How to Increase the Level of Inquiry in your Lab Activities

2016 Earth Educators' Rendezvous

Leader: Katherine Ryker, PhD. Eastern Michigan University.

Inquiry: easy to say we use in teaching, harder to prove! Inquiry learning parallels the process of scientific inquiry, and focuses on the students' role in asking and investigating scientific questions. Inquiry-based labs are one way to promote student-centered teaching and a strong conceptual understanding of the geosciences, including when labs are taught by Teaching Assistants. However, it is easy to default to cookbook labs in which students follow rote procedures to get a pre-determined result, especially when time is a factor. Participants will work in teams to measure the level of inquiry in several geoscience labs, including one of their own. By the end of the workshop, participants will have identified specific strategies to increase the inquiry level of their own lab activities, and created a plan for revising others.

Note: This workshop will include teaching tools and activities you can use in your class this semester.

Source for this presentation:

http://serc.carleton.edu/earth_rendezvous/2016/program/afternoon_workshops/w7.html

How to Increase the Level of Inquiry in your Lab Activities

Get a head start on the workshop!

1. Using your laptop, tablet or smart phone, go to kahoot.it
2. Enter Game PIN 831000
3. Pick a nickname (will be displayed on the screen!)

Please sit at a table with others!

Let's get active!

- Using your laptop, tablet or smart phone, go to kahoot.it
- Enter Game PIN 831000
- Pick a nickname (will be displayed on the screen!)
- You'll have 60 seconds to answer the first question. Pick the symbol that best represents your answer.
- ***Find a partner*** *and* ***explain*** *why you're feeling more cautious or adventurous today.*
- Let's try one more!
- ***Discuss:*** *Is anyone at your table thinking about the same lab?*
- ***Share:*** *WHO teaches this lab at your institution?*

***Kahoot! is easy and free to use**

Increasing Inquiry Level in Lab

<u>Goals of the program:</u>

1. Characterize the levels of inquiry present in sample geoscience lab activities, including at least one of your own
2. Identify specific strategies for increasing the inquiry level of lab activities that you plan to use in your own classroom.
3. Discuss the training necessary for Teaching Assistants to teach inquiry-based labs appropriately.

Dissonance activity

Yellow **Red**

Blue **Purple**

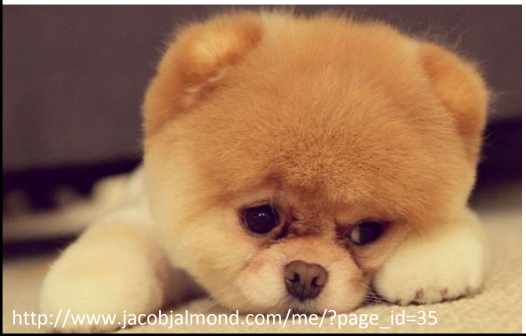
Orange **Green**

- *In 5 minutes at your table, describe a lab that would be the **LEAST** conducive to learning (geo)science.*

***Used in large lectures, small seminars and other workshops.**

Worst Lab Ever

- No clear relevance to students' lives, or at least the course
- No hands-on activities or materials
- Students don't have to do any prior thinking – jumping right on
- Working independently
- Definitions lab – vocab, vocab, vocab
- Metric and unit conversion lab
- Topo maps lab
- Step-by-step cookbook labs



Best Lab Ever

- Make it relevant to their lives
- "Just add rocks"
- Incorporate some kind of hands on activities and materials
- Warm up activities or questions, having students think for themselves
- Give context for the activity
- Opportunities to communicate
- Going beyond vocab to SKILLS, PROCESS, SYNTHESIS
- Inquiry-based labs

Source: Workshop participants, July 20, 2016

What are inquiry-based classrooms?

- Incorporate constructivist or “reformed” pedagogy[1]
- Diverse ways in which learners investigate the natural world, propose ideas, and explain and justify assertions on the basis of evidence[2]
- Requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations[3]

Scientific process

Student role

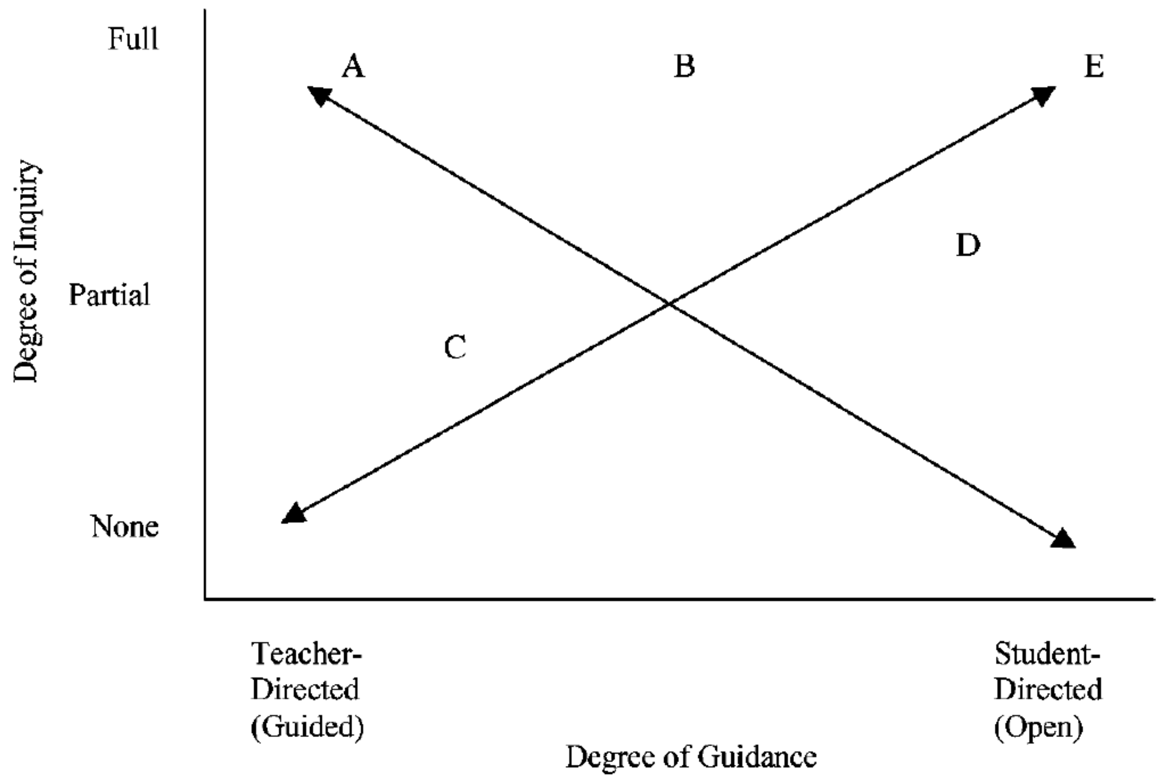
A group of students working on a lab activity in the classroom.

[1]MacIsaac & Falconer, 2002; [2]Hofstein & Lunetta, 2003; [3]NRC 2000

Measures of inquiry

- The Level of Openness in the Teaching of Inquiry (Herron 1971)
- The Laboratory Structure and Task Analysis Inventory (Fuhrman et al., 1978)
- Chinn and Malhotra (2002)
- The Inquiry Continuum (Brown et al. 2006)

The Inquiry Continuum



Abraham 2005; Anderson 2002; Bell et al 2003; Chinn and Malhotra 2002; Colburn 2000; Domin 1999; Eick and Reed 2002; Farrell, Moog, and Spencer 1999; Gaddis and Schoffstall 2007; Germann 1989; Germann, Haskins, and Auls 1996; Hancock, Kaput and Goldsmith 1992; Martin-Hansen 2002; Kyle 1980; NRC 2000; Mohrig 2004; Mohrig, Hammond, and Colby 2007; Pavalich and Abraham 1977; Schwartz, Lederman, and Crawford 2004; Windschitl 2004; Windschitl and Buttemer 2000

Measures of inquiry

- The Level of Openness in th[...] Inq[...]
- The [...] Stru[...] Ana[...] (Fu[...]
- Chi[...] (20[...]
- The [...] (Br[...]

The Inquiry Continuum

Traditional

Directed

Structured

Partial

Scientific

Authentic

Inquiry Learning

Inquiry Teaching

Guided

Full

Open

Abraha[...] and Spencer 1999; Gaddis and Schoffstall 2007; Germann 1989; Germann, Haskins, and Auls 1996; Hancock, Kaput and Goldsmith 1992; Martin-Hansen 2002; Kyle 1980; NRC 2000; Mohrig 2004; Mohrig, Hammond, and Colby 2007; Pavalich and Abraham 1977; Schwartz, Lederman, and Crawford 2004; Windschitl 2004; Windschitl and Buttemer 2000

Benefits of inquiry-based teaching

- Improve conceptual knowledge and attitudes[1-3], increase student involvement and engage students in science[4], and encourage positive attitudes toward science[5]

...but!

- Teach as we were taught[6]
- Time constraints and the challenge of new roles
- Perception of cookbook activities being "easier"
- Conflicting beliefs and values related to "coverage"[7]

[1]Beichner et al., 2007; [2]Knight & Wood, 2005; [3]McConnell et al., 2006; [4]Leonard, 1989; [5]Shymansky, Kyle & Alport, 1983; [6]Halpern & Hakel, 2002; [7]Anderson, 2002

Levels of Inquiry

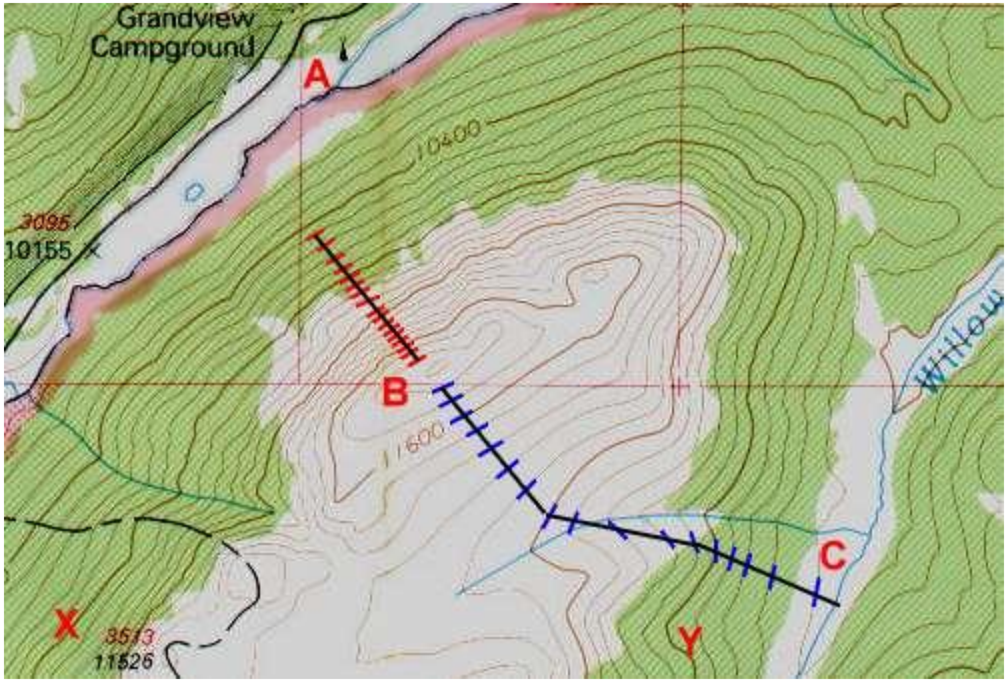
- Rubric to characterize inquiry present in college science laboratory classes[1]
- Identifies varying degrees of student independence

Characteristic	Level 0: Confirmation	Level 1/2: Structured Inquiry	Level 1: Guided Inquiry	Level 2: Open Inquiry	Level 3: Authentic Inquiry
Problem/Question	Provided	Provided	Provided	Provided	Not provided
Theory/Background	Provided	Provided	Provided	Provided	Not provided
Procedures/Design	Provided	Provided	Provided	Not provided	Not provided
Results analysis	Provided	Provided	Not provided	Not provided	Not provided
Results communication	Provided	Not provided	Not provided	Not provided	Not provided
Conclusions	Provided	Not provided	Not provided	Not provided	Not provided

[1]Buck, Bretz & Towns, 2008

Sample Inquiry Lab Activities: Confirmation

Confirmation - The problem, procedure, analysis, and correct interpretations of the data are immediately obvious from statements and questions in the laboratory manual.



- **Topographic Maps Lab:** Using the map provided, estimate the elevation of points A, B, C and X.

http://whslgrigg.weebly.com/uploads/1/3/1/5/13158546/five_themes_of_geography_ppt.pdf

Sample Inquiry Lab Activities: Confirmation

Confirmation - The problem, procedure, analysis, and correct interpretations of the data are immediately obvious from statements and questions in the laboratory manual.

Lab manual background: "Pumice and scoria are very porous, but their pores are not connected. Pore spaces must be connected for water to move from one to another – a property called permeability."

Question: "Hold pieces of highly porous pumice and scoria above two beakers or rest them on the rims. Slowly drop or sprinkle water onto the rocks and observe what happens. Are pumice and scoria porous? Permeable? Explain."

http://faculty.kutztown.edu/friehauf/classes/parks/exam_1_study_guide.html

Sample Inquiry Lab Activities: Structured

Structured – The lab provides the problem, procedures, and analysis by which students can discover relationships or reach conclusions that are not already known from the manual.

- **Weathering Lab**: Record the following data for each tabular marble tombstone; 1) Date of death on the stone; 2) Visual weathering class for tombstone inscriptions; 3) Average thickness of the stone at the top and bottom (in mm) measured with calipers
- **Sedimentary Rock Lab**: Use the information provided and the Sedimentary Rock Identification Key to identify the seven samples of sedimentary rocks.

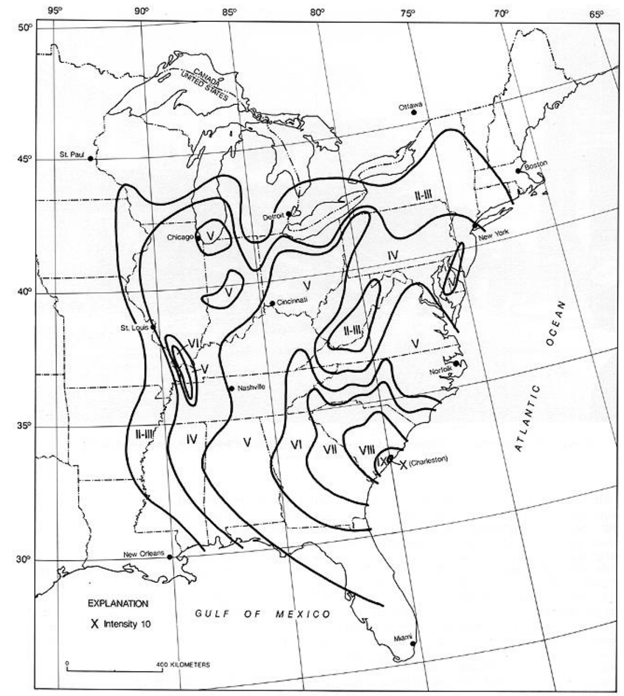
Students compare field notes with a TA during the weathering lab

Sample Inquiry Lab Activities: Guided

Guided – The laboratory manual provides the problem and procedures, but the methods of analysis, communication, and conclusions are for the student to design.

The pages that follow display maps that illustrate Modified Mercalli intensity scale estimates for **three earthquakes** that occurred in the eastern US. These earthquakes formed on ancient faults that break unpredictably over long time intervals and have the potential to affect Raleigh.

- If earthquakes of similar magnitudes occurred at the same locations today, what differences would you expect in the resulting damage in Raleigh, Asheville, and Charlotte? Describe the potential effects of the three earthquakes on people and structures for each location.
- If the state was going to give one of the cities $5,000,000 to protect key buildings from collapse, which city would you award the funds to?



https://www.thinglink.com/scene/507012052909293570

Sample Inquiry Lab Activities: Open

Open – The problem and background are provided, but the procedures/design/methodology are for the student to design, as are the analysis and conclusions.

Earthquake Lab: During each modeled "earthquake", the brick made a rapid change in position. Three hypotheses for fault movements are described below (periodic, time-predictable and random). Design an experiment to determine which best represents the movements that occur with the earthquake machine model.

Sample Inquiry Lab Activities: Authentic

Authentic – The problem, procedures/design, analysis, communication, and conclusions are for the student to design.

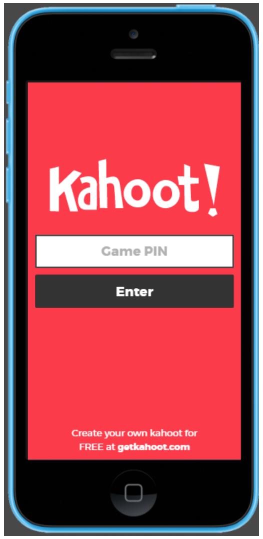
Undergraduate research projects

An "inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline." –Council for Undergraduate Research

Check out:

- Pedagogy in Action: Undergraduate Research http://serc.carleton.edu/sp/library/studentresearch//index.html
- 2014 Workshop Program "Undergraduate Research as Teaching Practice" http://serc.carleton.edu/NAGTWorkshops/undergraduate_research/workshop_2014/program.html

Examining sample lab activities in small groups.



- Apply what you've learned to characterize the inquiry level of lab activities from several geoscience disciplines.

First: Discovering Plate Boundaries

Second: Pick EITHER with someone at your table:

Hydrology

Rock Cycle

Third: Pick ONE based on your interests:

Paleontology

Mineralogy/Petrology

Geomorphology


Take a 10 minute break.
https://www.theodysseyonline.com/10-most-relaxing-songs

Astronomy (13)

Biology (37)

Chemistry (99)

Geology (46)

Meteorology (17)

Physical Science (33)

Physics (11)

TABLE 3

Evaluation of levels of inquiry for laboratory texts across science disciplines.

	Level of Inquiry						
	0	½	1	2	3	Experiments in manual	Experiments evaluated
ASTRONOMY							
PH-110 Principles of astronomy and space laboratory manual (Queensborough Community College Department of Physics 2006)	13					14	13
BIOLOGY							
★ *Inquiry into life lab manual* (Mader 2000)	22					32	22
★ *Introductory microbiology: An inquiry-based laboratory manual* (Otigbuo and Keyser 2006)		10	5			20	15
CHEMISTRY							
LASER experiments for beginners (Zare et al. 1995)	8					29	8
Cooperative chemistry laboratory manual (Cooper 2006)	2	4	9			15	15
★ *Laboratory inquiry in chemistry* (Bauer, Birk, and Sawyer 2005)	2	9	12			29	23
CHM 115 labaratory manual, fall 2006 (Purdue University Department of Chemistry 2006)		7				23	7
★ *Working with chemistry: A laboratory inquiry program* (Wink, Gislason, and Kuehn 2005)		24				26	24
★ *Inquiries into chemistry* (Abraham and Pavelich 1999)		5		5		63	10
Laboratory manual for general, organic, and biological chemistry (Timberlake 2007)		12				42	12
GEOLOGY							
Laboratory manual in physical geology (Busch 2006)	11					16	11
Laboratory manual for physical geology (Zumberge, Rutford, and Carter 2003)	17					29	17
Exercises in physical geology (Hamblin and Howard 2005)	18					23	18
METEOROLOGY							
Exercises for weather and climate (Carbone 2007)	17					17	17
PHYSICAL SCIENCE							
An introduction to physical science laboratory guide (Shipman and Baker 2006)		33				55	33
PHYSICS							
★ *Physics by inquiry, vol. 1* (McDermott and the University of Washington Physics Education Group 1996)	5	6				59	11

Buck, Lowery Bretz and Towns, Journal of College Science Teaching, Sept/Oct, 2008, p.52-58.

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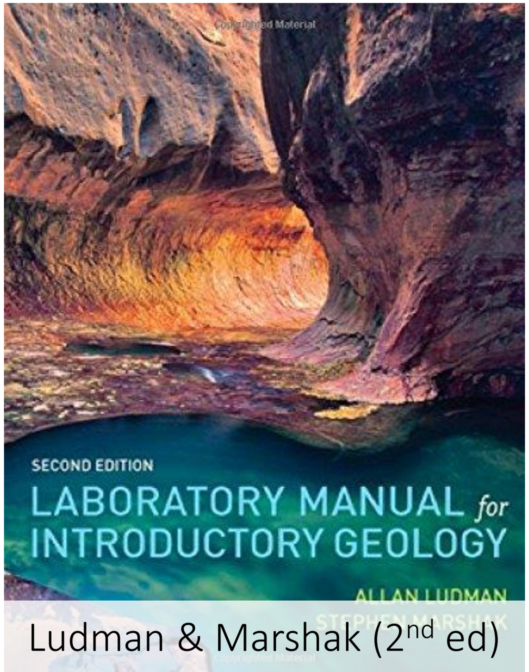
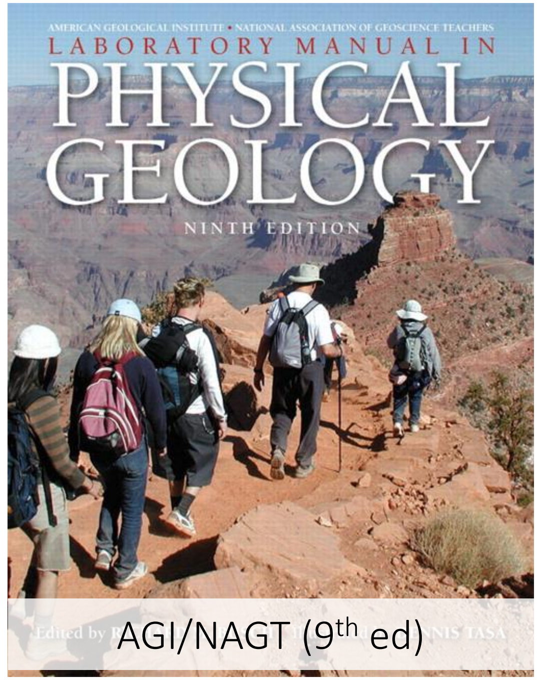
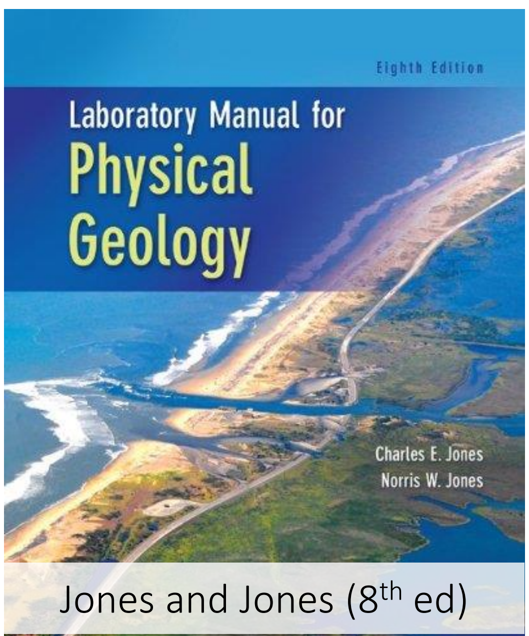


Ludman & Marshak (2nd ed)

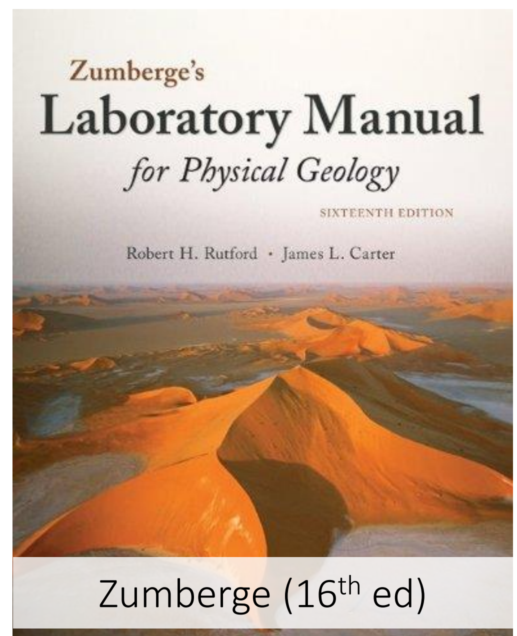


AGI/NAGT (9th ed)

NC State (2013)

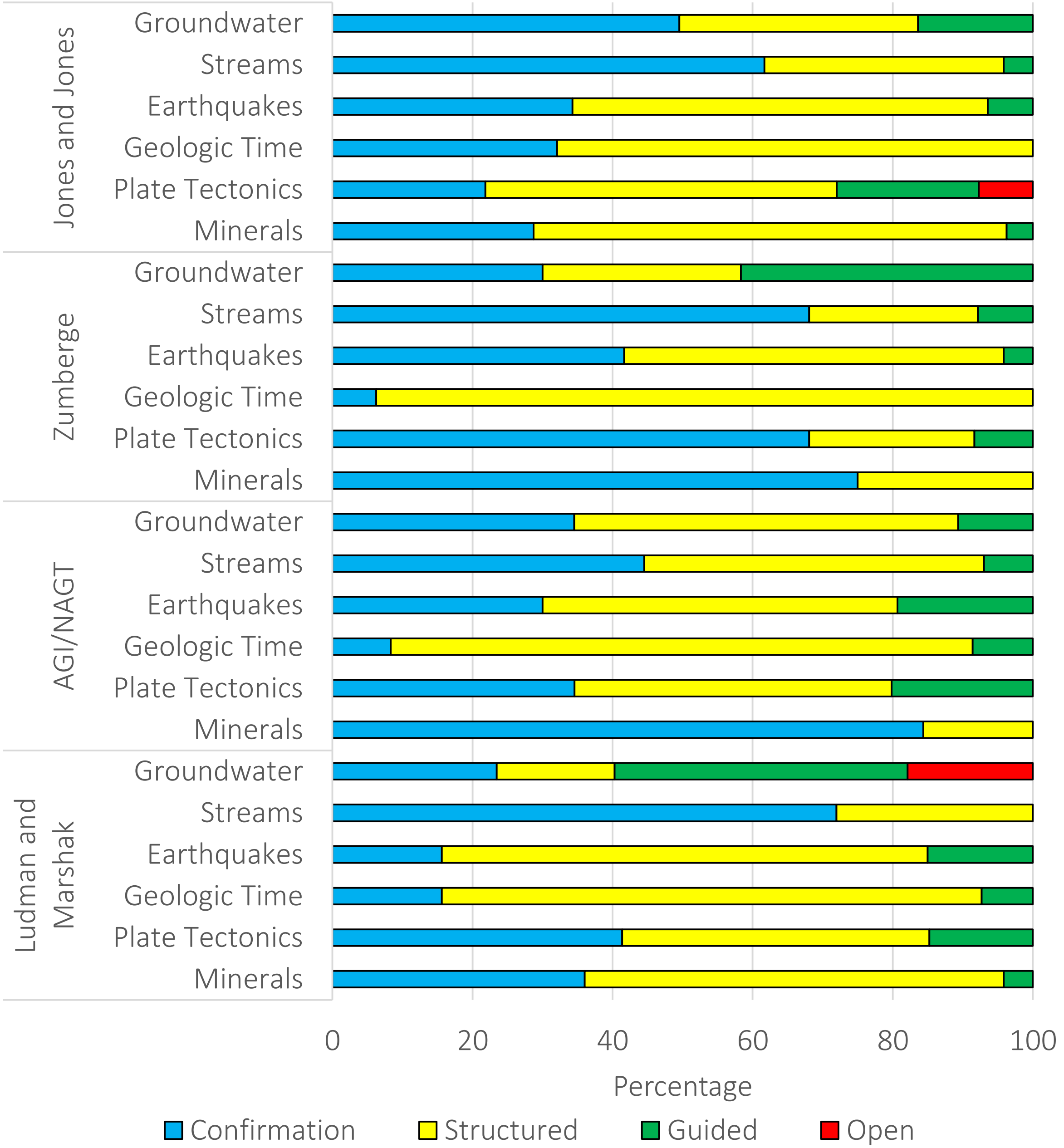


Jones and Jones (8th ed)



Zumberge (16th ed)

To what extent is inquiry present in introductory geoscience labs?



Proportion of each lab that can be attributed to each level of inquiry.

Ryker and McConnell, 2013

To what extent is inquiry present in introductory geoscience labs?

No significant difference between lab manuals (p = 0.669)

Average Inquiry Score

39.9% x 0 (Confirmation) = 0 points
48.1% x ½ (Structured = 24.05 points
10.9% x 1 (Guided) = 10.9 points
1.1% x 2 (Open) = 2.2 points
0.0% x 3 (Authentic) = 0 points

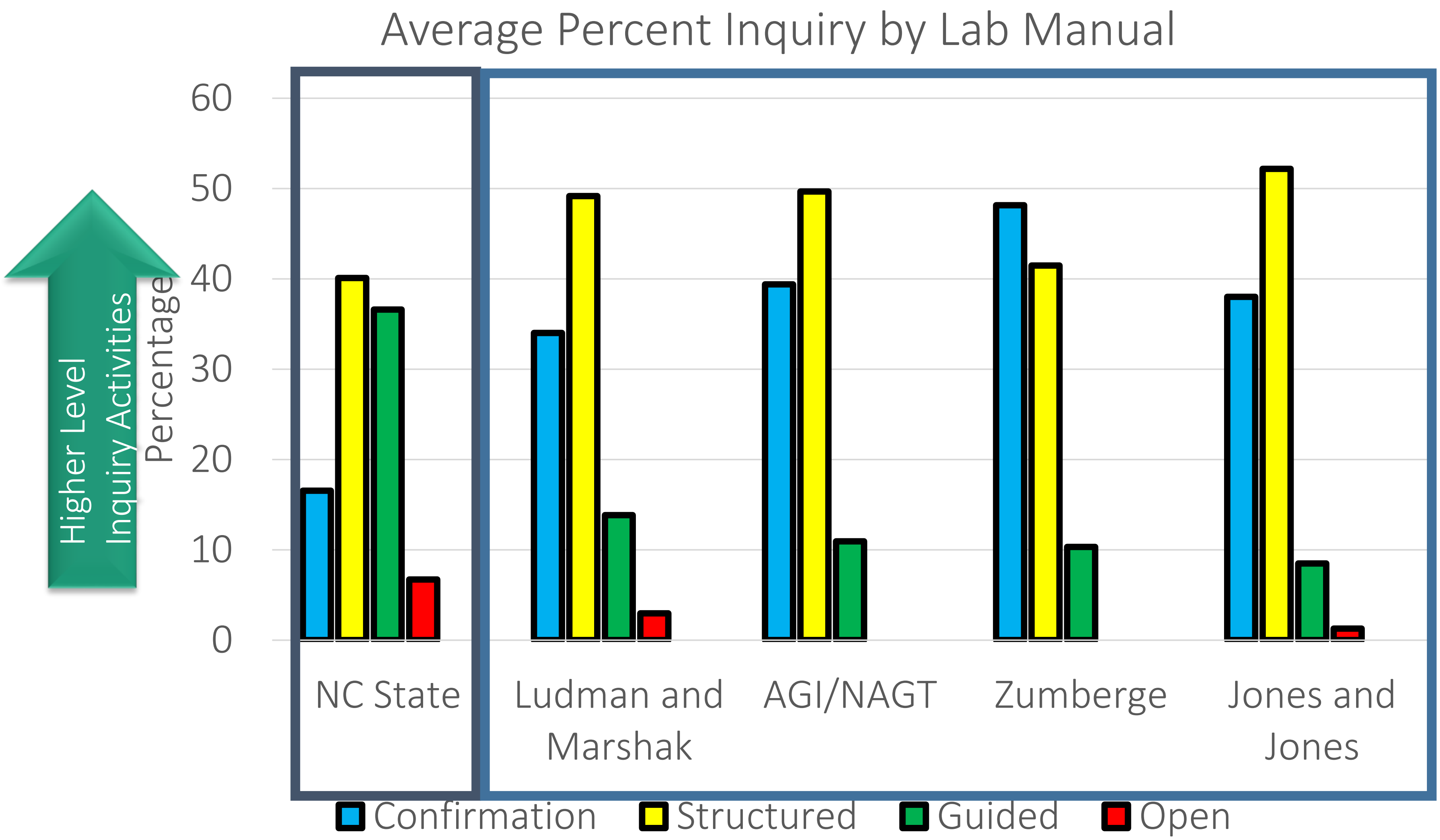
Total: 37.15 points

Confirmation Structured Guided Open

Proportion of each lab that can be attributed to each level of inquiry.

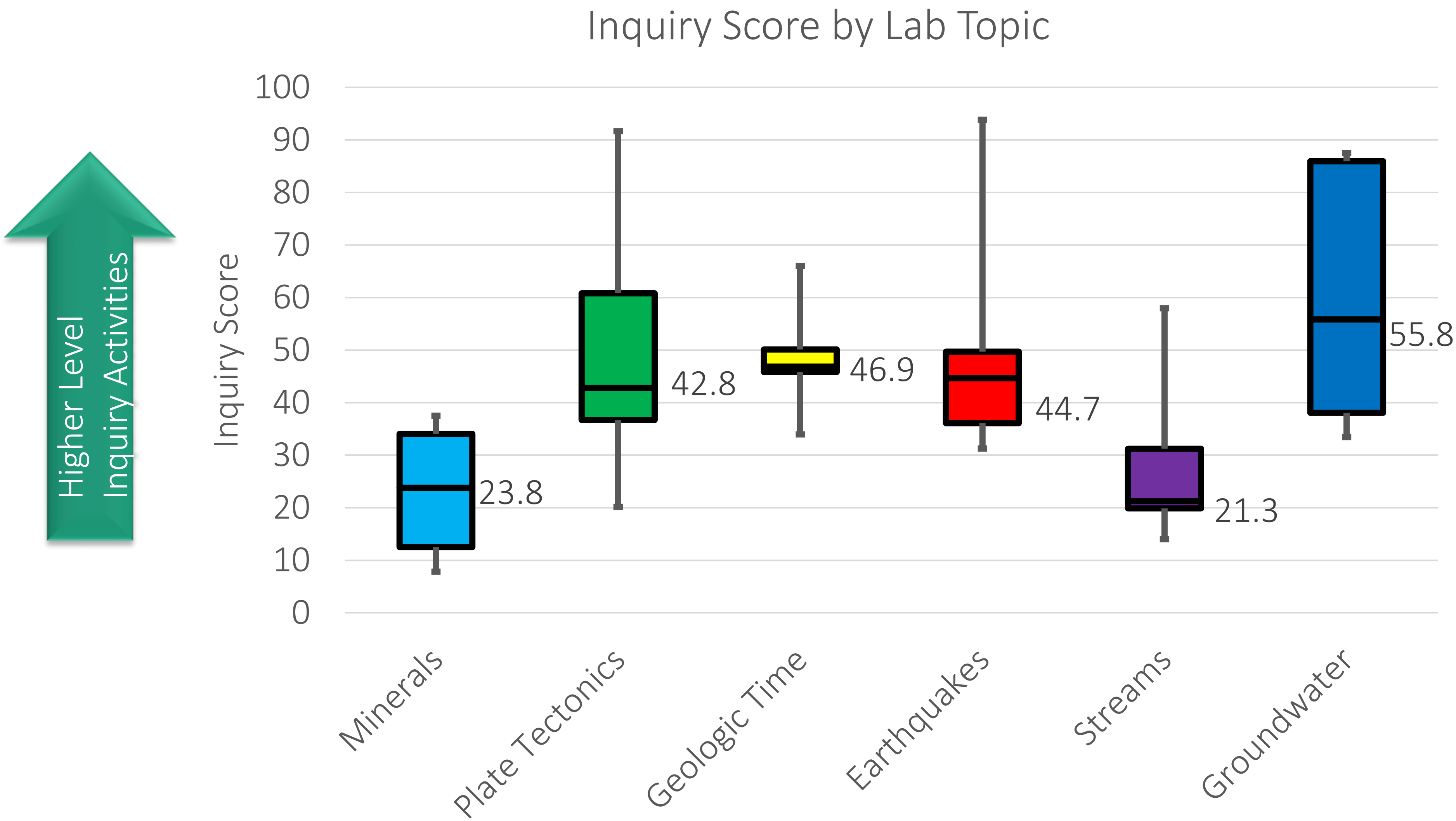
Ryker and McConnell, 2013

Levels of Inquiry in Physical Geology Lab manuals



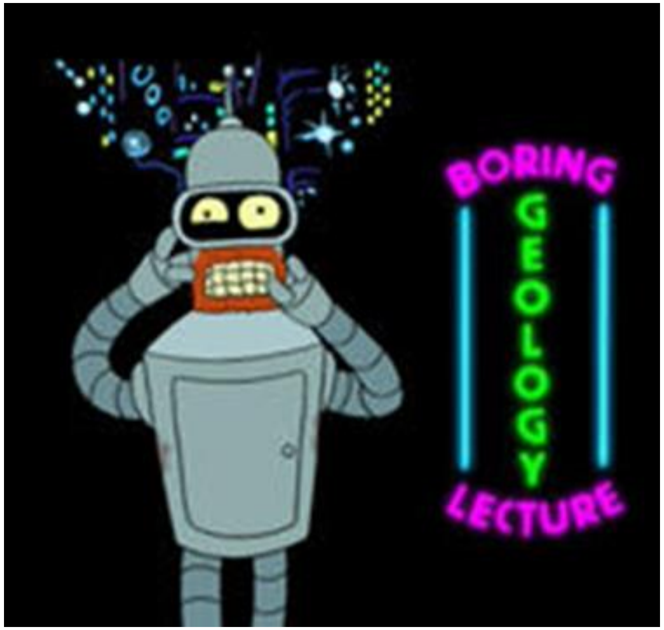
Ryker and McConnell, 2013

Levels of Inquiry in Physical Geology Lab manuals



Ryker and McConnell, 2013

Can we use inquiry to go from this…



Futurama (S1E3; "I, Roommate")

"Some of the labs seemed as if they were **made just to take up time**."

Student showing off his cross-section

"This course included interesting labs that I enjoyed doing. They were **challenging** but I enjoyed getting to work **hands on** with what we were learning."

…to this?

Course characteristics

- Physical Geology lab (1 credit)
- ~30 sections of 15-20 students each semester
- Taught by graduate teaching assistants
- 11 topical labs lasting 2 hours, 45 minutes
- Most students are not science majors
- Lab designed around hands-on, active-learning strategies

TAs taking strike and dip in preparation for a field lab

Students compare field notes with a TA during one of the active learning labs

Photos by Katherine Ryker

Typical Lab Structure

- Pre-lab Activity
- Learning Objectives
- Variety of activities and opportunities for interaction
    - Emphasis on scientific method
    - Connections with familiar real world phenomena (through personal experience OR previous labs)
    - Open-ended questions require negotiation of meaning
- Multiple scales of interaction
    - Class, small groups, pairs
- Post-lab Assessment
- Mastery quiz

- Informal discussion throughout
    - Assess and acknowledge students' ideas
    - Incorporate these ideas into the lesson
    - "How did you get to that answer?" (Reflection)
    - "Do you agree or disagree? Why?" (Justification)

Graduate Teaching Assistant (GTA) Training & Support

- New GTA orientation
- Lab coordinator/head GTA
- Weekly meetings
  - Leadership from old & new GTAs
- Suggestion Sheets:
  - Lab management
  - Illustrations
  - Sample divergent questions
  - Real world examples
  - Common misconceptions
  - Connections to other labs

GTA using information from the Suggestion Sheet to cover key concepts at the beginning of lab

How is increasing the level of inquiry in your lab activities like…

preparing a five-course dinner?

Image: http://www.bizbash.com/best_picture_nominees_inspire_menus_at_new_york_oscar_parties/new-york/story/10048/

EMU Intro Geology for Non-Majors Rule

"Nobody will be allowed to walk around the room during lab hours. Take your seat at the beginning of the class and leave it only when you are done with your assignment."

Where we want to go…

"Students will collaborate with each other to ask questions, construct hypotheses, gather and interpret data, and draw conclusions about scientific phenomenon."

Reflect and Report Out

- **Discuss:** What are the ideas you want to share with others when you leave this room?
  - The entire lab doesn't have to be open – it can be a combination
  - Labs currently have a lot of directions - students need some, but could split into two parts of lab with one more constructed and one more degrees of freedom
  - Ask students questions!! Rather than give the "right" answer, think about what would work best and why
  - Help students solve their own problems
  - Controlling how the learning happens – not just WHAT gets taught (content). A move to less prescriptive. Step back and let the students guide through the content.
  - Challenges of the assessment – rubrics that add up to more than 100%? (But students can only make up to 100%)
  - Have to try more than once! Never works exactly as you want the first time, but you keep making adjustments over MULTIPLE iterations. You will learn what starting point ends up getting people to the right spot.
  - How does this fit into the development process?
  - FANTASTIC for high school!! NOT JUST COLLEGE!! Training from the NGSS (if done to fidelity)
  - The published lab manual isn't always the "best" – home grown can be preferable and higher levels of inquiry

Source: Workshop participants, July 20, 2016

- **Workshop Evaluation**

Questions long after the workshop? E-mail me! kryker@emich.edu