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This I ~~Believe~~ Understand: The Importance of Banning the B-Word from Science

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Abstract

What our students hear when we say something is a "theory" is that it is a hunch or a guess, and because it is not "proven" and admittedly can never be, it is somehow not to be taken seriously. With the general public misusing and misunderstanding the concept of a theory as we mean it, it is vitally important that scientists and science educators be mindful of the power of language and take great care when communicating with students and the general public.

"I was brought up to believe, and I still believe, that physics is an experimental science." — Sheldon Glashow

1. INTRODUCTION

As teachers of science, we've all had the same dreaded experience. We finish explaining some exciting, important theory to our class of non–science majors with enthusiasm, patience, and what we consider artful language. But when we ask if there are any questions, or, more likely, on the next exam, we find that more than one student innocently deflates our intellectual balloon by proclaiming the Big Bang, evolution, or their kin "only a theory." "Only" a theory? That's an oxymoron. One might be tempted to term it outright *blasphemy*! As Murray Peshkin (2006) laments, such proclamations are tantamount to saying, "It's only science." Practitioners of science understand that theories are well-tested, experimentally and observationally supported, and peer-reviewed successful explanations of the natural world that also have the power to predict new phenomena and observations. We also know that our theories can never be absolutely "proved" true or complete, and we face the continual risk of being revised or replaced as our technology and understanding improve. However, what the general public and our students hear when we say that something is a "theory" is that it is a hunch or a guess (the common usages of the word outside the scientific sphere), and because it is not "proven" and admittedly can never be, it is somehow not to be

taken seriously. David Morrison (2005) warns that a serious symptom of this fundamental misunderstanding of the scientific meaning of the term "theory" can be found in polls that "indicate that three quarters of Americans agreed that evolution is commonly referred to as the theory of evolution because it has not yet been proven scientifically" (38). Is it any wonder, then, that students (and their parents) can fall sway to arguments of "fairness" put forward by proponents of so-called intelligent design? Isn't that also a theory that's just as good as any that the scientific establishment has developed? Another area for concern is that, as Brickhouse et al. (2002) have shown, "research literature tends to refer to all theoretical constructions as 'theories,' regardless of whether the ideas to which they are referring have the explanatory power of those ideas that are called scientific theories" (578). With both the general public, and the larger academic community outside of science, misusing and misunderstanding the concept of a theory, it is vitally important that scientists and science educators be mindful of the power of language and take great care when communicating with students and the general public (Morrison 2003; Quinn 2007). This article considers one particularly egregious misuse of language in popular-level science discussions, namely the dreaded B-word—*believe*.

2. "THEOLOGICAL HANDWAVING"

In an attempt to explain science in an engaging and accessible manner, popularizers of science and science educators sometimes fall into the general trap of using words and metaphors that have a decidedly religious connotation. We talk about the symmetry of large-scale structure in the universe as "an item of faith among cosmologists" (Smolin 2006, 208) and have faith that the "laws of the large and small should fit together into a coherent whole" (Greene 1999, 386). We are told of "Einstein's complete faith in his ideas" (Gleiser 2005, 254), and how Thomas Gold "kept the faith" with respect to the steady-state model (Singh 2005, 438) even though the discovery of the Big Bang's cosmic background radiation "gives us faith that we have not dreamed it all up" (Vilenkin 2007, 41). Astronomers possess "faith in the constancy" of the period-luminosity relationship for Cepheid variables but question the wisdom of having "unbounded faith in the evolutionary invariance" of a galaxy's luminosity (Goldberg 1982, 49, 304). We marvel at "mathematical miracles" (Woit 2006, p. 197) and "miraculous-looking discoveries" (Glanz 2001), we "confess" to being "an agnostic" when it comes to extra dimensions (Krauss 2005a, 244) or to being "agnostic" as to whether string theory will unite the four forces (Randall 2005, ix). Some of us are so enraptured by a particular discovery that we feel "like an atheist who has just received a message from a burning bush" and become "an immediate true believer" (Krauss 2005a, 138). Cutting-edge work is followed "religiously" (Kaku 1994, 151), leading some adherents to become "a passionate proselytizer" (Finkel 2005). As more evidence is gathered for our particular pet hypothesis, we may proclaim that it is becoming established "more solidly in the dogma of theory than ever" (Taubes 1986, 254). Dogma of theory? Should any scientist, science educator, or serious science writer utter such a phrase, even under the umbrella of creative license? As Scott (2004) reminds us in her classic work on the public tension between evolution and creationism, "dogma—an idea held by belief or faith—is anathema to science" (8). But Morrison (2003) deservingly chides the scientific community when he writes that "almost all of us speak of believing a particular scientific result or theory" and warns that "this usage has the unintended result of associating scientific results with a religious or philosophical belief system." Given the tendency of those outside the scientific realm to misunderstand the scientific method and the relationship between science and religion, such writers should understand that they are clearly walking where angels (and scientists) should fear to tread.

Not only are we guilty of utilizing religious language to describe the scientific endeavor, but the name of God is itself sometimes invoked. Scientists proclaim that "God is a techno-geek" (Smolin 2006, 75) and speak of a mathematical "language in which God wrote the world" (Woit 2006, 211). Temperature fluctuations seen in the data of the COBE satellite are compared to seeing the "face of God" (McDonald 1992, A8), and the Higgs boson is proclaimed to be the "God particle" (Lederman 1993). Scientists have even been so bold as to tell the general public that "the mind of God can be viewed as cosmic music vibrating through hyperspace" (Kaku 2006, 356). More troubling is when scientists improperly use religious language in a humorous (and perhaps even mocking) manner. Is there any legitimate reason for a conference on quantum gravity to be opened with the proclamation "There is one true Alain [Connes], and I am his messenger" (Smolin 2006, 7), or for a talk given at a meeting of the American Academy for the Advancement of Science to be entitled "The Power and the Glory of String Theory" (Woit 2006, 226)? Such disrespectful uses of religious language run the risk of widening the already sizeable gap between science and persons of faith. Consider another unfortunately common use of religious metaphor in popular science writing. In an attempt to convey concern about (or even open contempt for) string theory and M-theory, numerous authors have described it as "a cult" (Woit 2006, 210), "medieval theology" (Glashow 1991, 183), and even a "faith-based initiative" (Holt 2006, 90). We bemoan the "messianic tendency" of its practitioners (Smolin 2006, 275) and refer to them with the clearly pejorative term "religious fanatics" and their research as "religious fundamentalism" (Magueijo 2003, 236).

Regardless of one's personal views on string theory, what good can come from such "theological handwaving"? According to priest and cosmologist Michael Heller (1997), "neither theology nor science benefits" (19). Some scientists attempt to explain that terms such as "design, agency, and even God" are merely metaphors for the unknown. They point to Einstein's multiple references to God, such as "God is cunning but He is not malicious," which they purport to merely be metaphors for the natural laws of the universe (Susskind 2006, 8). Perhaps so, but the damage has already been done and continues as well. Modern science is mysterious to the average person, as is pseudoscience and paranormal phenomena. Popularizers of science, especially of such "sexy" and highly speculative areas of research as string theory and extra dimensions, have perhaps done their job too well. As a result, "aficionados of the occult," proponents of pseudoscience, and even well-intentioned persons of faith (attempting to find their own peace between science and religion) have hijacked modern science in an attempt to gain support for their nonscientific ideas (Finkel 2005; Kuttner & Rosenbaum 2006). Take, for instance, an article by Christian writer Nicola Hoggard Creegan (2005), in which she proclaims that "string theory gives us a glimpse of the enormity of God's resources, the enormity of the project that would bring the universe or universes to another phase of existence." She further affirms to her eager readers that

> the mysterious principle of the universe whether imbued with Spirit, or known as logos or wisdom would surely be known in the kinds of complexities M theory/String theory proposes. Wormholes, parallel universes, and eleven dimensions are like rumours of the mysterious interconnections between heaven and earth. As Christians we can be excited about such proposals, and the uncanny affirmations they bring to the existence of things unseen and unheard. (26)

Some scientists, including those not trained in higher dimensional physics, have also taken their sometimes admittedly popular-level understanding of extradimensional theories as evidence for their theological or philosophical leanings. Frank Lee, a biophysicist and convert to Christianity, has a rather extensive set of online essays that use brane theory to explain that God and heaven exist in the "bulk" that surrounds our four-dimensional brane. As he offers in his introduction, God could "be only a centimeter away from us without being detected. Physicists have discovered the mechanism that prevents us from

seeing the Kingdom of God!" (2005a). In other essays, he tells the reader that communication with God must be done through gravitational waves and, therefore, that "the existence of God will be confirmed if the gravitational waves from God are detected" (2005b). John Hagelin, who holds a PhD in physics from Harvard and is a longtime faculty member at the Maharishi University of Management (run by the followers of transcendental meditation's founder, the Maharishi Mahesh Yogi), organized what was meant to be a public demonstration of the existence of "a unified superstring field." It was claimed that a collection of minds simultaneously practicing transcendental meditation could generate such a superstring field, which would reduce crime in Washington DC by "reducing stress and spreading tranquility." As expected by the scientific community, no such reduction in community violence resulted from the "experiment" (Park 2000, 29).

3. BANNING THE B-WORD

If scientists, science educators, and science writers were to tackle the problem one word at a time, perhaps the place to begin would be the B-word, *believe*, and its variations. Particle physicist Helen Quinn (2007) reminds us that "for most people, a belief is an article of faith" (8). When scientists use that word, what they generally mean is that "the preponderance of evidence favors the interpretation" in question, quite a difference from how the general public uses the word. As a result, Quinn, Eugenie Scott, and David Morrison caution against using the word when describing scientific process and knowledge (Quinn 2007; Krauss 2005b; Morrison 2003).

3.1 Popular-Level Works

How widespread is the use of the B-word in a scientific context? According to Marcelo Gleiser (2005), electromagnetism proved the vindication of "Faraday's belief in a deep unity in nature" (180), and Simon Singh (2005) stated encouragingly that "there is every reason to believe that the standard laws of chemistry as we understand them were behind the construction of the first cell" (489). Readers of Philip Harrington's (1990) *Touring the Night Sky with Binoculars* learn that "some experts believe that Mare Humorum is the oldest of the maria" (14), while "astronomers believe that these amazing novalike flares are the result of the interplay between a red dwarf paired with a white dwarf" (156). Inglis's (2007) *Astrophysics Is Easy!* informs us that "from studying the Pleiades H-R diagram, astronomers believe that the cluster could be about 50 million years old" (72), and Oerter's (2005) *The Theory of Almost Everything* explains that "physicists believe that all of the galaxies in the observable universe consist of normal matter" (254). Physicist Alex Vilenken (2007) also repeatedly falls victim to the dreaded B-word in *Many Universes in One*, writing that "cosmologists believe that this is how galaxies, clusters, and superclusters were formed" (41), "there are strong reasons to believe that most of this dark matter is not made up of nucleons and electrons" (43), and "we have every reason to believe that general relativity applies inside black holes just as much as it does outside" (92). Even Lawrence Krauss (2005a), who cites Eugenie Scott's admonition in his article, "Mind Your Language," makes the same faux pas in his popular-level book, *Hiding in the Mirror*; when writing about density fluctuations, he explains that "we believe this is how all large-scale structures in the universe first formed" (261). Krauss further explains that "we currently have reason to believe that they formed due to the quantum mechanical effects at very early times, as a result of inflation" (261). Perhaps unparalleled in his overplay of "belief/believe" is Stephen P. Maran, former Assistant Director of Space Sciences for Information and Outreach at the NASA-Goddard Space Flight Center. His *Astronomy for Dummies* (2005) is littered with the word. Consider the five representative examples (italics added for emphasis):

> Astronomers *believe* that comets were born in the vicinity of the outer planets. (65)
>
> Many scientists *believe* that an asteroid hit Earth about 65 million years ago, wiping out the dinosaurs. (115)
>
> It merges into the singularity, which scientists *believe* is infinitely dense. (222)
>
> Astronomers *believe* in dark matter for yet another cosmic reason. (248)
>
> But that's what scientists *believe* about how the universe took shape. (253)

Given the prevalence and persistence with which this word is used, should we expect the casual reader to think anything other than that "beliefs" are a natural part of science?

3.2 Textbooks and Educators

But science popularizers are not the only ones to blame. Works written by science educators and education researchers also feature dubious uses of the word. For example, Brickhouse et al.'s 2002 article in *Science and Education* entitled "Evidence and Warrants for Belief in a College Astronomy Course" features the easily puzzling statement that "one of the goals of science education is the acquisition of justified belief—or knowledge—about the natural world" (581). As any science educator knows firsthand, there are many clearly erroneous explanations of natural phenomena that students can and have tried to justify, both in class discussions and on exams. The article continues to report that "students said they believed strongly in gravity" and "also said they believed strongly in evolution" (582). Similarly, well-known astronomy educator Michael Seeds (1996) lists among the important "messages" that need to be conveyed in an astronomy course the basic principle "that scientists believe there is a single reality, something called 'the truth'" (22). In his survey of common astronomical misconceptions, Neil Comins (2001) explains,

> The power of experiments and observations to show that experts are wrong in their *beliefs* is an accepted hazard of the trade. It should serve as a reminder to everyone that scientific *beliefs* are subject to change and that if you have come to *believe* something, even because of what reputable scientists have said, you have to face the possibility that this *belief* is incorrect. (italics added for emphasis; 211)

The present author would argue that it is the job of the theologian to elicit "belief" and that of the science educator to bring about the functions of Bloom's (1956) taxonomy: knowledge, comprehension, application, analysis, synthesis, and evaluation.

A casual survey of the numerous astronomy textbooks that tend to accumulate on the average astronomy educator's bookshelves also demonstrates the pervasiveness of the B-word in our lexicon. In four randomly chosen recent textbooks selected by the present author, examples were found in each without much effort:

> Most cosmologists believe that the intense background radiation in the early universe effectively prevented clumps of normal matter from forming or growing. (Chaisson & McMillan 2004, 465)

> The belief that terrestrial life descended from organisms created elsewhere in the universe is sometimes called panspermia. According to the theory. . . (Arny 2006, 533)

> That is, we believe in the law of "conservation of energy"—the combination of mass plus energy is neither created nor destroyed. (Pasachoff & Filippenko 2007, 465)

The fourth textbook surveyed, Michael Seeds's (2008) *Horizons* (10th edition), has an offset box entitled "Why Scientists Speak Carefully: Words Lead Thoughts." Here Seeds warns that "words lead thoughts. It works in advertising and politics, and it can work in science, too. . . . All scientists are careful of language because careless words can mislead" (326). Unfortunately, this advice is apparently ignored by the author himself, who writes a mere nine pages later that "cosmologists believe that the dark matter cannot be baryons" (335).

3.3 Student Misconceptions

In an attempt to explore the depth (and resulting problems) of the B-word's entrenchment in the science classroom, the present author included the following essay question on a take-home exam administered to a freshman-only honors class in science and science fiction for non–science majors:

> You tell your roommate about this course, and they say "I don't believe in the Big Bang. It's just some stupid theory and there's no evidence for it. Besides, you can't believe in God and the Big Bang." How would you use what you have learned in this course to counter all parts of their argument?

During the course of the semester, Stephen Jay Gould's (1999) viewpoint of the Nonoverlapping Magisteria relationship between religion and science was discussed, as well as the scientific method and the history of, evidence in support of, and changes made to, the Big Bang model. Of the 22 students, only four were able to completely and correctly answer the question. Three of the most egregious statements are listed below:

> "They assume that the universe was created from a huge explosion that continues to spread outward and cool down. They believe this to be true because of. . ."

> "Science and believing in god are quite similar because they both can't be proved."

> "Also, the big bang is just a theory and nothing is proven. . . . For my roommate to be able to believe in both, she would need to realize that both God and the Big Bang are just theories."

A total of 18 students either did not pick up on the problem with the use of the word "theory" or incorrectly explained what a scientific theory entails. An alarming 19 students either did not comment on the use of the word "believe" or incorrectly used it themselves in their answer, an especially disconcerting outcome because students were docked points for incorrectly using the word on papers and homework during the semester. Only a single student failed to dutifully list supporting scientific evidence for the Big Bang model. Therefore, if this question had been of the usual type included on astronomy exams ("regurgitation education" of facts), all but one of the students would have earned an A on this question even though it is clear that the vast majority of the class did not grasp the basic concept of a scientific theory and how the Big Bang fits the definition.

4. CONCLUSION

This disappointing result confirms the commonly cited argument that

> school science, if it is to contribute effectively to improved public understanding of science, must develop students' understanding of the scientific enterprise itself, of the aims and purposes of scientific work, and of the nature of the knowledge it produces. Such an understanding, it is argued, is necessary for students to develop an appreciation of both the power and the limitations of scientific knowledge claims, an appreciation which is necessary for dealing appropriately with the products of science and technology as informed citizens who can participate fully in a modern democracy. (Driver et al. 1996, 1)

However, there is an important facet to this that can no longer be ignored. As Quinn (2007) warns, "words shift their meaning; each community develops its own usage. That change in meaning leads to miscommunication" (8). The change itself can be in a direction that fosters increasing miscommunication rather than clarity. Morrison (2005) notes that "while older dictionaries give preference to the scientific definition" (38) of the word "theory," newer texts have given precedence to the colloquial meaning, namely referring to a theory as a "belief, something taken to be true without proof, an assumption, a suggestion, a hypothesis" (38-39). It is therefore vital that we as scientists, science educators, and popularizers of science watch our words carefully and model correct verbal behavior with those with whom we come into contact. If we do not, we risk confirming the general public's erroneous opinion that "in gravitation, electromagnetism, relativity, or evolution, scientists are just guessing or following their hunches" (Morrison 2003).

As in the case of most cultural changes, this one will be slow and tedious. We cannot expect to overcome decades of sloppy usage in a single course in a single semester, but planting the seed is the first step to achieving growth and eventually the desired outcome. The next time Brian Greene (1999) or another popular science writer asks us "how much faith should we really have in the big bang theory" (347), we should not hesitate to reply, "absolutely none at all."

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