 - Questions get better.
 - Class consistency improves (post error).

References on attached handout, & via
<http://www.eos.ubc.ca/research/cwsei/scientificskills.html>

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