Building Inquiry into the Astronomy 101 Labs

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With ASTR101 Course Instructor Prof. Aaron Boley

Special thanks to:

A UBC Skylight Development Grant, UBC Department of Physics & Astronomy; Head TA for ASTR101 Jacob White, ASTR101 TA team: Meiling Deng, Carolin Hofer, Chris Mann; Warren Code and Sarah Perez for helping plan assessments

Course Overview

- “Introduction to the Solar System”
- First-year students
- Mostly science majors (not physics or astro)
- 1 two-hour lab / week; ~20 students per lab section
- 3 one-hour lectures / week
- Lecture was transformed to active learning in 2016

Major Learning Goals

- Develop a life-long interest in astronomy
- Develop understanding of the scientific process
- Ask "Why" and "How do we know?"
- Develop your skills and mindset for evidence-based thinking

Inquiry-based teaching

Students learn science in ways that mirror authentic scientific research practices

Engaging the learner (asking questions)

→ Focused investigation

→ Making meaning together (synthesize and share results)

Selected references:

- Chinn C. A., & Malhotra, B. A., Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks, Science Education, 86, 175 (2002)
- Hunter L., Metevier A.J., Seagroves S., Kluger-Bell B., Inquiry Framework and Indicators, (Santa Cruz, USA: Institute for Scientist & Engineer Educators, 2014)
- National Research Council. (2000). Inquiry and the national science education standards
- Ontario Ministry of Education, Inquiry-based Learning, Capacity Building Series (2013)

For another formulation of inquiry, see “Investigative Science Learning Environments (ISLE)” described in Etkina E., Am J Phys (2015)

Inquiry lab sequence in Astronomy 101 Fall 2017

Overall goals:

- Students learn astronomical distance-measuring techniques
- Students value and gain confidence in scientific practices
    - Coming up with their own questions to investigate
    - Breaking down a challenging question into a simpler question
    - Designing their own way to take observations
    - Figuring out their own way to calculate something

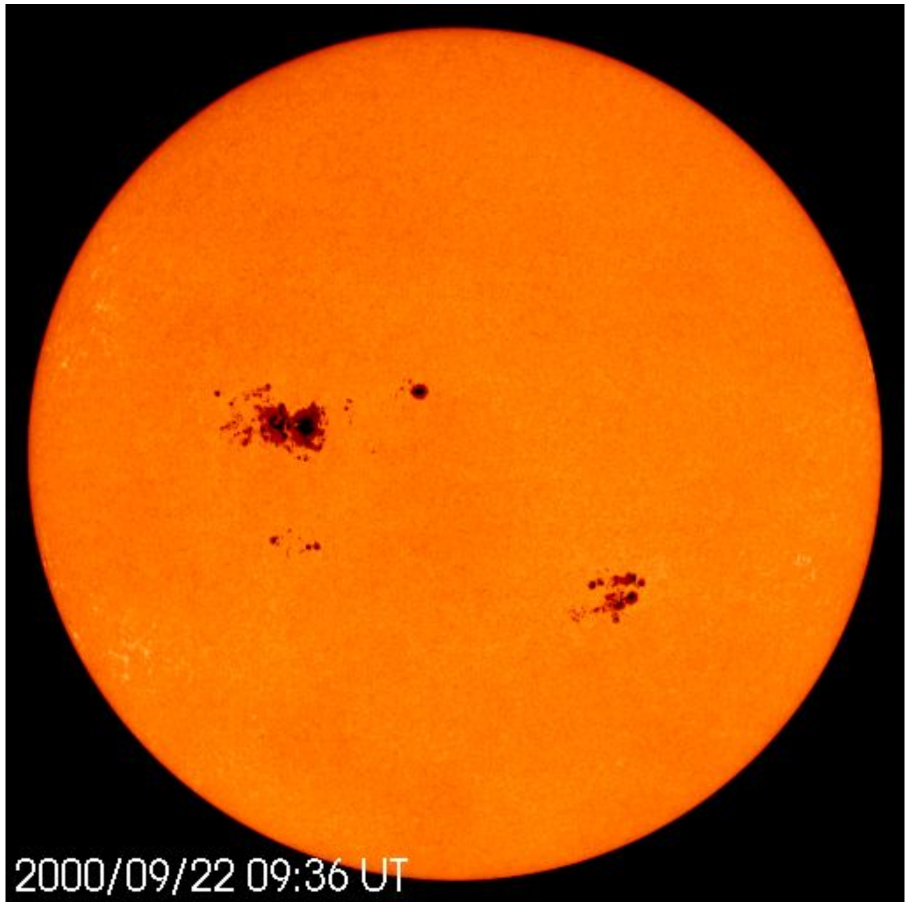
Inquiry Curriculum:

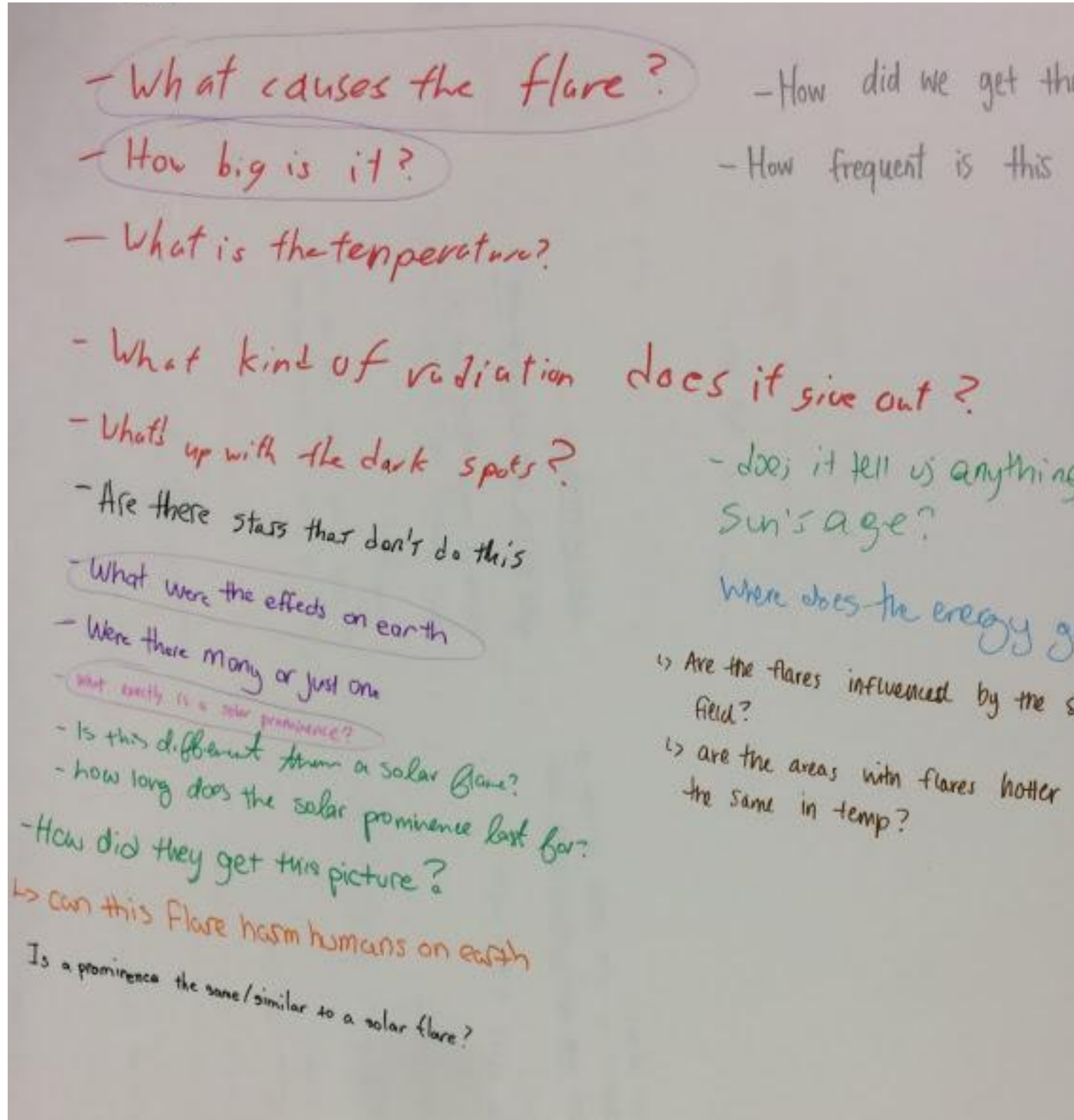
- Lab A (Week 3) - Parallax challenge problem (Inquiry warm-up)
- Lab B (Week 7) - Inverse-square law challenge problem (Inquiry warm-up)
- Lab C (Week 8) - Ask questions about astronomical images, choose question to investigate, break question into investigable parts
- Lab D (Week 9) - Investigate question in groups
- Lab E (Week 10) - Present results to classmates

Lab A - Parallax

Challenge:
Develop a method to measure the distance to a model planet without leaving "Earth" (line on the sidewalk)

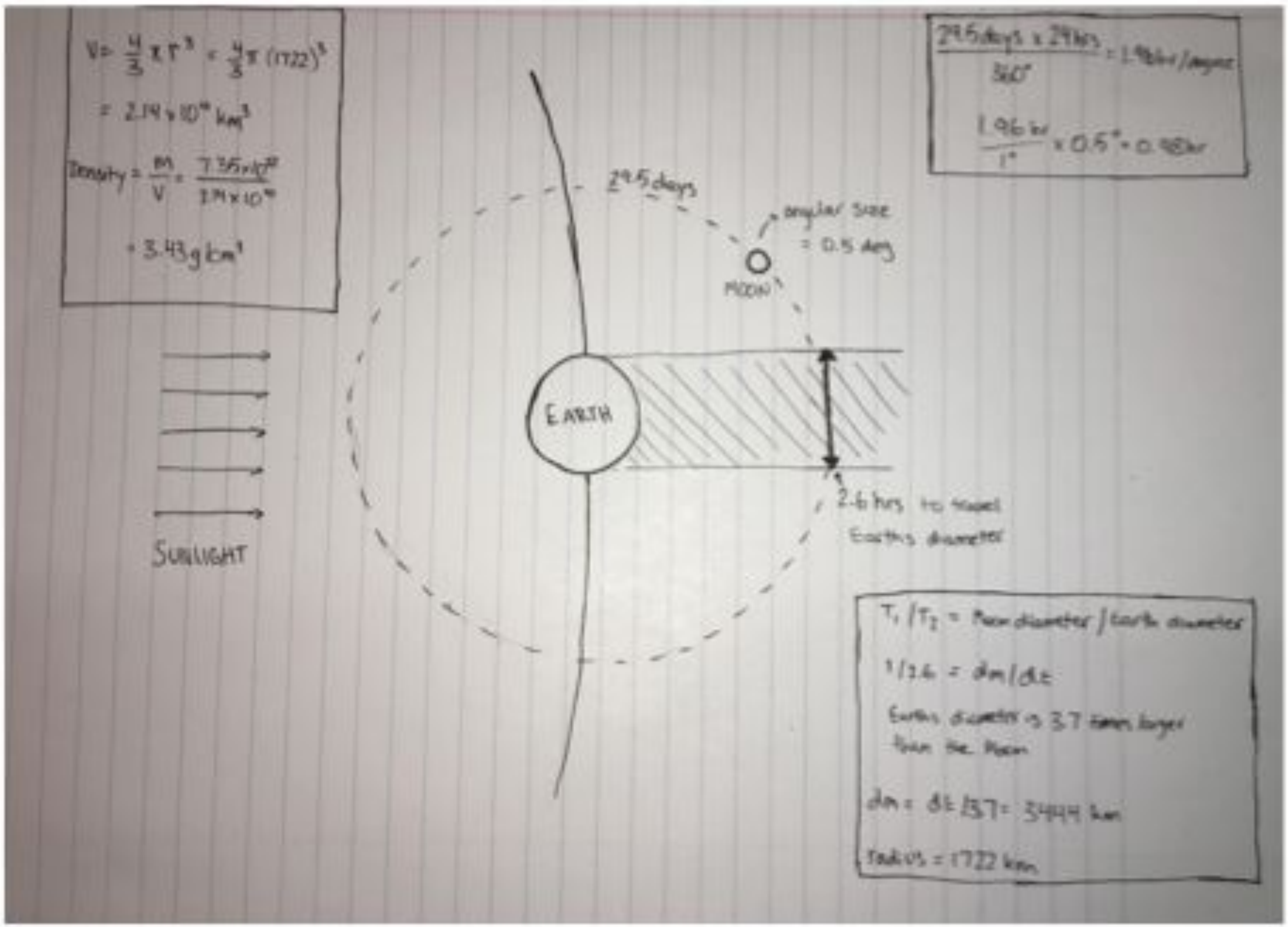
Lab C - Asking Questions





Lab E - Presentations

Sub question: What is the Density of the Moon?



Distance to Moon:

$L = d\theta$

$d = L / \theta$

$= 3444/0.5(\pi/180)$

$= 394\ 653$ km

Advantages and challenges of inquiry

Advantages of inquiry

- Students engage in science in more authentic way than traditional lab
- Offering variety of questions, paths to explore, ways to succeed can be more inclusive and motivating
- Can increase students' self-confidence, sense of ownership in their work, sense of belonging in science
- Teaches scientific content in a deeper and student-constructed way

Challenges of inquiry

- Requires significant time investment to design effective activity
- Students might be unfamiliar and (at least initially) uncomfortable with open style
- Can be challenging to facilitate; needs significant facilitator training
- Challenging to assess effectiveness of teaching scientific practices

TA training for inquiry

- Recruited TAs who were motivated to learn to facilitate inquiry
- Weekly TA meetings + Additional 3-hour extended training
  - TAs engaged in Labs C and D *acting as students*
  - Then debriefed experience & discussed facilitation techniques

TA feedback:

> *"I thought that engaging us TAs in the exercise as if we were students was particularly useful. It helped give a sense of what the students will be going through and I feel much more able to give quality guidance."*
>
> *"[I learned to] (1) Give room for the students to explore. Take a more observational approach near the beginning, only starting to guide/step-in as things progress farther. (2) The students will struggle somewhat. It's important to let them try to work through it before giving too much direction. (3) There is not a "proper way" to go about figuring things out. Of course we have goals we want them to reach, but they may come up with a novel way of doing so."*

Assessing the effectiveness of UBC ASTR101 inquiry lab curriculum

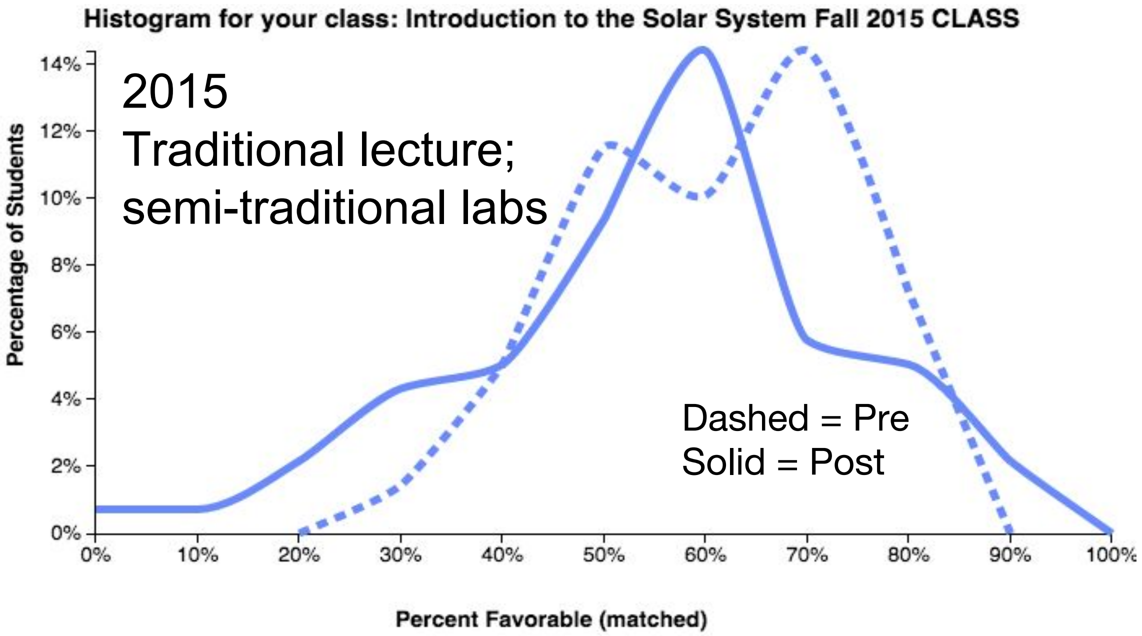
- Standard diagnostic surveys:
  - CLASS-Phys + self-identity + real-world connection
  - Astronomy Diagnostic Test 2.0 + additional distance questions

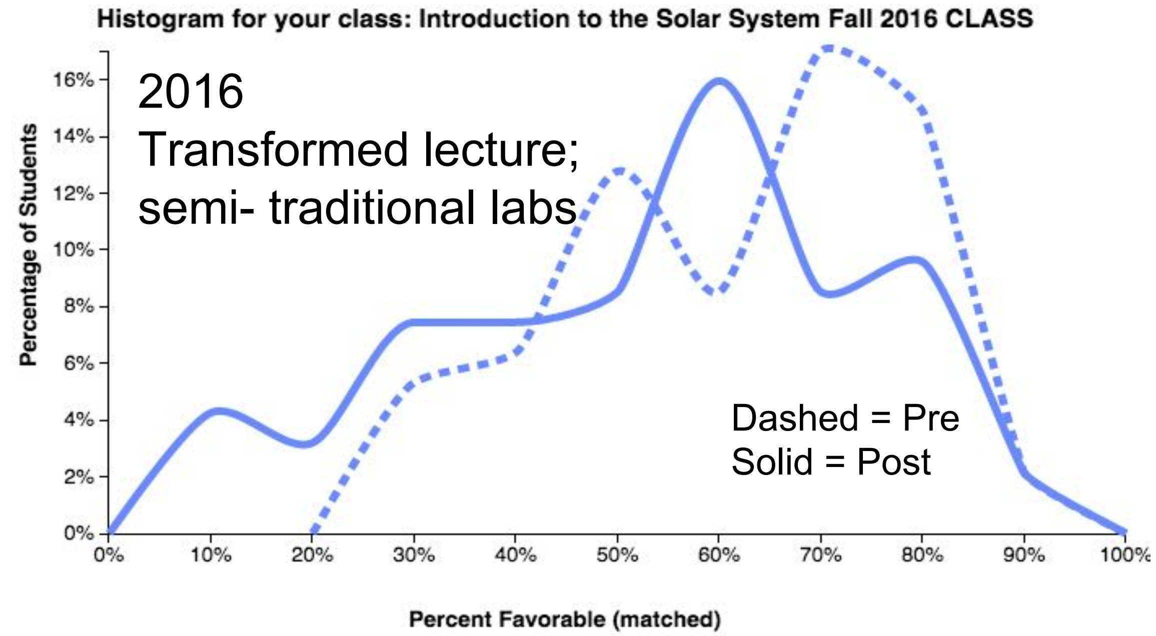
- Post-course survey, including specific questions about lab effectiveness

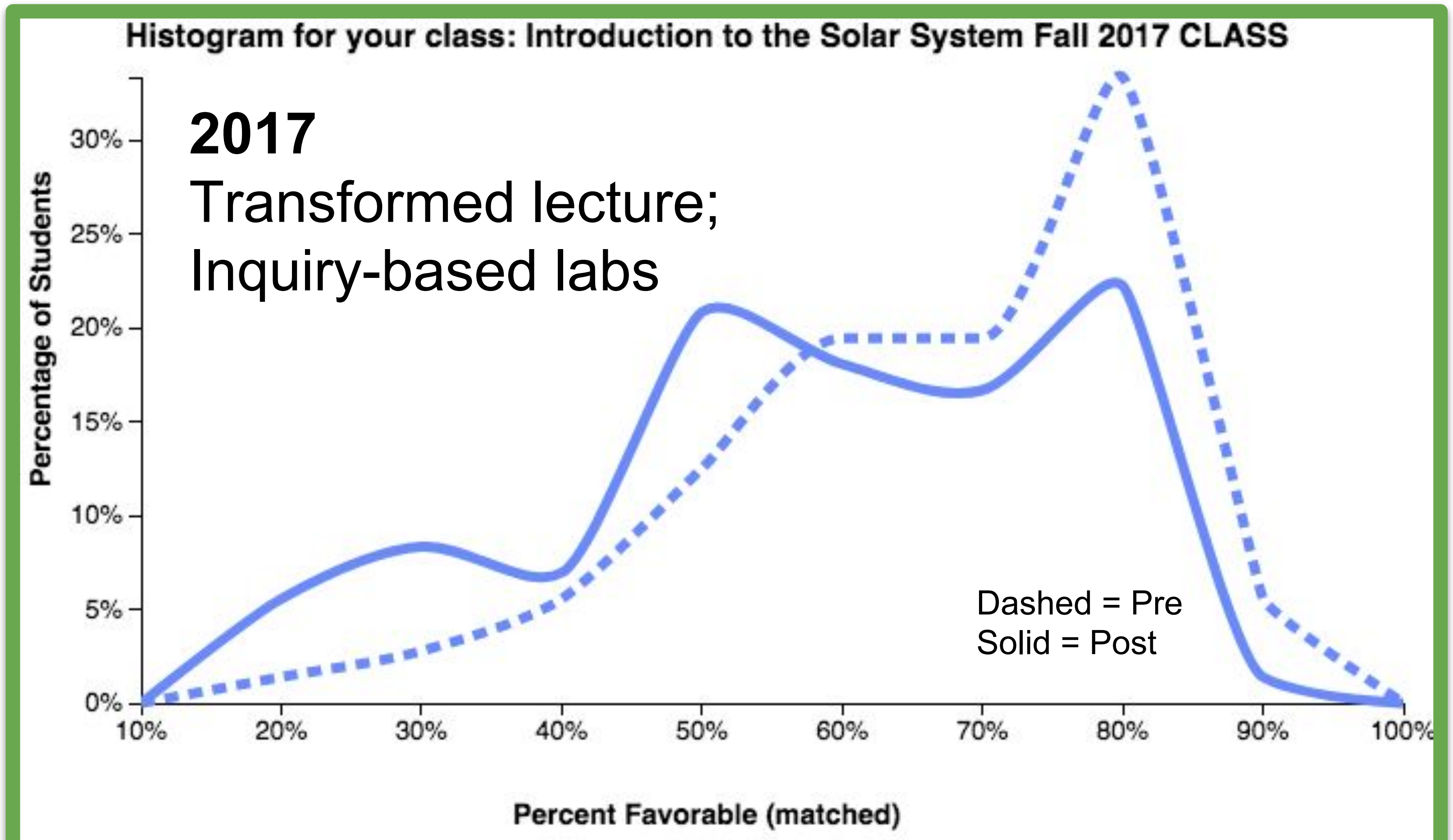
- Post-lab surveys (3 times)
  - What scientific practices did students engage in?
  - What did they learn about conducting a scientific investigation?
  - How did they feel about the labs?

Plan to share curriculum on PhysPort.org

Results: Attitude survey (CLASS) (2015, 2016, 2017)



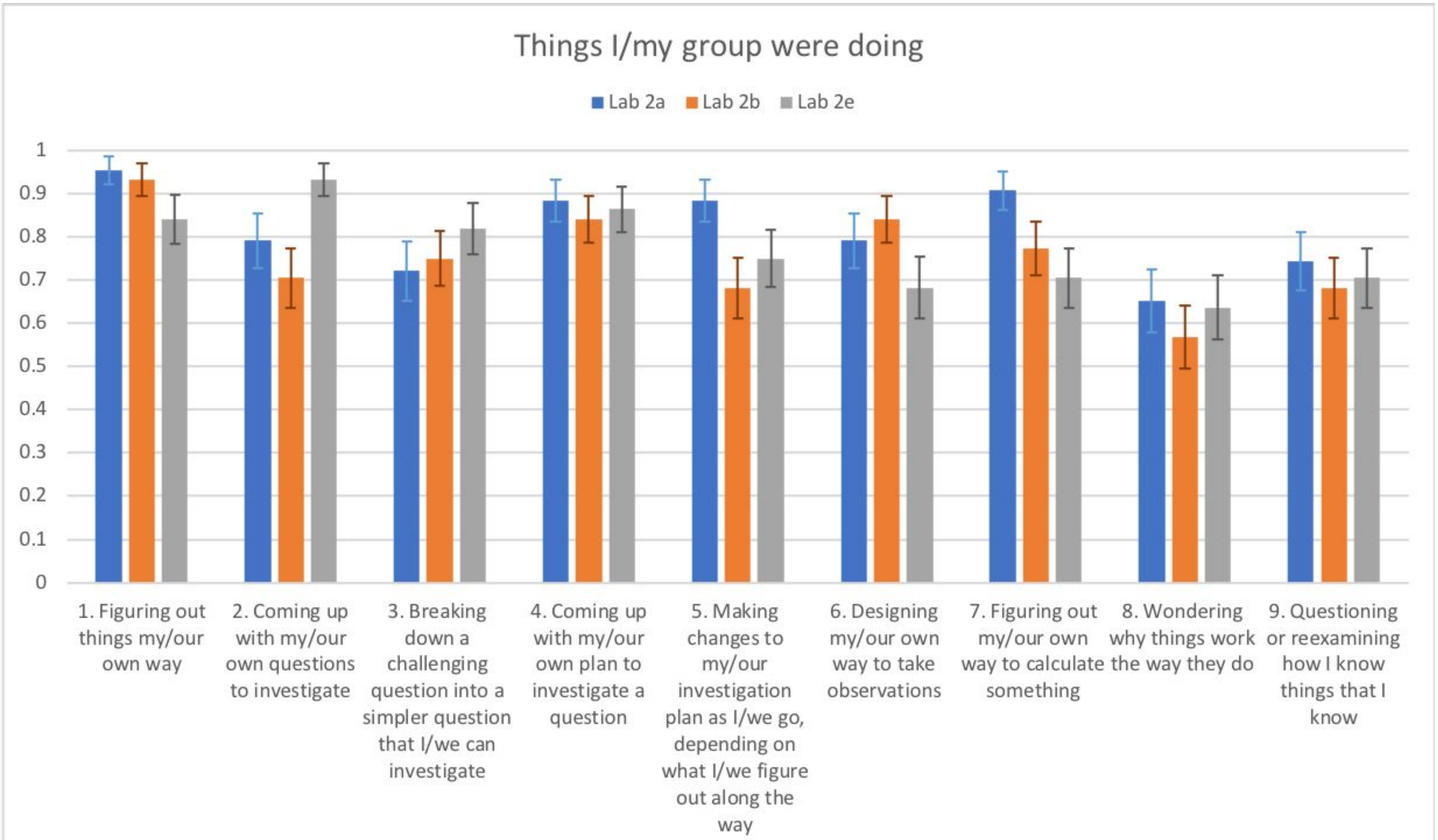




(Analysis by Physport)

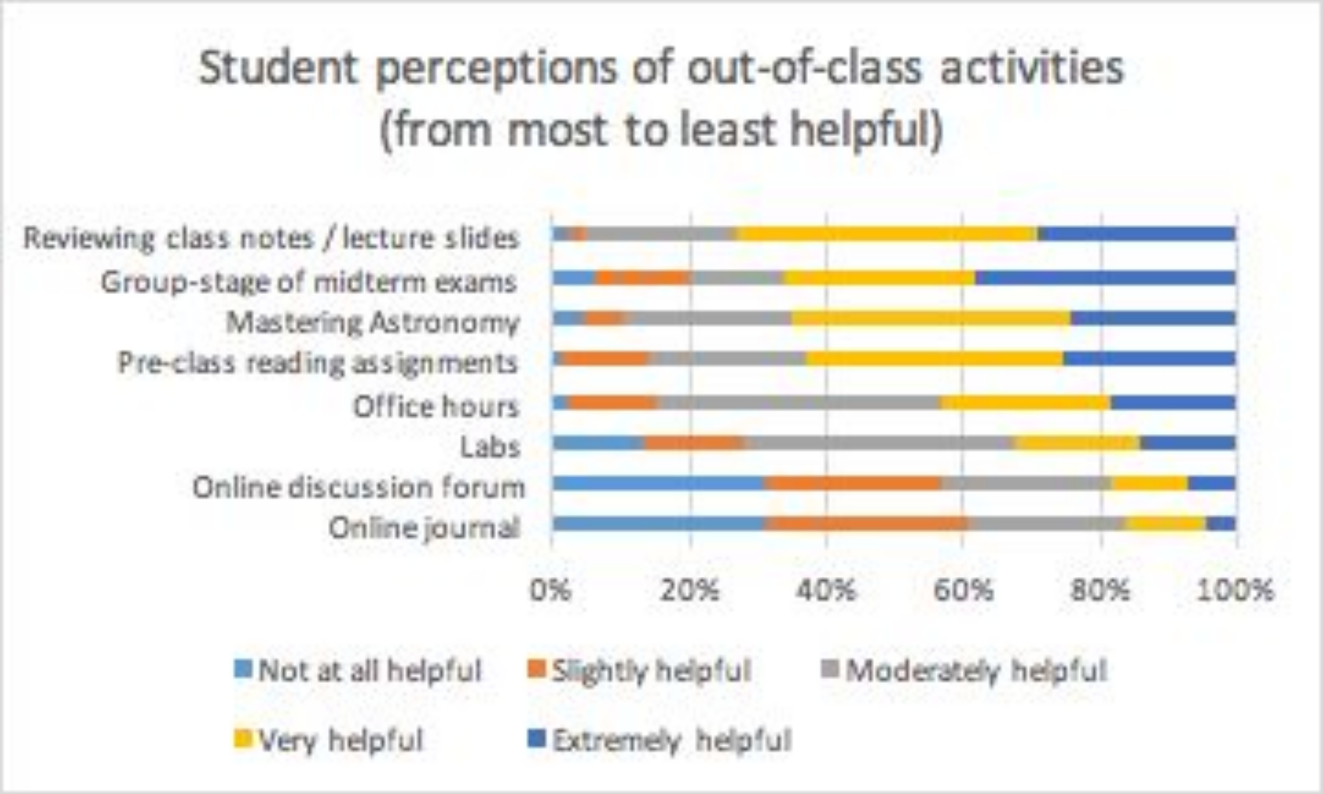
Similar results 2015-17:
Small negative shift in student attitudes (typical result even for transformed courses)

Assessing UBC ASTR 101 Inquiry: Scientific Practices Survey

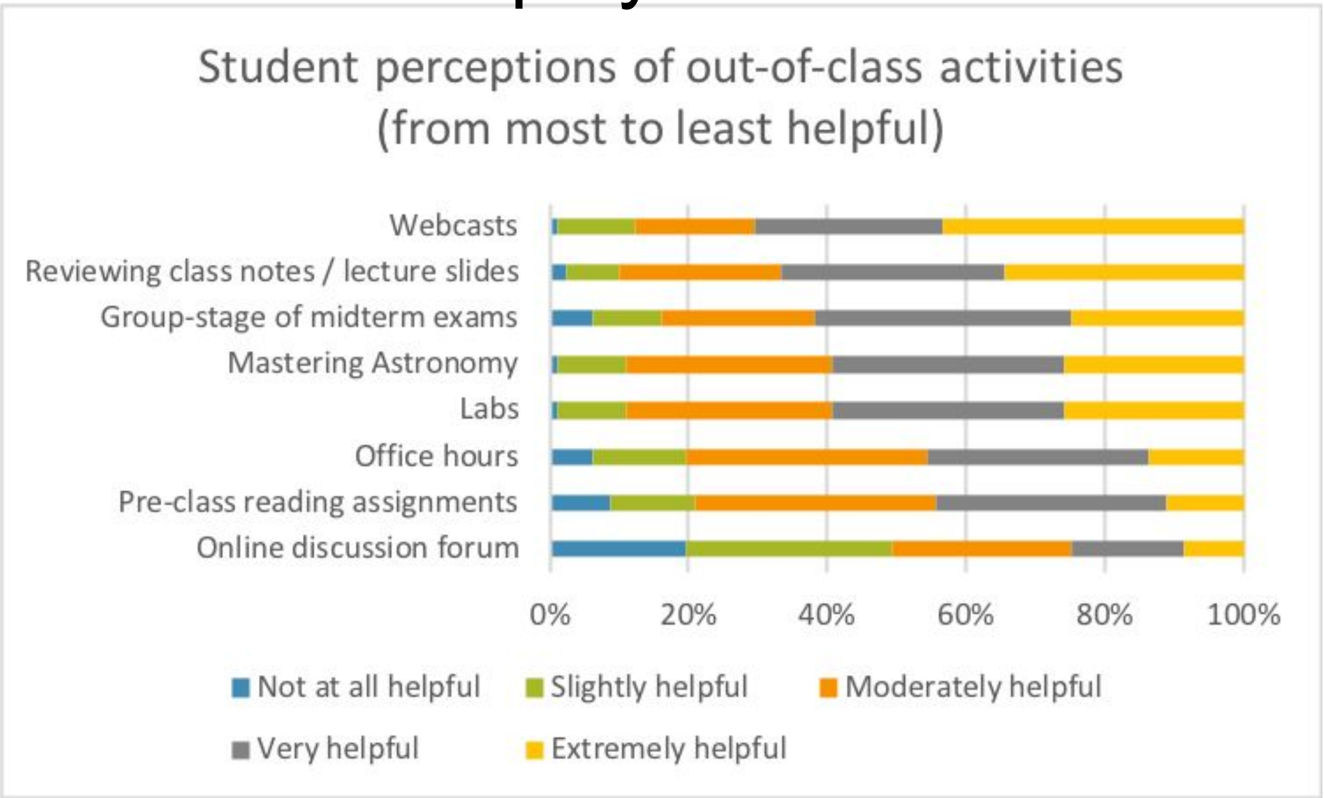


Assessing UBC ASTR 101 Inquiry: As a course component

Fall 2016 - Traditional labs



Fall 2017 - Inquiry labs



2017: 59% of students found labs either very or extremely helpful!

(Only 11% not at all or slightly helpful.)

Quotes from students

“This week's lab was different in a positive way compared to other labs I've done in that we weren't just given a step by step recipe to follow but had to come up with a plan by ourselves which I found both rewarding and challenging.”

“The main thing I learned about being a scientist is that answering [a] large question does not have to be intimidating. Just because I don’t know something at the present moment does not mean I can’t figure it out by asking the right questions. Another thing I learned is that I don’t have to ask the right questions on my first try. There is room for error in the scientific process and some of the best progress is made by making learnable mistakes first.”

“We were very actively involved with the material and we essentially had to solve the problem for ourselves with almost no help. It really helped me to improve my critical thinking and problem-solving skills.”

Post-lab question: “*Think of other lab classes you’ve taken or are taking, either at UBC (or another university), or in high school. What did you get out of this week’s ASTR101 lab that was different from other lab classes you’ve taken or are taking (if anything)? What advantages and/or disadvantages do you see for learning this way?”*