ALTERNATIVE PLANETARY SCIENCE CONCEPTIONS EXHIBITED BY COLLEGE-EDUCATED AMERICANS: RESULTS FROM QUESTIONNAIRES AND THE GEOSCIENCE CONCEPT INVENTORY.

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Introduction: Assessing the effectiveness of Education and Public Outreach (EPO) activities and college-level courses focusing on planetary topics is problematic because accurate, reliable and valid assessment tools are not available to measure conceptual development in this scientific discipline. We therefore cannot accurately gauge whether planetary-focused EPO activities and college-level courses are truly having an effect on the conceptual development of our participants and students.

EPO and classroom activities affect the intellectual development of individual students or student populations in a number of different ways. Student attitudes towards science and scientists, discipline-specific science content, skill development (such as 3-D visualization), and conceptual understanding are all factors that may change as a result of the classroom experience. A reliable measurement of change in any of these areas would provide instructors with information that they could use to evaluate the effectiveness of their courses and assess whether modifications should be considered for future class offerings.

However, these factors are difficult to evaluate independently, requiring unique assessment instruments that accurately measure the progress of our students. Valid and reliable tools for measuring change in the factors listed above simply do not exist for many scientific disciplines. Thus, most studies of the effectiveness of various educational philosophies and pedagological approaches rely heavily on anecdotal or qualitative data to estimate changes that occur over time in a classroom. Thus, little valid data exist to study relationships between teaching and learning, hampering our ability to pinpoint which classroom variables that affect student learning.

Instructors may view the relative worth of the aforementioned factors differently, placing greater emphasis on some over others depending on their goals for the class. One area that clearly ranks high in terms of relative importance for many college-level faculty is conceptual understanding. Conceptual understanding implies both a familiarity with content and the ability to apply it to complex questions, and constitutes some of the more advanced thinking skills important in a college-level education.

Accurate and reliable assessment instruments to measure conceptual change as a result of instruction have been created for Physics [1] and Geology [2,3]. The first step in developing tools to measure conceptual development is to discover what people believe about a certain scientific topic (such as the planets) through a testing, questionnaires and interviews [4,5]. The overall objective of this project is to begin the process of developing tools to assess changes in conceptual understanding of the planetary sciences as a result of instruction through EPO activities or in the classroom. To this end, we report here on alternative conceptions in the planetary sciences that have been revealed through both testing and questionnaires aimed at a college student population. We find that students exhibit a number of non-scientific conceptions about the planets, and that many of these alternative ideas persist even after college-level instruction [6,7].

Approach: To discover what students believe about the planets, we used 2 sources of information. First, we looked at questions that pertained to planetary topics found on the Geoscience Concept Inventory (GCI) [2,3], which is the mostly widely used concept test in the Earth sciences. The recent widespread dissemination of the GCI provides us with a large set of valid and reliable data for assessing alternative conceptions held by college students. Since the GCI is not a planetary-specific concept test (it simply contains some questions that overlap into the planetary science arena), we paired the GCI results with data gathered from the a planetary-specific questionnaire given to nearly 50 college students in South Dakota. From these 2 data sources, we have uncovered a number of alternative conceptions, a number of which persist even after instruction.

GCI data were collected from institutions scattered across the U.S., at over 42 institutions, with 3595 students participating in the pre-test (usually on the first day of class and no later than two weeks into the year). We also have post-test data from ~1750 students, collected during the last week of class or during the final examination. In all, 59 courses in Physical Geology, Environmental Science, Oceanography, and Historical Geology, and with class sizes ranging from 8-210 are included in this study. Participants were almost equally split between men and women, and about 20% of the students were non-Caucasians. Specific information about courses and students participating in this study are detailed in Libarkin and Anderson [2].

A survey consisting of 11 open-ended questions was given to a college-level physical geology class at Black Hills State University. Questions focused mostly on planetary surfaces. Below is a partial list of the questions, along with the top 5-10 tabulated number of responses in parantheses:

1. ***Describe how a planet is different than a star?***

   A star is a hot/burning body (11)
   Planet orbits the sun/star (10)
   Planets always have land or solid/is not a gas ball (9)
   Planets are closer/stars are far (4)

Some planets can support life (3)

3. Is the Moon a planet? Why or why not?

No, it orbits a planet/doesn't orbit a star or sun (15)
No, it's too small (2)
No, because it doesn't have a moon
No, because it is the moon
No, because of gravity. Things float on the moon
No, it's a meteor
No, it's a star
No, it doesn't have air/water/sustain life
Yes, because it is solid
Yes, because it is round

4. If you were able to hike completely around the surface of the moon, what features (if any) would you see on the Moon's surface? Would you expect to see any of these features on Mars or Venus (explain your answer).

Moon features

Craters (24) Rocks (5)
Valleys/channels (4) Mountains/cliffs (3)
No life (2)

Same features on Mars and Venus?

Yes (9)
Yes, but less craters on Mars and Venus (4)
Not sure if craters on Mars or Venus (2)
Mars would be rougher (1)
Mars would look similar but Venus different - half of Venus is hot and half is cold (1)
Yes for Mars, not sure about Venus (1)
No, not enough gravity (1)
No, some don't have a solid surface (1)

11. Is the Earth a planet? Why or why not?

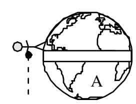
Yes (26) No (0) I don't know/maybe (2)

Why or why not?

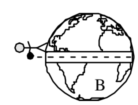
Yes, because it's in the solar system (6)
Yes, it rotates around the sun/star (6)
Yes, it's above a certain size (3)
Yes, it is capable of supporting life (2)
Yes, because it has mass (2)
Yes, because it's a land mass (2)
Yes, my teacher told me it was (2)
Yes, when I took astronomy there was no formal definition of a planet (1)
Yes, it's gravitationally propelled through the solar system (1)
Yes, it's just like the rest (1)
Yes, because it has a moon (1)
Yes, it has distinct solar absorption habits (1)
Yes, I don't know why. I thought Pluto was a planet (1)
I don't know because scientists change the definition (1)

Trends: Several trends are evident this sampling of student ideas. *First, the definitional structure of the planetary sciences is not well-understood by a college-educated general public.* The effect of the recent debate on whether to remove Pluto from the list of recognized planets was evident even in the limited administration of a questionnaire. Although public debates hold the promise to educate Americans and bring attention to the planetary sciences, an unfortunate side effect is that it serves to weaken the conceptual framework that the general public uses when they think about the planets. It is clear that scientists must show that the planetary sciences has a solid foundation of definitions and concepts to alleviate confusion. *Second, many basic physics and chemistry misconceptions are deeply entrenched, and they affect the public's understanding of the planetary sciences.* "Entrenched" ideas are those that resist conceptual change [8]. Anderson and Libarkin [6,7] found that nearly 1/3 of the questions on the GCI showed no significant change as a result of college-level instruction, and that nearly half of these questions were related to basic physics and chemistry. For example, we looked at a subset of test data consisting only of those students who took the exact same versions of the pre- and post-test, and found that students scored the same, or worse, on some questions. The following is an example of one of these questions from the GCI. The number of students who choose each response on both the pre- and post-tests are listed in parantheses (pre/post).

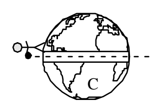
14. Imagine that a tunnel has been cut all of the way through the Earth's center, as shown in the pictures below. Which of the following is the best explanation of what would happen if you stood over the hole and dropped a rock? The dashed line shows the rock's path.



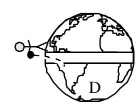
A. The rock would fall down (5/3)



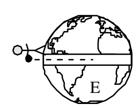
B. The rock would fall all of the way through the Earth and stop at the other side (3/8)



C. The rock would fall all of the way through the Earth and fall out the other side (6/7)



D. The rock would fall towards the side of the hole and stop in the ground. (15/13)



E. The rock would eventually stop at the center (22/18)

Third, a significant number of students have planetary conceptions that are limited solely to their Earth-dominated view of the solar system. We note that 10 of the 25 responses regarding whether the moon is a planet are either incorrect, or based solely on the view of our moon as compared to Earth.

References: [1]Hestenes *et al.,* 1992. [2]Libarkin and Anderson, 2005. [3]Libarkin and Anderson, 2006. [4]Halloun and Hestenes, 1985. [5]Libarkin et al., 2005. [6]Anderson and Libarkin, 2006. [7]Anderson and Libarkin, 2007. [8]Vosniadou, 1992