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The Gender Gap in Cosmology: Results from a Small Case Study of Undergraduates

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Abstract

Survey tests given to astronomy students--most notably the Astronomy Diagnostic Test National Project conducted in 2001--have shown a sizeable gender gap: males score consistently higher than females on tests conducted before and after taking a given astronomy course. This article, based on confidential interviews with six undergraduate students (three males and three females) enrolled in an introductory astronomy course at the University of Maryland, focuses on identifying some of these gender differences. These interviews show that, relative to males, female students consistently estimate the scale of the universe to be smaller, especially outside the solar system; have less confidence about their answers, even when they are correct; and have less previous exposure to astronomy through reading, movies, and pre-college classes.

1. INTRODUCTION

Every young man and woman entering college has a set of beliefs about the Universe and the way it works. These beliefs have been formed throughout their lifetimes by simple observation and analysis. Some may not be aware that they possess these ideas, or that they may contradict modern science. On the other hand, the awaiting professors may not be aware that these student beliefs exist at all. Instruction that does not consider pre-established beliefs is thought by experts to be completely unproductive for the majority of students (Hestenes 1992). Identifying initial beliefs has been a major concern of researchers in recent years because incorrect ideas can often hinder learning of the correct explanations for physical phenomena (A Private Universe 1994).

A group of astronomy educators began developing the Astronomy Diagnostic Test (ADT) in 1998 (Hufnagel 2002). As part of the ADT National Project in 2001, introductory astronomy students from all over the country were given the ADT as a pre-test (5,345 students) and as a post-test (3,841 students). It

was designed to identify misconceptions that students may have when they enter the classroom. In addition to 21 content questions, the students were asked 12 background questions, including gender identification.

2. METHOD AND RESULTS

The results from the National Project data have been processed and scanned for widespread correlations. A distinct difference has been found between the scores of males and those of females. Although both have similar gains from pre- to post-test results, there is a gender gap for both average pre- and post-test ADT scores in every class studied. For the pre-test, the females have an average score of 27% (0.23% standard error), while the males have 38% (0.32% standard error). Post-test scores give a female average of 41.5% (0.39% standard error) and a male average of 53.7% (0.47% standard error) (Deming 2002). The gender difference is clear throughout the test, although the gap is more pronounced for the subjects of cosmology and the scale of the Universe. Three such questions appear on the ADT:

12. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. To where would you have to travel to first observe a considerable change in the shape formed by these stars?

Pre-test Results ADT National Project

	Females (%)	**Males (%)**
a. across the country	6	4
b. a distant star	**31**	**53**
c. Europe	8	6
d. Moon	33	18
e. Pluto	20	18

13. Which of the following lists is correctly arranged in order of closest to most distant from the Earth?

	Pre-test Results ADT National Project	
	Females (%)	**Males (%)**
a. stars, Moon, Sun, Pluto	12	4
b. Sun, Moon, Pluto, stars	6	3
c. Moon, Sun, Pluto, stars	**48**	**75**
d. Moon, Sun, stars, Pluto	22	8
e. Moon, Pluto, Sun, stars	12	10

16. According to modern ideas and observations, what can be said about the location of the center of the Universe?

	Pre-test Results ADT National Project	
	Females (%)	**Males (%)**
a. The Earth is at the center.	6	2
b. The Sun is at the center.	27	15
c. The Milky Way Galaxy is at the center.	7	5
d. An unknown, distant galaxy is at the center.	12	24
e. The Universe does not have a center.	**47**	**54**

There could be many reasons for this large gender gap in cosmology and the scale of the Universe. A simple explanation could be that television programs, movies, or books on these subjects tend to appeal more to males rather than females. A more complicated explanation could be found in the confidence level of women vs. men, or society's unspoken label of a "girl's" or "boy's" subjects.

A small study was conducted at the University of Maryland as part of a senior research project. Confidential interviews were carried out in order to investigate the following questions: 1) What do students understand about cosmology and the scale of the Universe? 2) Where did these ideas come from?

3) What are the differences between the beliefs of men and those of women? 4) Do men and women enter an introductory astronomy course with the same resources? The interviews included three men and three women who had just started their introductory astronomy course at the University of Maryland. (They had not yet been exposed to the cosmology portion of their course.) These students took the ADT as a pre-test and were selected to get a representative sample. One woman and one man were selected from each of the "high," "middle," and "low" categories of ADT pre-test scores. The pseudonyms were given based on their ADT scores; all students with an "A" name (e.g., Adam, Amy) are from the top of the class, students with a "B" name are from the middle of the class, and students with a "C" name are from the part of the class with the lowest scores. The interviewer questioned the students about relationships in the Solar System and the Milky Way Galaxy, as well as the Universe and cosmology.

The interviews began with questions regarding the scale of the Solar System and continued by moving farther away from Earth. First, each student in the study was shown a variety of balls: a large beach ball, a basketball, a balloon slightly larger than a softball, a tennis ball, a slightly smaller Styrofoam ball, and a small rubber ball about an inch in diameter. They were asked to select a ball that would represent Earth, and one that would accurately represent the Moon. They were also asked how far apart these two objects would have to be in order to have an accurate model of the Earth (E)-Moon (M) system. They were then asked about the size of the Sun (S) compared to this model, where the Sun would be located, and where the nearest star (*) would be. The results are shown in Table 1 and in Graph 1.

Table 1. Scale of the Solar System from Group I

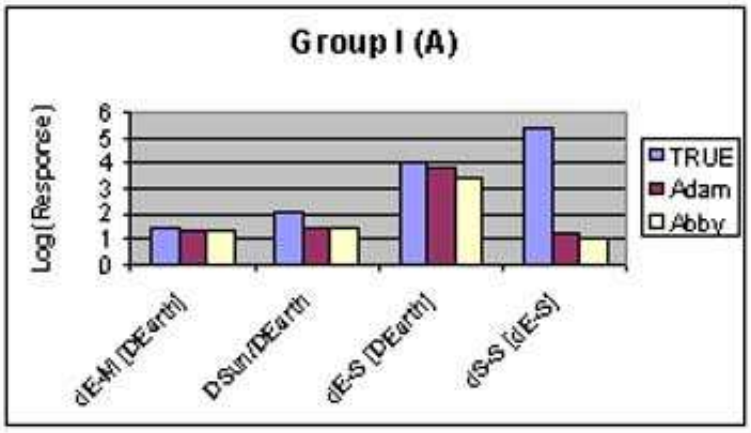
	Earth-Moon Distance $d_{E-M}[D_E]$	**Sun/Earth Diameter** D_S/D_E	**Earth-Sun Distance** d_{E-S} $[D_E]$	**Sun-star Distance** d_{S-*} $[d_{E-S}]$
ACTUAL	**30**	**108**	**11,500**	**271,000**
Abby	20	30	2,500	10
Becky	10	3	2,500	4
Carrie	60	1/12	15,000,000	2
Adam	20	30	7,500	15
Brad	1,000	80	5,500	70
Chris	2	2	6	25

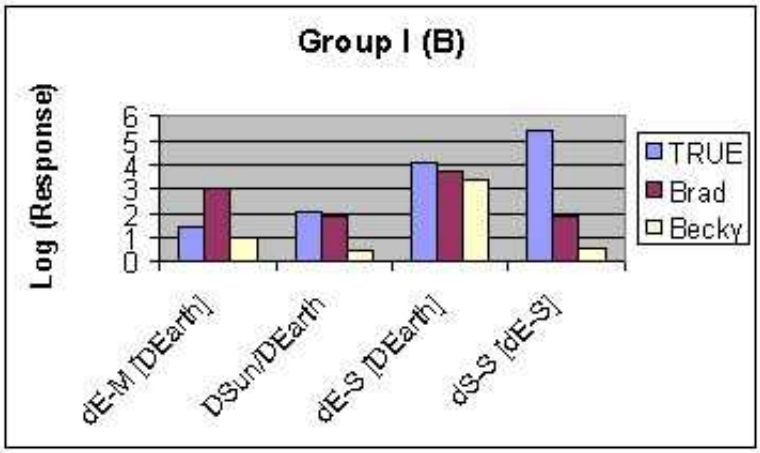
The ratio of the diameters of the Earth and Moon are omitted because all but one of the students (Chris) selected the basketball to represent Earth and the tennis ball to represent the Moon. Chris selected the balloon and Styrofoam ball, which is also an accurate representation of the Earth and Moon. Most of the students did so because they remember their instructor demonstrating this concept on the third day of

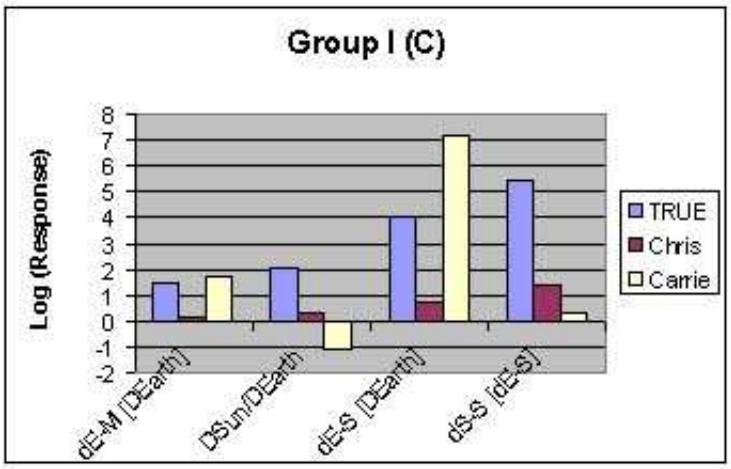
class, and representing the Earth and Moon with a basketball and tennis ball. However, this is where the similarities in the answers end.

When the average female response is compared to the average male response, the individual answers get lost in the average. For example, taking the average male response for the Earth-Sun distance would not represent how any of the males responded to the question. It would be much smaller than Adam's and Brad's responses, but much larger than Chris's. Therefore, we can look at each group (A, B, C) individually and compare the answers for each gender. We do this to see how the top male compares to the top female and to compare groups A, B, and C with one another. Because of the large range in responses, the vertical axis is measured in the logarithm of each response, with the appropriate units in brackets below the horizontal axis.

Graph 1. A, B, and C students compared







The females held a consistently smaller model than the males, especially beyond the Solar System. For example, Abby and Adam had the exact same answers for the first two measurements, but the further they got from Earth, the further apart their answers became. Also notable is that the smallest distance between the stars for a male (Adam) was still larger than the largest distance for a female (Abby).

Another Solar System question asked in the interview related directly to question 13 from the ADT. Four cards were placed in front of the students, with one word on each: Moon, Sun, Pluto, and stars. Students were asked to put these in order of closest to farthest away from the Earth. Each male put them in the correct order (Moon, Sun, Pluto, stars) with no problems and with high confidence.

The females, however, responded very differently from the males. Abby was the only female with the correct order. The others had switched the Sun and Pluto in the order. All of the women lacked confidence in their order. Becky switched her answer from the correct model to an incorrect one, and Carrie had trouble deciding where in the order she should place the stars. Each female took her time and quite obviously did not have a beginning model in her head. Abby even said "that's my guess" when she was done with the order, indicating that she was not sure of herself. The males clearly were more confident and had a more accurate model than the females.

The students were then asked question 12 from the ADT: "How far would you have to travel to see a considerable change in the form of the stars that make up the Big Dipper?" The students' answers are in Table 2.

Table 2. Student responses to "How far would you have to travel to see a considerable change in the form of the stars that make up the Big Dipper?"

Abby	distant star	**Adam**	distant star
Becky	the Sun	**Brad**	nearest star
Carrie	other side of Earth	**Chris**	past Pluto

It is interesting to note that group A students are correct, and Brad and Chris are closer to the correct model than Becky and Carrie. All of the males realize that the stars that make up the Big Dipper are far enough away that one would have to get at least out of the Solar System to see a change, while Abby was the only female who made this connection. Becky and Carrie both are unaware of the distance to these stars, and that the distance between the Earth and Sun is insignificant in comparison.

The students were then asked question 16 from the ADT: "What or where is the center of the Universe?" Their answers are in Table 3.

Table 3. Student responses to "What or where is the center of the Universe?"

Abby No center--Universe is infinite.	**Adam** Wherever Big Bang began.
Becky Some galaxy far away.	**Brad** Nobody knows, but there is a center.
Carrie I don't know.	**Chris** There may not be a center.

None of the students knew the currently accepted theory that there is no center. Although Abby stated that the Universe has no center, the logic behind her answer was jumbled; she did not know why the Universe has no center. Chris said that maybe there is no center, but only after prompted. Chris insinuated that he had never given this topic much thought when he said "I don't know, that's weird. I can't even think about that." In fact, none of the students came across as being confident in his or her response. This leads one to believe that all of the students were guessing. It is interesting to note, then, that the men seem to have a better foundation for their guesses. They concluded that the center of the Universe is where the Big Bang occurred, a common belief. The women seemed to be pulling their answers out of nowhere, while the men relied on what they knew to postulate a hypothesis.

The students were also asked what the Big Bang is. Their answers are listed in Table 4.

Table 4. Responses to "What is the Big Bang?"

Abby Creation of Solar System	**Adam** Creation of Universe
Becky Creation of Earth	**Brad** Creation of Universe
Carrie Never heard of it	**Chris** Creation of Universe

While all of the males have a common correct idea that the Big Bang is a theory for the creation of the Universe, none of the females held that same idea. When prompted, however, Becky agreed that it may apply to the rest of the Universe as well.

3. DISCUSSION

It would be false to say that men in this small case study have an ideal impression of the scale of the Universe. For example, Chris's Solar System could fit into one room when the Earth was represented by a basketball. Brad mentioned "stars in the Solar System" and said that the Milky Way is made up of "other galaxies," among other things. There is no question that these students all have an idea of the Universe that is grossly smaller than reality.

Although none of the students interviewed portrayed his or her knowledge of a perfect Universe during the interviews, the women seem to have an idea that the Universe is smaller than what the men believe. The average woman consistently fell behind the average man when it came to estimating the vastness of the Solar System, the Milky Way, and the Universe. It seems that thinking outside of the Solar System is an effort for women, and they do not consider it unless prompted.

The females interviewed all expressed a lack of confidence. The level of confidence that the males exerted during the interviews is well beyond the level of the females. One quick way to measure the confidence level of each student is to scan the interview for the number of times the phrase "I don't know" appears. The results are in Table 5.

Table 5. The number of times "I don't know" was said during interview

Abby 12	**Adam** 6
Becky 14	**Brad** 9
Carrie 22	**Chris** 18
Average Female 16	**Average Male** 11

From this small case study, it is clear that every student had some beliefs established at a time prior to the interview and that the agreement of their beliefs with modern science varies dramatically among the students. Although every student comes from a different background and exposure to astronomy, some obvious trends have been identified.

Each student was asked a variety of background questions in order to investigate prior informal educational experiences. Among other questions, the students were asked to name any scientific or astronomical books or magazines they had read, any movies they had seen, and any television programs they had watched. Their answers are in Table 6.

Table 6. Background Questions

	Abby	Becky	Carrie
Reading	Children's books	No	No
Movies	Fiction	Fiction	Fiction
Classes	Elementary	Elementary	Elementary
	Adam	**Brad**	**Chris**
Reading	Star charts, subscription to *Scientific American*	Black holes, stars, subscription to *Air & Space*	Favorite book when young: *Our Universe*
Movies	Fiction, documentaries	Fiction	Fiction, at least one documentary
Classes	Astronomy (high school), elementary	Physics (high school), elementary	Physics (high school), elementary

By looking at this table, is it obvious that the males had more exposure to astronomy than the females did. All of the males had high school courses that incorporated at least some astronomy into them, while the females remember only classes from elementary school. Everyone had seen at least one fiction or science-fiction movie involving space (e.g., Armageddon, Star Wars, and so on), but two men had seen at least one documentary about astronomy, while the women claimed that they had not seen any. Finally, all of the men had read at least one book on astronomy, and two of them even had subscriptions to scientific magazines. Abby was the only woman who remembered reading any sort of astronomical material, and it was a children's book.

The females were afforded many of the same opportunities as the males, yet declined to seize them. The males most likely did not have a greater selection of books or magazines to choose from at the library, nor did they likely have a different selection from which to view television programs and documentaries. Most (if not all) of these students grew up on the East Coast of the United States, and all are attending the same university and therefore likely had similar opportunities for exposure to astronomy. When Carrie was asked where she had seen pictures of the Milky Way, she responded by saying:

> Well, just recently. Like, our textbook and like I've seen other pictures, like in a magazine if it'd have just like a--just a picture of it, like an article on it. But it's not like I would read it, I'd just look at the pictures.

Carrie admits that she did not take opportunities to expand her knowledge about astronomy.

It should be emphasized here that this is a small study of only six students. An ideal situation would be to interview many more students to find whether this group had any bias. However, it is assumed that these students are a representative sample of introductory astronomy undergraduates, and conclusions can still

be made based on these six students' answers. All of the students' responses indicate that they do not hold a model of the Universe that agrees with modern science. The males, however, had a model much closer to the scientific model. When their backgrounds were examined, it was discovered that the males had a greater exposure to science and astronomy, and, unlike the females, applied their resources when establishing scientific beliefs. The males showed more confidence in their wrong answers than the females showed when they were correct.

Whether the females lack exposure to science or confidence in their explanations when compared to their male peers is to be debated. Whatever the reason for the gender gap, something has to be done about it. Simply identifying these issues will not solve the problems acknowledged above. For example, why do women choose not to read science print media or watch science-related television programs? There is hope for these students. Abby was asked why she was taking the class:

> Yeah, like I look up and like you kinda wonder...'Cause I mean, if you actually take the time to look up, which a lot of people don't do...you're just like, 'what is that?' Like, it looks like a flashlight to me. Like a Christmas light. You know? But what is it really, you know? And so, I guess...curiosity.

These students are eager to learn about the Universe. In order to maximize learning, astronomy professors must become more aware of how students construct their ideas about the Universe. Effectively teaching these students may require an educator who understands student misconceptions and their effect on learning.

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