Development of a Lecture-Tutorial for Comparative Planetary Geology

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Rationale

Important in introductory sciences

- Mental model building
- Cause and effect relationships

Goal

- Promote strong conceptual understanding

Comparative Planetary Geology

Fundamental properties

Size

Distance from the Sun

Rotation Rate

Comparative Planetary Geology

Fundamental properties → Surface processes

Size

Distance from the Sun

Rotation Rate

Volcanism

Tectonics

Erosion

Impact Cratering

Interactive method: lecture-tutorials

Research-based, collaborative worksheets build conceptual understanding

Easy implementation

Improve learning over traditional lecture

(Prather et al., 2005; Wallace, 2011)

Tutorial design

Follows published tutorial pedagogy

Typical components:

- Start with basic questions
- Predict and interpret graph to verify prediction
- Student reasoning debates
- Explain reasoning
- Progress to analysis and synthesis questions

Builds upon intuitive knowledge pieces

(McDermott & Shaffer, 2001; Wallace, 2011; Kortz & Smay, 2012; Prather et al., 2013)

Study population

Over 1100 students

11 classes

- Introductory astronomy: The Solar System
  - Non-majors
  - Mostly freshmen/sophomores

7 instructors

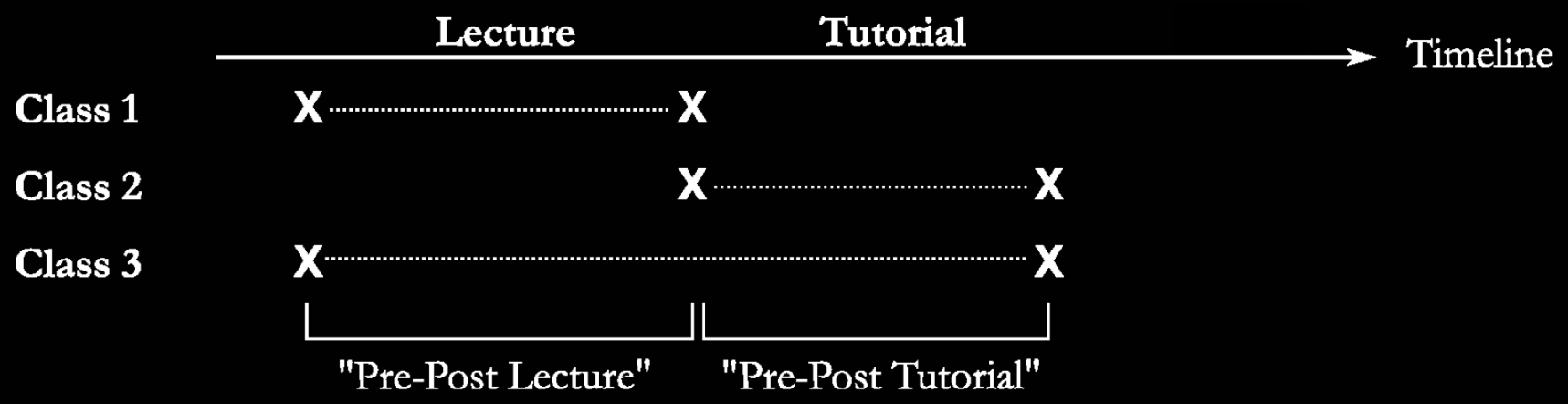
5 semesters

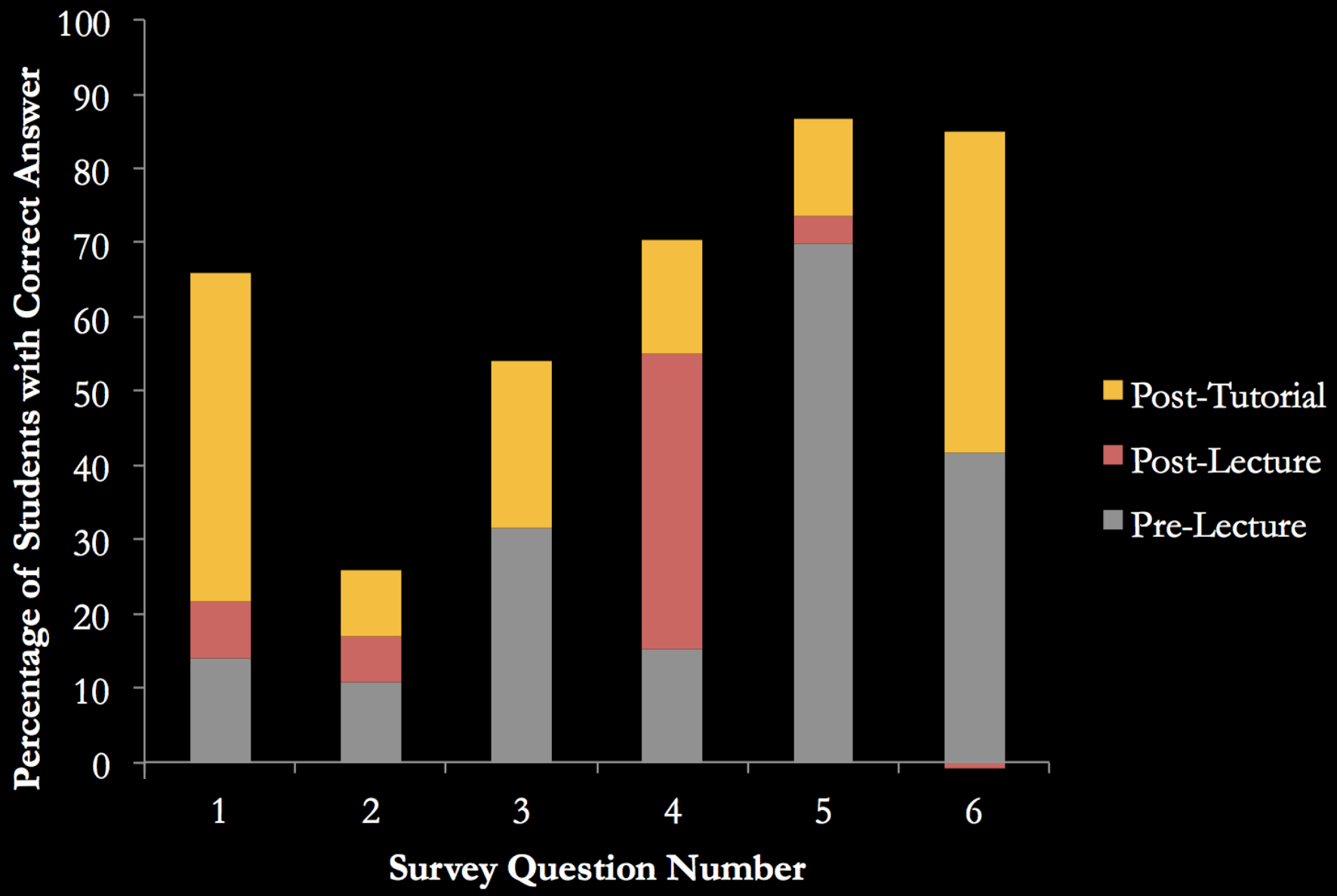
Study Methods

Iterative approach

- Assessment surveys
  - Free-response → multiple-choice
  - Instructor & student validation
- Audio recordings during lecture-tutorial

Testing the lecture-tutorial format




Percentage of Students with Correct Answer
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Survey Question Number
Post-Tutorial
Post-Lecture
Pre-Lecture

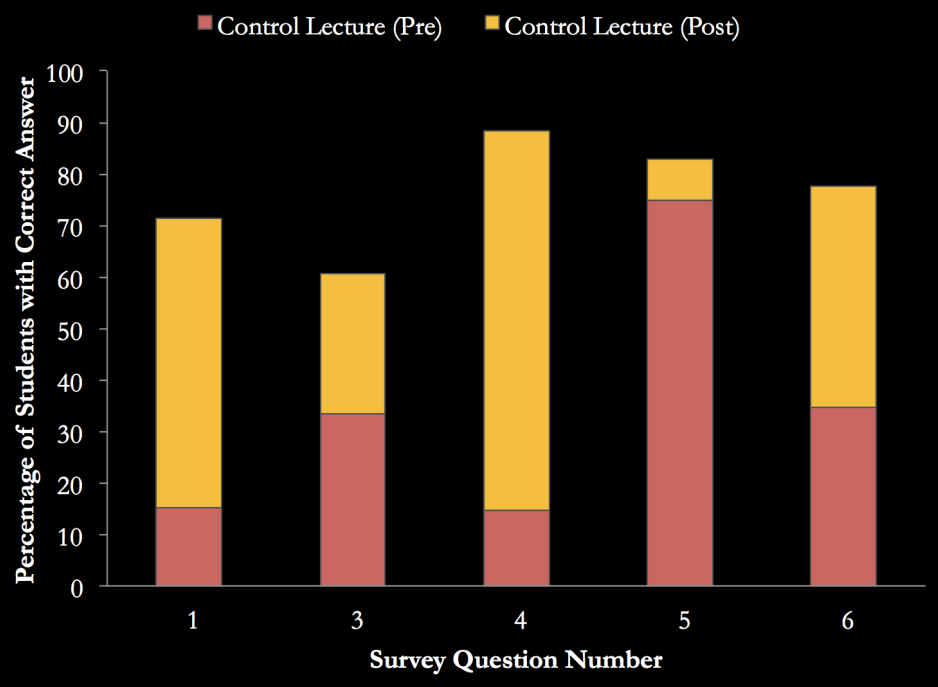
Lecture-tutorial vs interactive lecture

Already demonstrated: increased learning gains over traditional lecture

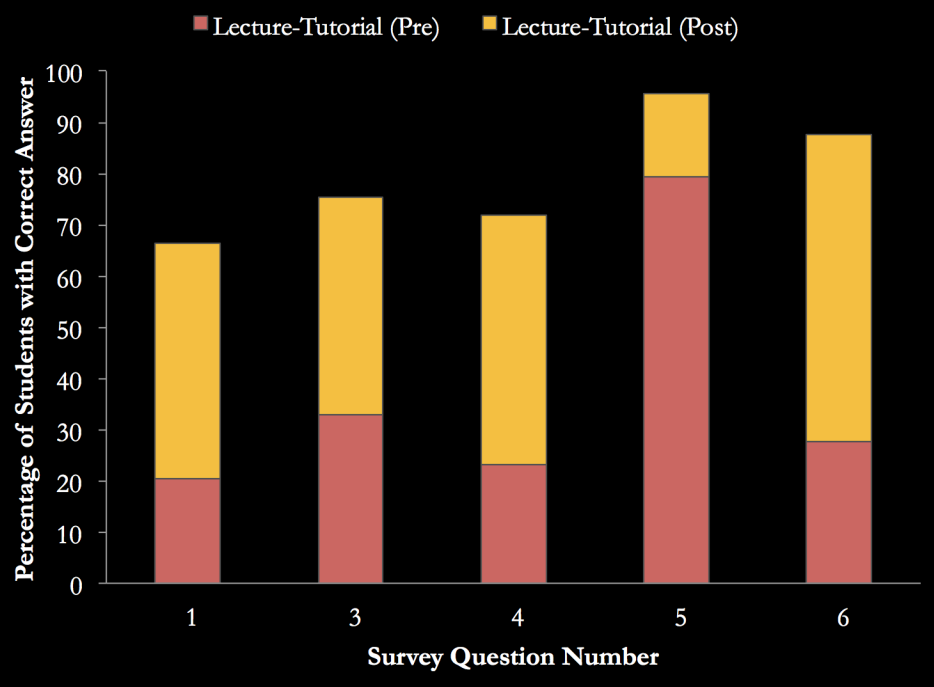
Our study: test against a fully-interactive lecture

(Prather et al., 2005; Wallace, 2011)

Control



Lecture-Tutorial



Survey Score Results

Lecture-tutorial

0.9 of 5 (18%) → 3.4 of 5 (67%)

Control

1 of 5 (20%) → 3.2 of 5 (64%)

Summary

Characterized student understanding of comparative planetary geology

- From an astronomical perspective

Developed & tested an effective new lecture-tutorial

- Survey results & audio recordings indicate development of conceptual understanding

Availability of lecture-tutorial

For a copy of the lecture-tutorial, instructor's guide, and associated publication (when released), please contact Briana Ingermann at:

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Learning goals

1. Three fundamental properties of terrestrial planets govern surface processes.

2. These properties are linked to four observable surface processes.

3. Given a planet's fundamental properties, one can predict the large-scale geologic features.

Intuitive knowledge items

Examples:

- A slower-rotating planet will have less gravity
- A planet closer to the Sun will have a higher surface T
- A thick atmosphere will cause more erosion

Often difficult for students to connect items logically into full conceptual understanding

Can start to combine items if practiced explicitly, as evidenced by survey gains and lecture tutorial

Intuitive knowledge items

Intuitive knowledge item	Correct reasoning?	Addressed by lecture-tutorial?
A larger planet will keep internal heat longer than a small planet	Y	Y
A larger planet will have a thinner lithosphere because it hasn't had time to cool and solidify	Y	Y
Erosion erases craters	Y	Y
A faster-rotating planet will have stronger surface winds	Y	Y
A planet closer to the Sun will have a higher surface temperature	Y	Y
A planet closer to the Sun will have a higher internal temperature	N	Y
A slower-rotating planet will have less gravity	N	Y
Earth's atmosphere protects us from large impactors	N	Y
A thick atmosphere will cause more erosion	N	Y
A planet with a stronger gravitational field will have more cratering (per area)	N	Y
A stronger gravitational field will lead to more internal shifting, more volcanism and/or tectonics	N	Y
A larger planet will have more internal heat to activate volcanism and tectonics	Y	N
A larger planet will have a thicker lithosphere that acts to insulate the planet and keep it warm	N	N
A faster-rotating planet will have more volcanism and/or tectonics	N	N
A larger planet will have a stronger magnetic field	N	N

Table 1: Common correct and incorrect intuitive pieces of knowledge about planetary geology. Concepts addressed directly by the lecture-tutorial are displayed in the top portion of the table. Concepts outside of the scope of this lecture-tutorial are given in the bottom portion of the table.

Rotation Rate

The rotation rates (the time for a planet to make one complete spin around its axis) of the terrestrial planets are:

Mercury: 58.6 days	Earth: 24 hours
Venus: 116.8 days	Mars: 24.7 hours

Planets that have a fast rotation rate are observed to have more weather and stronger winds than planets that have a slow rotation rate. Like liquid, weather and winds can cause erosion. However, to have weather and winds, a planet also requires an atmosphere.

Student 1: *Earth and Mars should have the most erosional features due to wind out of the four terrestrial planets because they both rotate rapidly.*

Student 2: *I agree that Earth should have many erosional features, but I think that Venus should also have a lot of erosional features because it has such a thick, heavy atmosphere.*

Student 3: *I don't think Venus or Mars should have many wind erosional features compared with Earth. Mars rotates rapidly, but its atmosphere is so thin that it wouldn't have much wind or weather. And even though Venus has a thick atmosphere, it rotates so slowly that it wouldn't have much erosion.*

13) Which students do you agree or disagree with? Explain your reasoning.

15) In the following chart, indicate which of the three fundamental planet properties influence (directly or indirectly) the four geologic processes. For example, size influences the amount of volcanism present.

	Volcanism	**Tectonics**	**Erosional Features**	**Proportion of Visible Impact Craters**
Size	X			
Distance from Sun				
Rotation Rate				

Because a planet's size, distance from the Sun, and rotation rate are fundamental properties that determine its geologic evolution, we can predict the basic geology of newly discovered planets once we know their fundamental properties. Suppose we discover a planet around a star similar to the Sun. We detect that the planet is smaller than the Earth, orbits about 0.7 AU from its host star, and rotates once every 12 hours.

16) Circle how you would expect this new planet to compare to Earth in the following categories:

Internal temperature:	hotter	colder	same
Surface temperature:	hotter	colder	same
Volcanism:	more	less	same
Tectonics:	more	less	same
Erosional features:	more	less	same
Visible cratering:	more	less	same

1. There are less than 300 craters total over the entire Earth (compared to >300,000 on the Moon). Why does Earth have so few compared with the Moon?

A. Earth has more geologic activity and atmospheric erosion
B. Earth's oceans cover most of the craters
C. Earth's larger magnetic field deflects meteors
D. Earth's atmosphere burns up most meteors before they strike the ground
E. Earth's strong gravity protects it

2. [*This question was removed from the final round of testing.*]
Suppose we discover a planet orbiting another star similar to our Sun. The planet is twice as big as Earth, orbits at the same distance, and spins much more slowly on its axis. What can we deduce about the planet?

(1) It would have a large magnetic field
(2) It would have more volcanism and tectonics
(3) It would have many erosional features

A. 1 only
B. 2 only
C. 1 and 2
D. 1, 2, and 3
E. A combination not listed above

3. What can the number of craters per square kilometer on the surface of a planet tell us about that planet? The planet with more craters per square kilometer...

A. …has a stronger gravitational force
B. …is older
C. …is less geologically active
D. …is larger
E. …is closer to its host star

4. Why do larger planets have more volcanism and tectonics than smaller planets?

A. Larger planets have thicker lithospheres and therefore retain heat for longer
B. Larger planets have stronger gravity, attracting more impactors that heat the planet
C. Larger planets have stronger gravity, leading to more shifting and movement within the planet
D. Larger planets have thinner lithospheres that are easier to crack and penetrate

5. A terrestrial planet's distance from its host star has a significant affect on… (More than one answer can be used, mark all that apply)

A. …the planet's internal temperature
B. …the planet's rotation rate
C. …the number of craters on the planet
D. …the planet's surface temperature
E. …the planet's gravitational force

6. Does a planet's rotation affect wind, gravity, volcanism and/or tectonics? (More than one answer can be used, mark all that apply.)

A. Wind
B. Gravity
C. Volcanism
D. Tectonics
E. A planet's rotation affects none of these.

7. Learning about other planets in our solar system can help scientists learn about the Earth.

A. Strongly agree B. Agree C. Neutral D. Disagree E. Strongly disagree

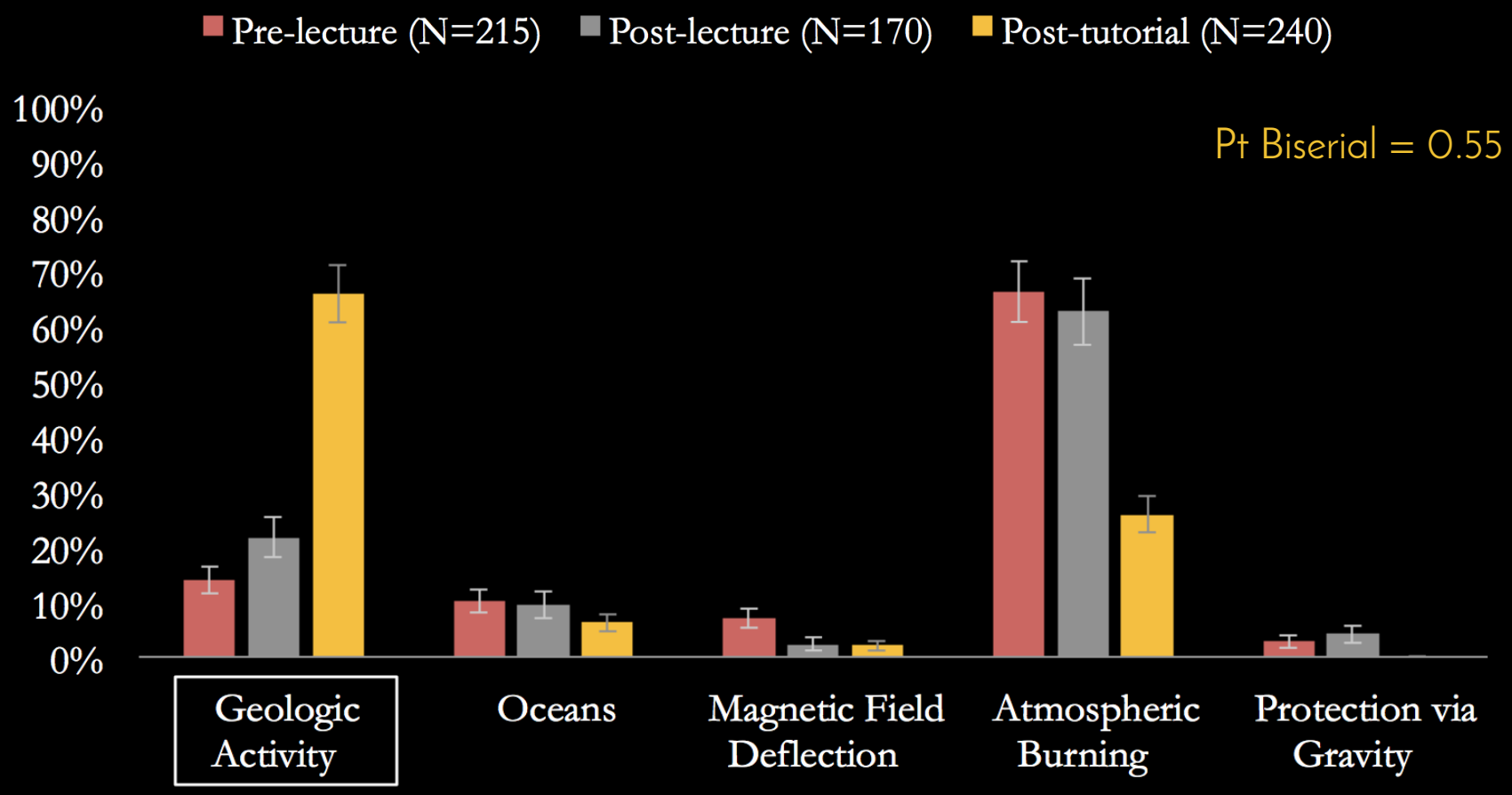
8. Understanding the evolution of planets is important for astronomers, but not important for the general public.

A. Strongly agree B. Agree C. Neutral D. Disagree E. Strongly disagree

9. Each planet is unique and unrelated to other planets.

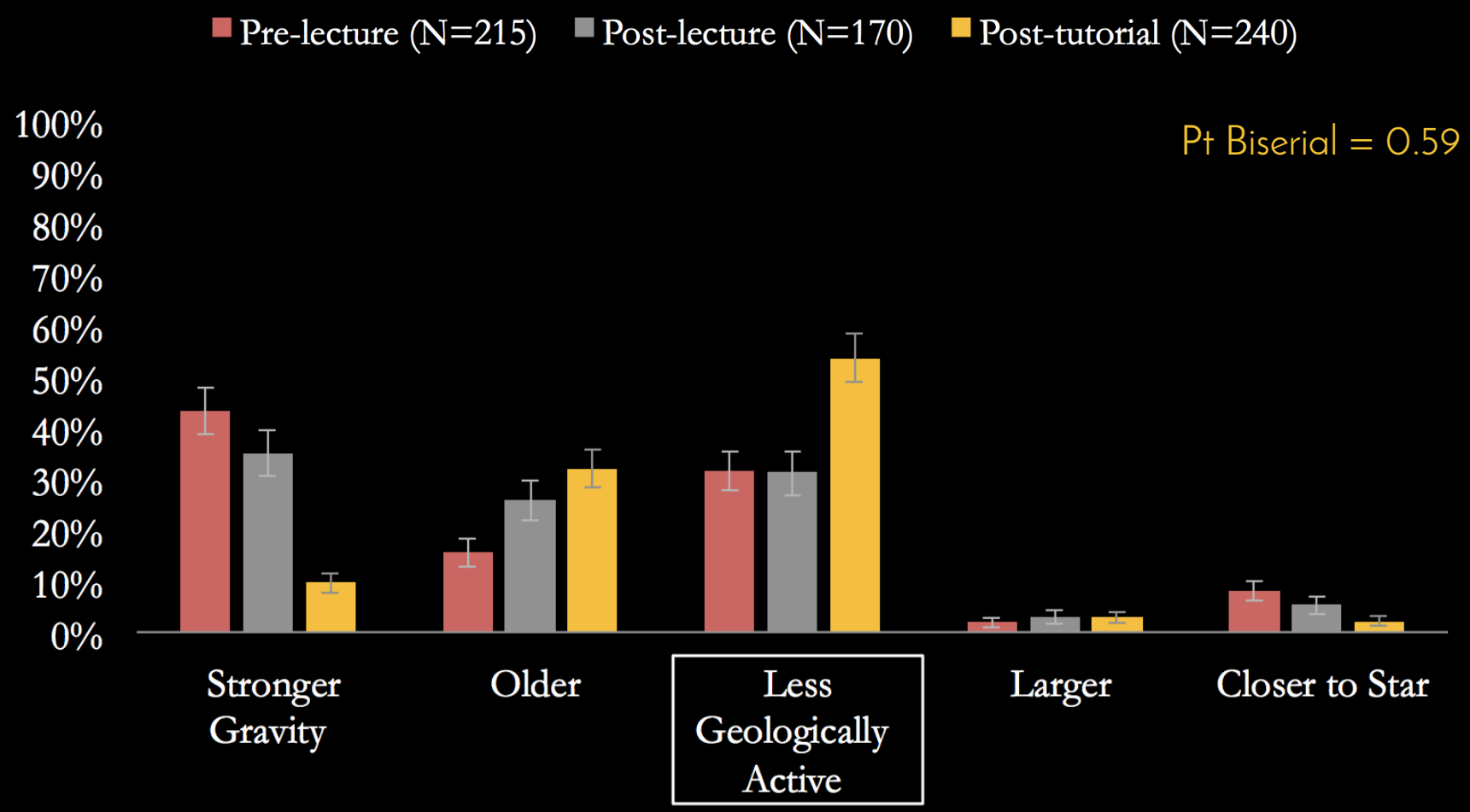
A. Strongly agree B. Agree C. Neutral D. Disagree E. Strongly disagree

Q1: Fewer Craters on Earth vs Moon



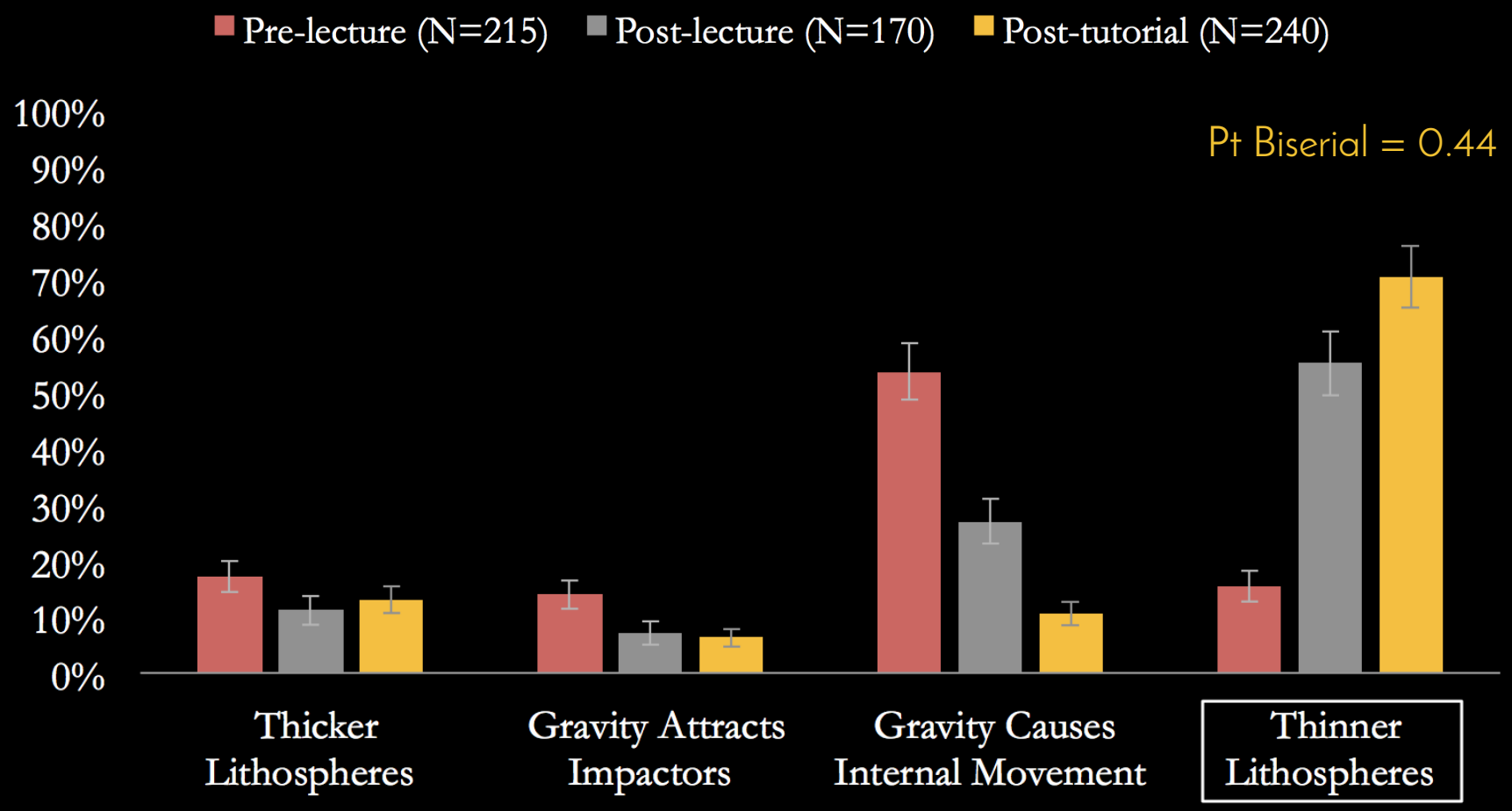
Shift toward correct answer post-tutorial

Q3: More Craters Per Area



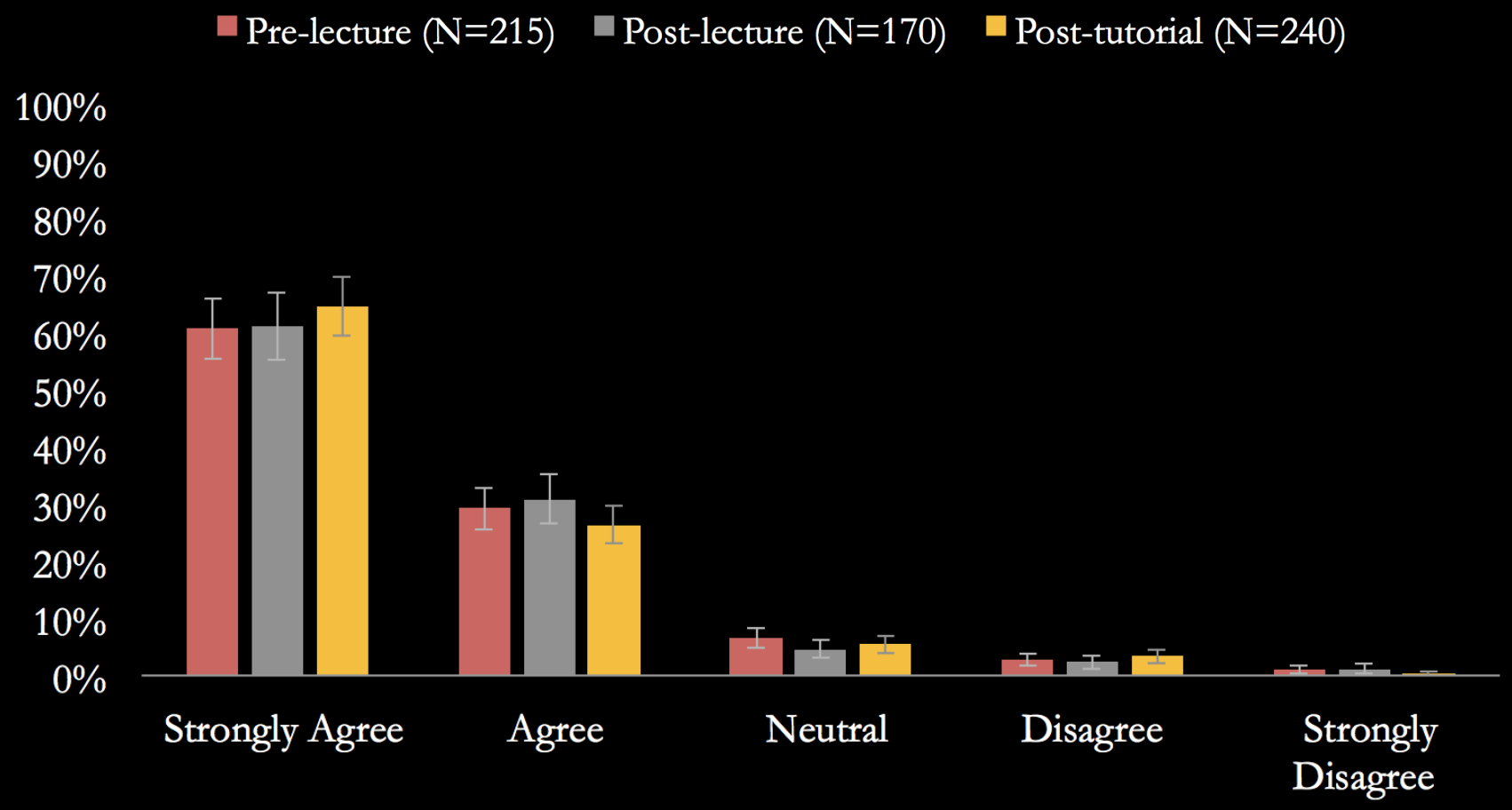
Shift toward correct answer post-tutorial

Q4: Larger Planets Experience More



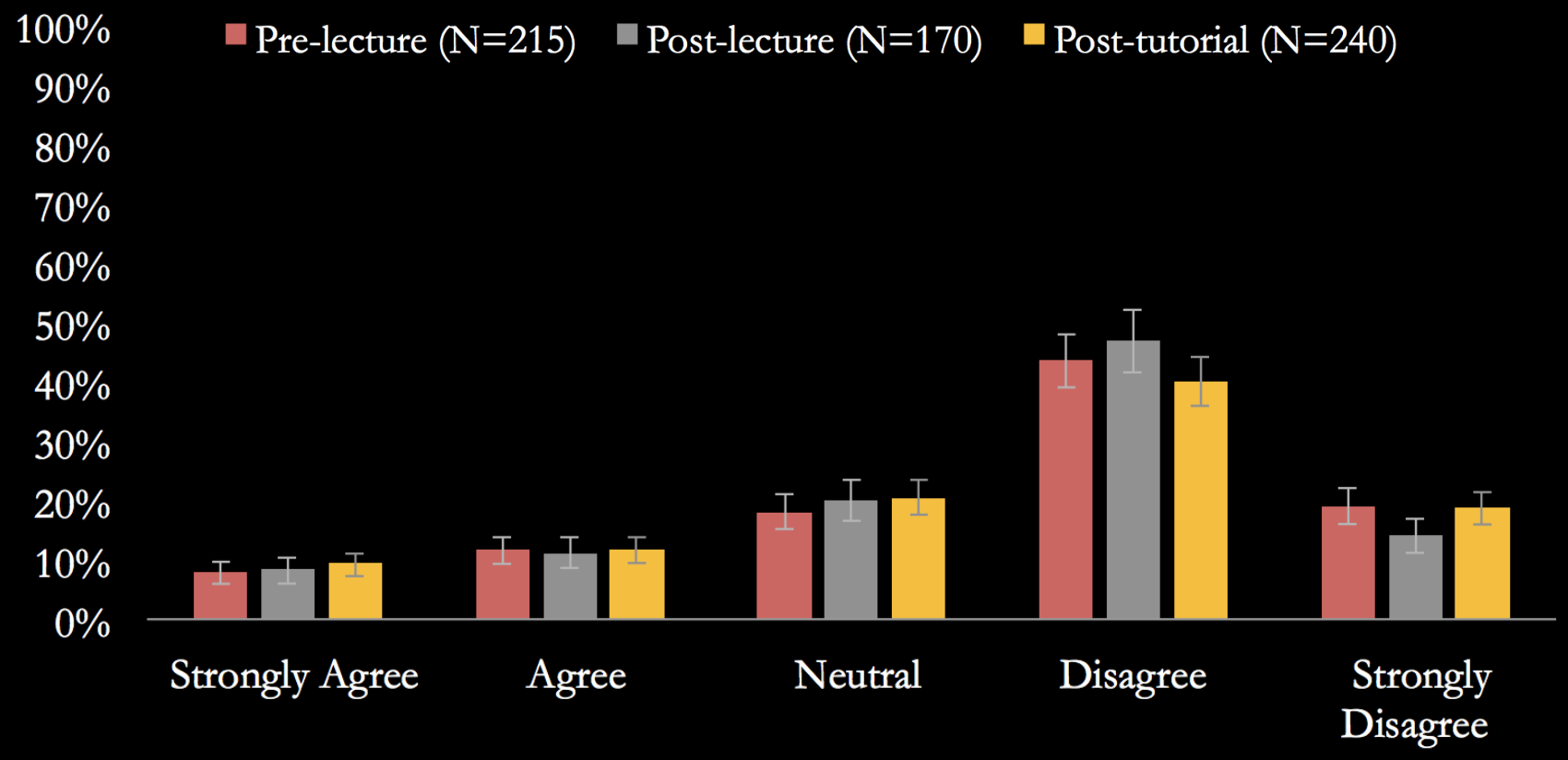
Shift toward correct answer post-instruction

Q7: Scientists Can Learn about Earth

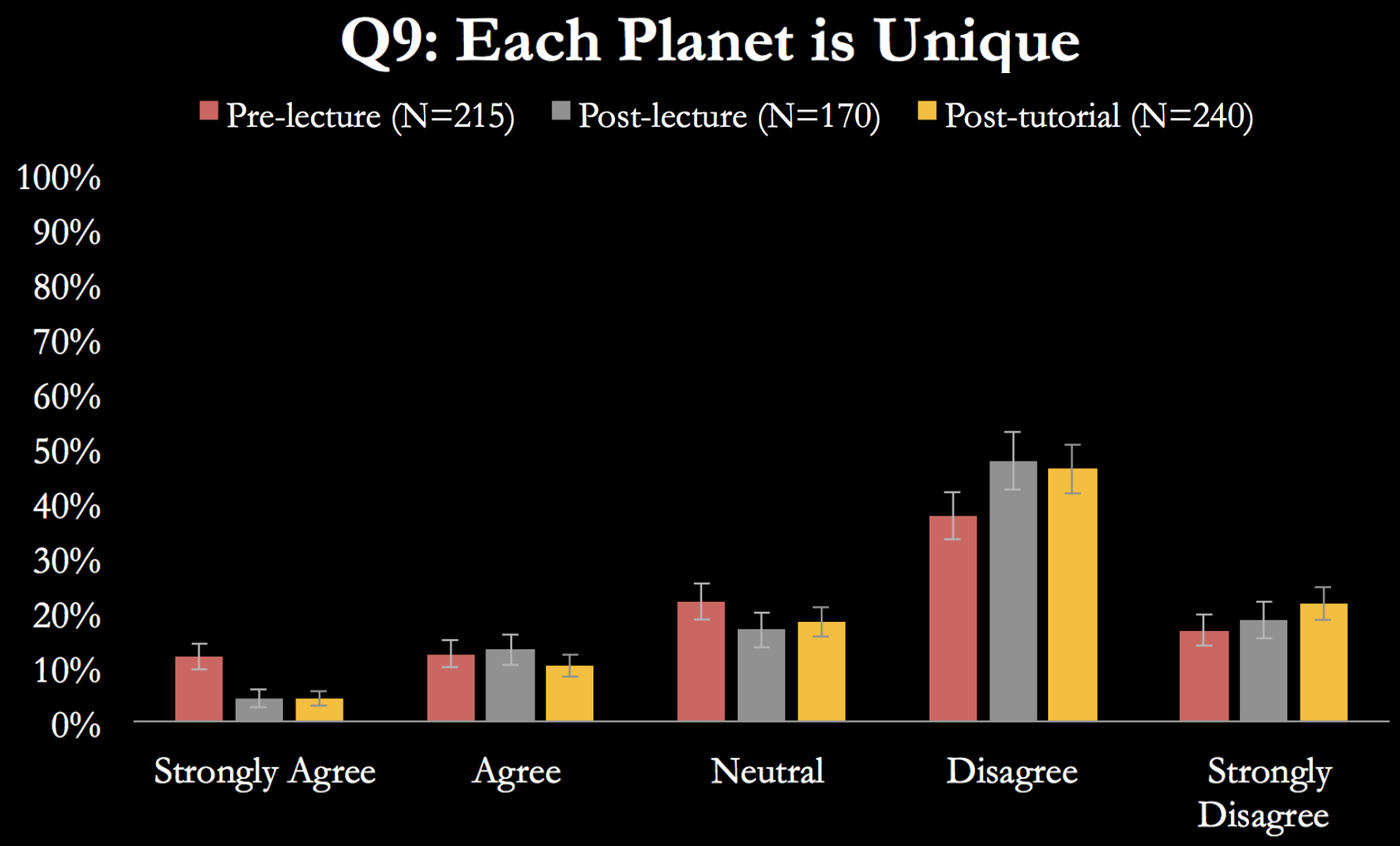


No significant shift

Q8: Planetary Evolution is Important for Astronomers, not the General Public



No significant shift



No significant shift

Free-response survey questions

1. Recent evidence suggests that Mars once had a global magnetic field that may have protected the planet against solar wind. Assuming this is true, what could explain why Mars today lacks a global magnetic field like that of Earth?

2. There are less than 300 craters total over the entire Earth (compared to >300,000 on the Moon). Why does Earth have so few compared with the Moon?

3. Suppose we discover a planet orbiting another star similar to our Sun. The planet is about twice as big as Earth, orbits at the same distance, and spins much more slowly on its axis. What can we deduce about the planet?

Free-response survey questions

4. How can the number of craters on the surface of a planet reveal the age of that planetary surface?

5. Of the following four things: wind, gravity, volcanic activity, magnetic field, which are strongly affected by whether a planet rotates or not? Explain your reasoning.

6. Why do larger planets have more volcanism and tectonics than smaller ones? Explain this connection in as much detail as possible.