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Non-Scientific Beliefs Among Undergraduate Students

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Abstract

A survey of over 11 000 undergraduate students' knowledge and attitudes related to science and technology over a 22-year period included statements that probed faith-based beliefs and various aspects of pseudoscience belief and superstition. The results reveal that nonscientific ways of thinking are resistant to formal instruction, changing surprisingly little over the course of a college career that typically includes three science courses. The level of basic science knowledge among undergraduates is only weakly coupled to attitudes towards pseudoscience, and it coexists with attitudes and beliefs that are faith-based. These results provide a challenge for educators who seek to improve the generally low level of science literacy among college graduates and members of the general public.

1. INTRODUCTION

The generally low level of science literacy has been a cause of concern for educators and policy makers for several decades. Surveys show that the U.S. general public has an imperfect grasp of basic scientific concepts, which affects individuals' ability to act as informed citizens in a world that is increasingly governed by issues of science and technology, as well as their ability to make reasoned judgments about issues like nuclear power, climate, genetic engineering, and the space program. Notably, science literacy has been tracked by the National Science Board (NSB) as part of the biennial Science and Engineering Indicators series (1979–2012), a report presented to the U.S. government, which is used to guide education and research policy. In the latest NSB survey (National Science Board 2012), less than one in three adult citizens correctly answered 8 or more out of 12 basic science knowledge questions, recognized astrology as nonscientific, and was able to describe adequately in their own words what it means to study something scientifically.

Astronomy educators are important players in the attempt to diagnose and improve this situation. Introductory astronomy college classes for nonscience majors enroll over 250 000 students per year and often represent a student's last formal exposure to science. Nationwide, about 10% of all students take such a class (Fraknoi 2002). Most teachers have goals that go beyond conveying astronomy knowledge and instilling an appreciation for the subject; they also want students to learn about the rational way of thinking and experimenting that has been so successful in revealing the underlying rules of the natural world. Constructivism, a theory of how people learn, posits that students do not enter the college science classroom as "empty vessels," ready to be filled with scientific knowledge (Bransford, Brown, and Cocking 2000). Students have a complex web of prior belief systems and understandings about nature based on experience, upbringing, popular culture, and social interactions (Donovan and Bransford 2005).

The relationship between what someone "knows" and what they "believe," and the basis for each, is subtle and complex and cannot be fully explored in this paper. Some beliefs are rational and align with scientific understanding, while others are largely or wholly irrational and can be classified as superstitions. Another category often is called pseudoscience: defined here as a belief system that presents itself as scientific or has some of the trappings of science, but is not based on logic or evidence (Shermer 1997). Pseudoscience claims, but does not uniformly possess, the attributes of logical rigor, evidence-based reasoning, predictive power, and empirical verification or falsification that are the hallmarks of science. Astrology is the archetypal example (Thagard 1978). As a result, the term is often used pejoratively. Knowledge is also a variegated concept. The process of science is one well-trodden path to knowledge, but knowledge also can be gained by experience or association and by transmission from another person or source. In this paper, we do not declare rigid distinctions between science and pseudoscience or faith and reason; the difficulty of doing so is the well-known "demarcation problem" in the philosophy of science (Resnick 2000). However, in the title and elsewhere we use the term "nonscientific" to refer to beliefs or knowledge that are not acquired through an application of commonly agreed upon tools of the scientific method (Gauche 2003). That is, nonscientific is not considered to be the same as antiscientific, and it is not intended pejoratively, since there are varied pathways to knowledge. However, many science educators have found that nonscience beliefs can interfere with the learning of science and hence with increasing overall science literacy (Losh *et al*. 2003; Martin 1994).

It is an open question whether or not nonscientific views or belief systems actually interfere with or compromise learning science and having a scientific worldview. Religious belief provides an interesting perspective. A survey by the Pew Charitable Trust shows that a third of all professional scientists adhere to a major religion and believe in a conventional Creator (Pew Research Center for People and the Press 2009). Faith and reason have coexisted in scientists as great as Newton, Planck, and Einstein, and there are prominent current examples like Francis Collins, Director of the National Institutes of Health. Perhaps surprisingly, only 40% of professional scientists in the U.S. classify themselves as atheists (Ecklund and Scheitle 2007). This may be an example of what paleontologist Stephen Jay Gould called the "nonoverlapping magisteria" of science and religion, where scientists can accommodate natural and supernatural worldviews without apparent conflict (Gould 2002). A majority of U.S. undergraduates sees no inherent conflict between science and religion, and the sense of a harmonious relationship tends to increase as they progress through their education (Scheitle 2011).

We have been surveying nonscience majors regarding their scientific knowledge, attitudes toward science, and pseudoscience beliefs for over twenty years. Initial results from the survey have been published in the last two years (Antonellis *et al*. 2012; Buxner, Antonellis, and Impey 2010; Impey 2010; Impey *et al*. 2011). Previously, we have used this extensive set of data of over 11 000 students to investigate the prevalence of beliefs in astrology, the proposition that the positions of celestial objects affect everyday life or are correlated with personality attributes (Sugarman *et al*. 2011). In this paper, we extend the analysis to encompass a wide range of nonscientific belief systems. Is acceptance of these belief systems an accurate gauge of scientific literacy? Do the pseudoscientific misconceptions coexist with scientific understanding? What are the implications for how we teach science in the college classroom? The first two questions are answered by this study, while the third question still has no simple answer, and so debate is likely to continue. In terms of scholastic aptitude test (SAT) scores and other academic indicators (College Board 2012), the University of Arizona is near the mean of the largest state universities, so we assume that our results are a fair indicator of similar college populations nationwide.

2. THE SURVEY

The survey instrument used in this study has been stable, using the same questions, since 1988 and has two parts. The first is based on, and has a substantial degree of overlap with, the instrument used by the National Science Foundation (NSF) in the biennial survey of public knowledge of science and technology. It is designed to measure general scientific knowledge using a set of 21 knowledge-based questions, four of which are open-ended with short written answers and 17 of which require true/false or multiple choice responses. The second part is original and is designed to measure attitudes about science and technology, perceptions of and susceptibility to some forms of pseudoscience, and certain aspects of faith and religious belief. It utilizes a set of 24 statements where the responses are on a five-point Likert scale. For a more detailed discussion of the instrument, its reliability and completion rate, plus a description of the data entry and coding process, see Impey *et al*. (2011).

The survey is administered each year to students in large astronomy lecture courses that consist mostly of freshmen and sophomores and satisfy the natural sciences General Education requirement at the University of Arizona. Administered in the first week of class, it is voluntary and does not count for any part of a student's grade. Ten to fifteen minutes are allowed for its completion. Although the survey is anonymous, a modest amount of demographic information is collected: gender, major, grade-point average, class standing, and the number of college science courses already completed. The survey is administered on paper, and subsequent data entry and coding are done manually. General characteristics of the sample are that the over 11 000 respondents are equally divided into men and women; the fractions of freshmen, sophomores, juniors, and seniors are 47%, 31%, 12%, and 10%; the largest three categories of major are business and professional (33%), social and behavioral sciences (21%), and fine arts and humanities (16%); and 41% of the sample had not previously taken any college science classes, while 12% had completed the General Education requirement of three one-semester long science classes intended for freshmen and sophomores (and not requiring labs).

The survey measures some aspects of science literacy with 17 forced-choice knowledge-based questions that cover a broad range of scientific subjects, from physics ("Which travels faster, light or sound?") and astronomy ("Does the Earth go around the Sun, or does the Sun go around the Earth?") to biology ("The oxygen we breathe comes from plants, true or false?"). In the analysis presented here, we used 15 of the 17 forced-choice questions to have maximum overlap with the NSB Science Indicators survey; the 15 questions used here include 9 that are consistently part of the NSB survey. From the answers to these questions, each student gets a score on a scale from 0 to 15, with each correct question worth one point. Four open-ended questions ask for definitions of the scientific method, DNA, radiation, and computer software; they were not used for the analysis in this paper.

Students also responded to a set of 24 statements on a five-point Likert-scale of strongly agree, agree, no opinion, disagree, and strongly disagree. A sampling of the items gives a sense of the range of topics addressed. Statements like "Pure science should be funded regardless of its lack of immediate benefit to society" and "Genetic engineering is a good idea" probe general attitudes towards science and technology. "We should make a concerted effort to search for life on other planets" addresses expectations in astrobiology, while a related item "Some ancient civilizations were visited by extraterrestrials" alludes to belief in unidentified flying objects (UFOs). Others such as "There are some circumstances when medical science should not be used to prolong life" address ethical issues. Another set of items probes superstitions and beliefs in pseudoscience; examples include "Some numbers are especially lucky for some people" and "The positions of the planets have an effect on everyday life." There are also statements that relate to religious belief, such as "The Biblical story of creation should be taught alongside evolution in our schools" and "Faith healing is a valid alternative to conventional medicine." The survey is shown in Appendix A.

Some caveats and qualifications are in order. It is not possible to capture the nuances of any individual's science beliefs and knowledge in a fifteen-minute survey. Nor is it possible to combine such results into an "identikit" picture of the beliefs and knowledge of a population; the variance of responses on any particular survey item is large, so information is lost in forming means or looking for trends. Moreover, items in the survey are not uniformly strong and do not have equal diagnostic power. This is not as much of a problem with the forced-choice and open-ended science knowledge questions, which have been used and validated by the NSB for over two decades, as it is for some of the attitudinal Likert-scale statements. For example, "The universe was created in an enormous explosion billions of years ago" might elicit student disagreement because they did not agree with the scientific story of creation or because they did not agree with the overly declarative phrasing (or because they recognized that an explosion is a poor analogy for the instantaneous creation of all space-time). Similarly, a student might concur with the statement "UFOs are real and should be investigated" because they think alien space ships have visited the Earth or because they think that unidentified aerial phenomena are worthy of further study. Disagreement with positive statements about genetic engineering and nuclear power might arise from lack of information and antipathy or from a balanced judgment based on a high degree of information. Nonetheless, we contend that the survey has utility in the aggregate, and for example, as we will show in Section 4, the items that relate to pseudoscience have diagnostic power as a group.

3. OVERALL RESULTS

Before analyzing the landscape of beliefs and their relationship to science knowledge, general results from the survey can be summarized. There are no major changes in student response over the more than two decades of data, so we collapse the time axis to use the statistical power of the entire sample. As reported by Impey *et al.* (2011), University of Arizona undergraduates scored an average of 7.2 out of 9 correct (80%) on the knowledge items the survey has in common with the NSB survey, compared with 5.6 out of 9 (62%) for adults in the general public. Overall, students scored 11.2 out of 15 correct (75%) on the forced-choice knowledge items of the survey. Freshmen performed 20–30% better than the public on most of the knowledge items, with the exception of the questions about evolution and the big bang, where the gains were 50–60%.

As seen in Figure 1, aggregate improvements over the course of an undergraduate career (based on class standing rather than tracking cohorts) are no more than 5–10% for all items except for understanding about lasers, with an increase of 15%, and understanding of antibiotics, with an increase of 22%. Additionally, there was an increase of 30% in correct responses to the astrology question between freshman and seniors. Due to well-known issues with students' confusion with the words "astrology" and "astronomy," this question was not included in the science literacy analysis of this paper. For a full discussion of this aspect of the survey and students' conceptions of astrology related to this study, see Sugarman *et al*. (2011). Completion of the college science requirement leads to very little improvement in science knowledge score. Educators cannot be satisfied with a situation where one in three graduates thinks antibiotics kill viruses as well as bacteria, one in four thinks that lasers work by focusing sound waves, and one in five thinks atoms are smaller than electrons, are unaware that the Earth goes around the Sun, or that humans evolved from earlier species.

The attitudinal part of the survey reveals a rich landscape of beliefs, where strong support of science and its agenda coexist with a susceptibility to nonscientific thinking or modes of thought like pseudoscience, which do not fare well when subjected to skepticism and evidence-based reasoning. On the plus side, 93% strongly agreed or agreed with the statement that "Overall, the progress of science and technology has been beneficial to our civilization." Reassuringly for astronomers, who use taxpayer dollars to study objects and processes that can seem esoteric to a layperson, four times more students agreed rather than disagreed with the statement "Pure science should be funded regardless of its lack of immediate benefit to society." There was also solid support for astrobiology and NASA; half strongly agreed or agreed that "We should make a concerted effort to search for life on other planets," and two thirds similarly affirmed that "The government should strongly support the manned space program." The distribution of responses to these questions can be seen in Figure 2.

However, other Likert-scale items show that college students did not uniformly embrace a purely rational worldview. More than two thirds strongly agreed or agreed with the contention that "There are phenomena that physical science and the laws of nature cannot explain." Care must be taken not to over-interpret such an item, since respondents might be thinking of phenomena that involve human behavior, such as the behavior of stock

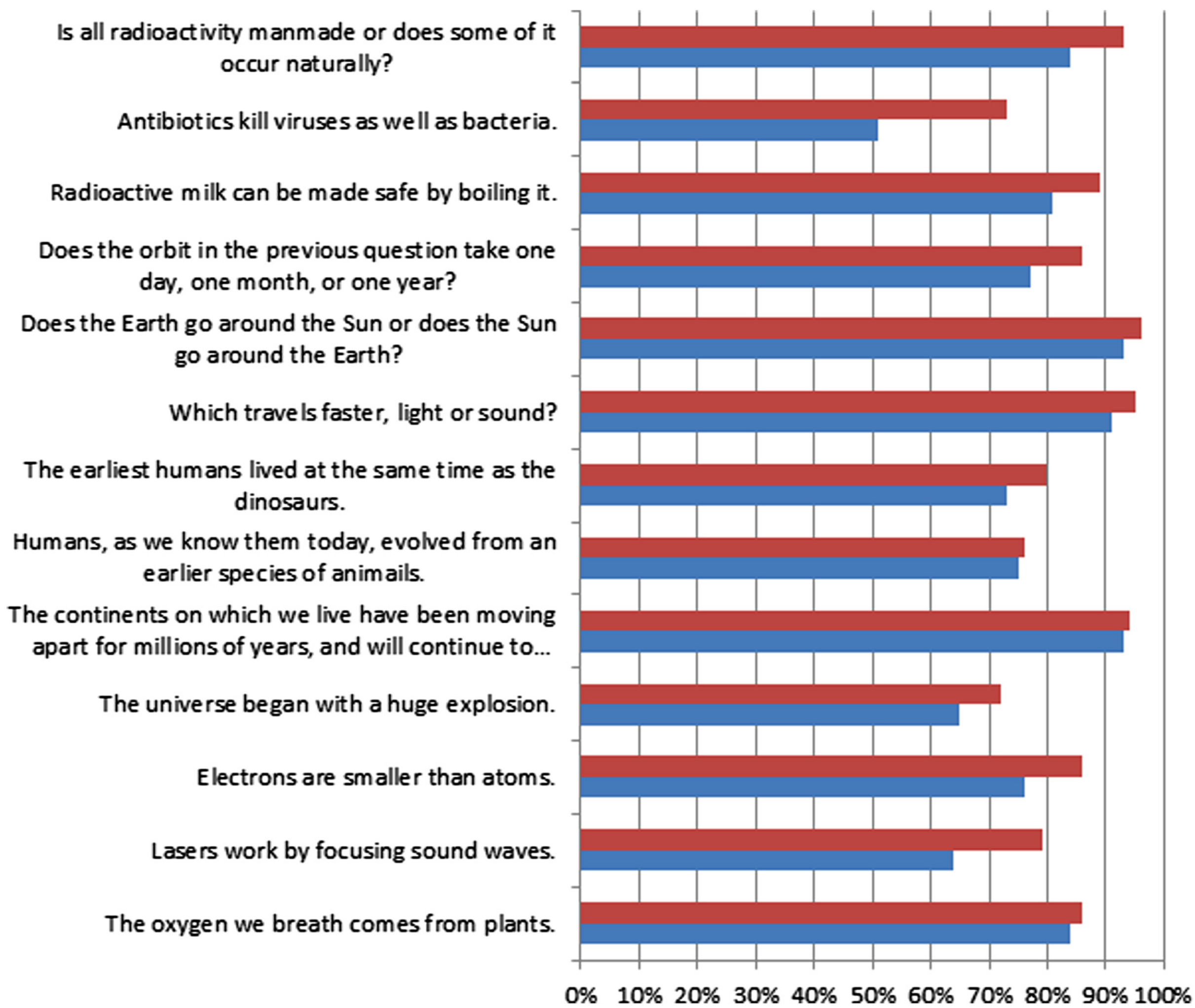

Figure 1. Comparison of percent correct between Freshman (blue) (n = 5190) and Seniors (red) (n = 1094) for select science literacy questions.

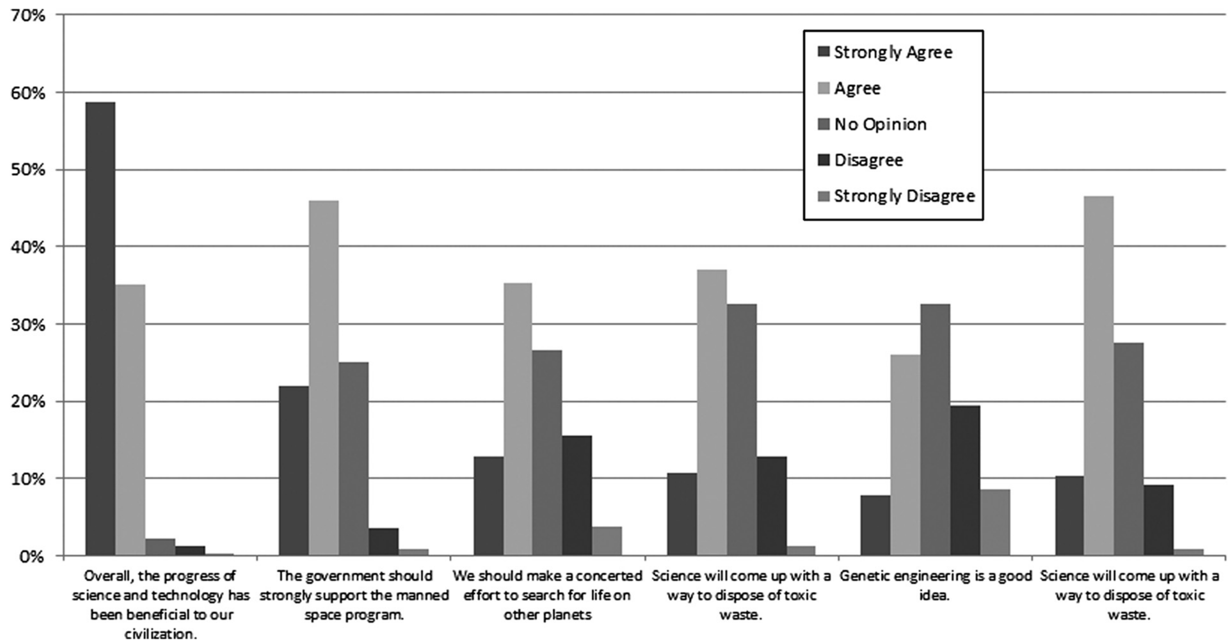

Figure 2. Distribution of student responses to questions about the benefit of science and technology.

markets, or emotional states such as sadness and love. At the very least, the responses conveyed a strong sense that the explanatory reach of science is limited. In the realm of pseudoscience, significantly more students agreed than disagreed with the statements that “The positions of the planets have an influence on the events of everyday life” and “Some people possess psychic powers.” In the realm of superstition, more than a quarter thought that “Some numbers are especially lucky for some people.” On the topic of life in the universe, over half strongly agreed or agreed with a statement that “It is almost certain that there are intelligent life forms elsewhere in the universe.” Many astronomers might concur since the prevalence of potentially habitable exoplanets increases the probability that some of them will host intelligent life. However, scientists would diverge from students in the conclusions they drew from the existence statement, where one in three students thought “UFOs are real and should be investigated” and one in six thought “Some ancient civilizations were visited by extraterrestrials.” See Figure 3 for a distribution of student responses to these questions.

This survey is not designed to measure religious belief, which is multifaceted and complex. However, it contains three items that address aspects of faith in the Christian tradition, and in particular its more conservative and fundamentalist strands. Nearly 40% of all undergraduates strongly agreed or agreed that “The Biblical story of creation should be taught alongside evolution theory in our schools,” while less than a third disagreed or strongly disagreed with that statement. The minority of dissenters are supported by the U.S. Supreme Court, which has ruled that creationism does not belong alongside evolution in the science classroom, in Edwards vs. Aguilard (1987). The statement taps into substantial disagreement; the standard deviation on the Likert scale is the largest among all 24 items. About one in four students responded that “Faith healing is a valid alternative to conventional medicine,” a position that is not supported by the American Medical Association (Hafner 1993). The incidence of Biblical literalism, however, appears low in this student cohort as only 15% disagreed with the statement that “The universe was created in an enormous explosion billions of years ago.” As noted previously, some within that group may have disagreed not based on religious grounds but because the statement is unequivocal while the evidence for the big bang is based on inference about remote realms of time and space. See Figure 4 for a distribution of student responses to these questions.

4. CATEGORIZING BELIEFS AND ATTITUDES

For a deeper level of scrutiny of the data, and to connect measurement of science knowledge to measurement of attitudes and beliefs, we looked for commonalities among the Likert-scale items. As a first step, the three authors and three other young education professionals in our team each grouped the items into a small number of categories based on what each saw as the common themes underlying them. After sharing our rationales for why we each grouped items as we did, we agreed that they all fell into five categories: belief in nonscientific phenomena, positive attitude toward science and technology, belief in UFOs and aliens, ethical concerns about science and technology, and faith-based beliefs. The items associated with each of these initial categories are listed in Table 1.

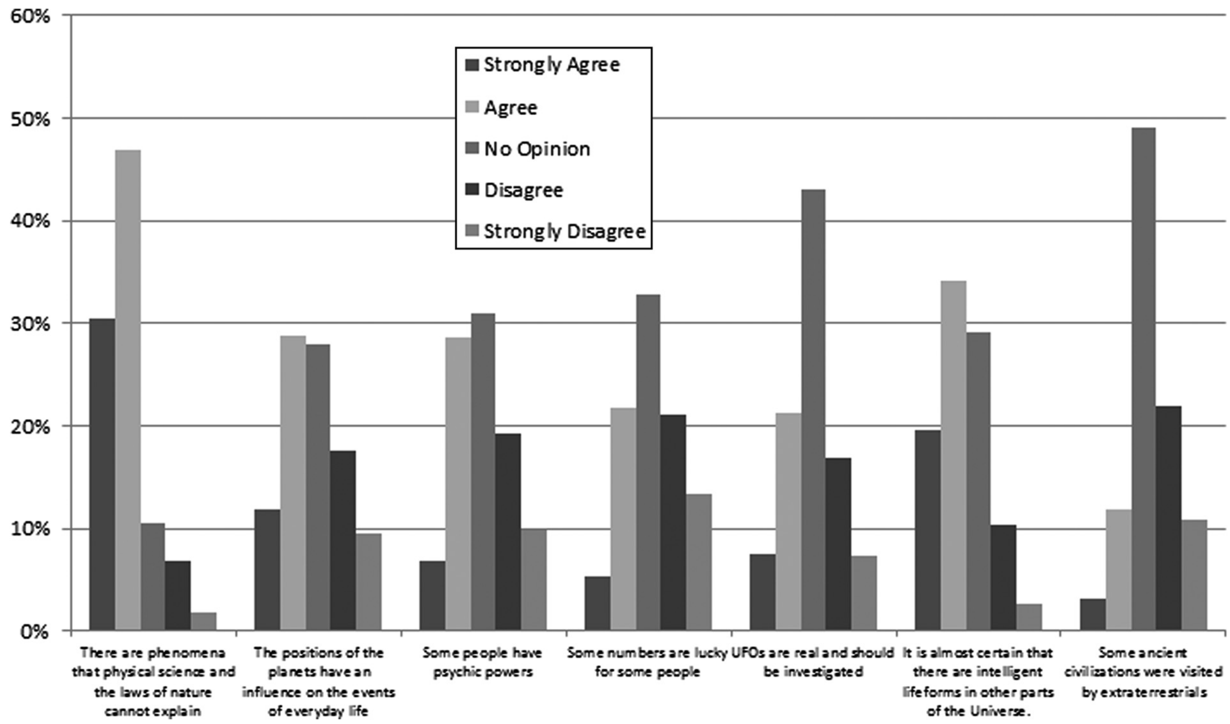

Figure 3. Distribution of student responses to pseudoscience and astrobiology related questions.

With this grouping as a prior expectation, we undertook an exploratory factor analysis on a random subsample of the data for all 24 items. This process helps empirically determine if the original 24 questions can be grouped together or reduced into categories because multiple items tap into similar student ideas. In this procedure, a grouped set of items that is found to strongly correlate with one another, but not with other items, is called a factor. From this initial exploratory factor analysis, we compared items that loaded onto factors to the original categories that we had derived and adjusted the categories accordingly, including dropping several items. We then used confirmatory factor analysis to test the new model and finalize the categories of responses. A forthcoming companion paper (Buxner, Impey, and Antonellis 2012) includes a full description of this analysis.

Table 2 shows the items that were retained for each of the factors, along with the original factor loading scores from the exploratory factor analysis. Based on these loadings and the model fit of the confirmatory factory analysis, only four of the original categories were retained: belief in life on other planets, faith-based belief, belief in

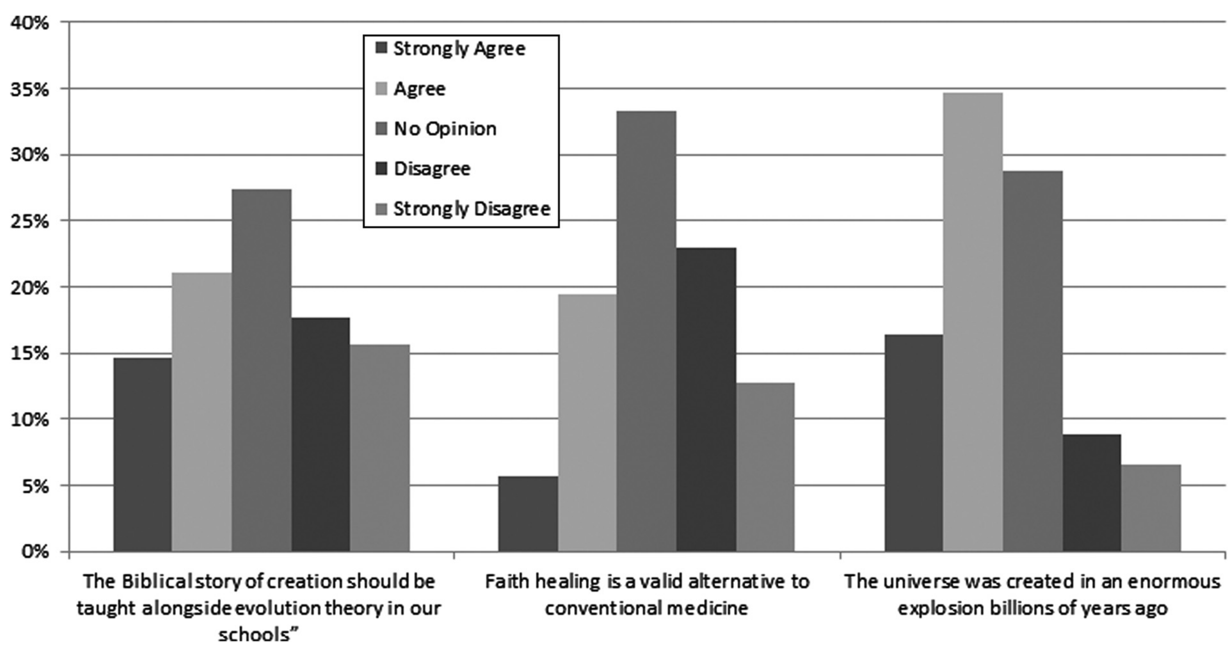

Figure 4. Distribution of student responses to faith-based questions

Table 1. Initial categories developed for Likert-scale attitude science and technology items

Category 1: Belief in unscientific phenomena
There are phenomena that physical science and the laws of nature cannot explain.
The positions of the planets have an influence on the events of everyday life.
Some people possess psychic powers.
Some numbers are especially lucky for some people.
Category 2: Belief in aliens/life elsewhere in the universe
UFOs are real and should be investigated.
It is almost certain that there are intelligent life forms in other parts of the Universe.
Some ancient civilizations were visited by extraterrestrials.
We should make a concerted effort to search for life on other planets.
Category 3: Faith-based beliefs
The Biblical story of creation should be taught alongside evolution theory in our schools.
The Universe was created in an enormous explosion billions of years ago. (reversed)
Faith healing is a valid alternative to conventional medicine.
Category 4: Factor: Positive attitude toward science and technology
Overall, the progress of science and technology has been beneficial to our civilization.
Nuclear power is an important energy source and its use should be expanded.
The government should strongly support the manned space program.
Genetic engineering is a good idea.
Pure science should be funded regardless of its lack of immediate benefit to society.
Science will come up with a way to dispose of toxic waste.
Computers will eventually be intelligent enough to think like humans. (reversed)
Technology has too much control over our lives. (reversed)
Category 5: Ethical concerns
There are some circumstances when medical science should not be used to prolong life.
Scientists should take responsibility for the bad effects of their theories and inventions.
We should devote more of our money and scientific resources to repair damage done to the environment.
We should exert more control over the nuclear weapons developed by scientists.
Scientists should be allowed to do research that causes pain to animals, if it helps solve human health problems. (reversed)

unscientific phenomena, and positive attitude towards science and technology. In confirmatory factor analysis, the quality of a model is assessed based on how well the model accounts for the observed relationships in the data set. In this type of comparison, there is no one single measure that indicates this relationship, but rather a set of fit indices that researchers use as a barometer of overall fit. The final fit of the model was acceptable for several indicators of fit. Values of fit for the model were: goodness-of-fit index (GFI) = 0.96, adjusted goodness-of-fit index (AFGI) = 0.92, comparative fit index (CFI) = 0.89, normed fit index (NFI) = 0.88, and root-mean-square residuals (RMSR) = 0.07. For the first four indices, values closer to 1.0 indicate better fit of the model to the data, with a general rule of thumb of 0.90 being an indicator of good fit. For the RMSR, smaller values are used of evidence of good fit. Responses to items within each factor are correlated, and this analysis is a quantitative way of seeing some of the contours of the “landscape” of student attitudes and beliefs. Additionally, binning these items into categories allows us to see how students’ beliefs are related to their science literacy scores.

One of the most striking results of the survey so far has been the fact that the science knowledge score and attitudes and beliefs varied so little with passage through an undergraduate degree or with the number of college science classes taken (in the aggregate, rather than for a particular cohort). This implies that the bulk of a young adult’s information and attitudes towards science is formed before they leave school. Similarly, and surprisingly, we find little correlation between science knowledge score and attitudes or beliefs. For example, students who thought that astrology is scientific did not score substantially lower on the science literacy questions than students who thought it is nonscientific (Sugarman *et al*. 2011).

To get the most leverage on this issue, we looked at the mean science knowledge score for students in the margins of the distributions for each of the four factors on the attitudes and beliefs part of the survey. Students

Table 2. Final factors and questions for Likert-scale attitude items

Factor: Belief in life on other planets	Factor loading from EFA analysis
UFOs are real and should be investigated.	0.76
It is almost certain that there are intelligent lifeforms in other parts of the Universe.	0.62
Some ancient civilizations were visited by extraterrestrials.	0.70
We should make a concerted effort to search for life on other planets.	0.46
Factor: Positive attitude toward science and technology	
The government should strongly support the manned space program.	0.42
Genetic engineering is a good idea.	0.41
Pure science should be funded regardless of its lack of immediate benefit to society.	0.40
Science will come up with a way to dispose of toxic waste.	0.44
Factor: Faith-based beliefs	
The Biblical story of creation should be taught alongside evolution theory in our schools.	0.54
The Universe was created in an enormous explosion billions of years ago. (reverse)	0.47
Factor: Belief in unscientific phenomena	
The positions of the planets have an influence on the events of everyday life.	0.50
Some people possess psychic powers.	0.37
Some numbers are especially lucky for some people.	0.55

with a mean factor score of 4 (agree) or higher were compared with students with a mean factor score of 2 (disagree) or lower. The results are given in Table 3. Differences between groups were tested using independent *t*-tests. Results with significance (or *p*) values below 0.05 indicate a statistically significant difference between groups. Statistically significant differences in science literacy scores were detected for students for both those with very high and very low mean scores for faith-based beliefs ($t\ (4823) = 17.0\ p < 0.001$), a mean difference of 1.1 questions, and those with very high and very low mean scores for unscientific beliefs ($t\ (3054) = 9.7$, $p < 0.001$), a mean difference of 0.8 questions. Only small differences were found for the other two factors. A multiple regression was used to investigate the relative contribution each variable had on students' science literacy score. Results with significance (or *p*) values below 0.05 indicate a statistically significant difference between groups. The r^2 value is a measure of effect size, which indicates the amount of variance in the outcome (students' science literacy scores) explained by the predictors (students' beliefs). A multiple regression revealed a small effect of students' beliefs on their overall science literacy score, with an overall explained variance of less than 4% ($F\ (4, 9852) = 97.1$, $p < 0.001$, $\mathrm{r}^2 = 0.038$).

5. DISCUSSION

NSF's Science and Engineering Indicators provide an important context for understanding the prevalence of nonscientific beliefs among members of the U.S. public. The section on belief in pseudoscience from the 2006 report (National Science Board 2006) leads with a very succinct statement about the issue: "Although science

Table 3. Average science literacy scores of students with average factor scores at or more extreme than "agree" or "disagree" for each category

Factor/category	**Agree ≥ 4 across factor mean (s.d.)**	**Disagree 2 ≤ across factor mean (s.d.)**
Belief in life on other planets	11.4 (2.2) n = 1785	11.2 (2.3) n = 816
Faith based beliefs	10.6 (2.3) n = 1592	11.7 (2.2) n = 3233
Positive attitudes towards science and technology	11.5 (2.3) n = 2576	11.0 (2.3) n = 113
Belief in unscientific phenomena	10.9 (2.3) n = 1457	11.7 (2.2) n = 1599

and technology are held in high esteem throughout the modern world, pseudoscience beliefs continue to thrive. Such beliefs coexist alongside society's professed respect for science and the scientific process." An analysis of 20 years of NSF data concluded that belief in astrology, lucky numbers, extrasensory perception, and UFOs as alien spacecraft were widespread (Losh *et al*. 2003). Roughly one in three American adults believes in telepathy, ghosts, and extrasensory perception, and roughly one in five believes in witches, astrology, clairvoyance, and communication with the dead. Three quarters hold at least one of these beliefs, and a third has four distinct pseudoscientific beliefs.

In discussions among scientists and educators, it is often assumed that pseudoscience belief stems from a lack of critical thinking skills and that pseudoscience belief is negatively correlated with science knowledge and an understanding of how science works. For the analysis described in this paper, those conjectures were hypotheses to be tested. In addition, we were interested in how pseudoscience beliefs change during progress through the undergraduate experience, and whether or not susceptibility to pseudoscience is related to religious belief.

Although we see small differences in the performance of students who held strong faith-based beliefs or strong beliefs in unscientific phenomena, these corresponded to about a one point difference, out of 15, in science literacy. This difference is less than the difference we see between science and education majors in the sample, which corresponds to an average of two points out of 15 on the science literacy scale. We also see relatively small reductions in pseudoscience belief over the course of an undergraduate career that includes at least three science courses. Confused signs of the nature of any relationship between formal education and pseudoscientific thinking have also been noted elsewhere (Goode 2002).

These generally null results present a challenge to educators. If nonscientific ways of thinking are widespread and resistant to standard modes of instruction, do educators need to be concerned and what do belief systems have to do with efforts to create a citizenry that is informed enough to vote on issues that involve science and technology? Some commentators have contended that pseudoscience and the paranormal are often skirted in the classroom, or treated as taboo subjects, meaning that nonscientific belief systems are not confronted (Martin 1994). Another point of view holds that pseudoscience beliefs cannot be addressed without classroom content that is relevant to societal issues (Hobson 2000, 2008). But psychologists Lindeman and Aarnio (2007) find support for a conceptual framework where a variety of superstitious, magical, and pseudoscientific beliefs accrue from the same kind of ontological confusion, and analytic thinking coexists with nonscientific forms of intuitive thinking. Moreover, research shows that people tend to motive their reasoning process based on prior beliefs and biases (Kunda 1990), and those with the strongest opinions on complex societal issues are highly selective in their consideration of relevant evidence (Lord, Ross, and Lepper 1979). Both of these effects mitigate against a completely rational world view. Religious beliefs exist in a distinct realm since they are based on faith. They may be similarly decoupled from aspects of worldview that are associated with evidence and causal connection, explaining the weak relationship seen here between religious belief and science knowledge. Improving science literacy will require a more nuanced approach that takes account of this psychological landscape. Since we also have found that science knowledge and attitudes are not substantially altered by the college experience, we have embarked on a separate study to understand where young adults get their information about science and technology.

Appendix A: Science Literacy Survey

- Are you male ____ or female ____?
- Are you a freshman ____, sophomore ____, junior ____, or senior ____?
- What is your major ________ and estimated GPA ?
- How many science courses have you taken at the U of A ____?
- What does it mean to study something scientifically? ____
  ____
- Would you say that astrology is very ____, sort of ____, or not at all scientific ____?
- The oxygen that we breathe comes from plants. True or False?
- Lasers work by focusing sound waves. True or False?
- Electrons are smaller than atoms. True or False?
- The universe began with a huge explosion. True or False?
- The continents on which we live have been moving apart for millions of years, and will continue to move in the future. True or False?
- Humans, as we know them today, evolved from earlier species of animals. True or False?
- The earliest humans lived at the same time as the dinosaurs. True or False?

- Which travels faster, light ____, or sound ____?
- Does the Earth go around the Sun ____, or does the Sun go around the Earth ____?
- Does the orbit in the previous question take one day ____, one month ____, or one year ____?
- What is DNA?____
  ____
- What is radiation? ____
  ____
- If the rate of inflation is falling, are prices decreasing ____, level ____, or increasing ____?
- Radioactive milk can be made safe by boiling it. True or False?
- Antibiotics kill viruses as well as bacteria. True or False?
- Is all radioactivity manmade ____, or does some occur naturally ____?
- A doctor tells a couple that they have a one in four chance of having a child with an inherited illness. Does this mean that,
  a. If they have only three children, none will have the illness. Yes or No?
  b. If their first child has the illness, the next three will not. Yes or No?
  c. Each of the couple's children will have the same risk of suffering the illness. Yes or No? ____
  d. If the first three children are healthy, the fourth will have the illness. Yes or No?
- Briefly, define computer software. ______________________________________
  ____
- Which is the largest contributor to heart disease: smoking ____, eating a lot of animal fat____, stress____, not getting enough exercise ____, or lack of vitamins ____?

	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Overall, the progress of science and technology has been beneficial to our civilization.	☐	☐	☐	☐	☐
The Biblical story of creation should be taught alongside evolution in our schools.	☐	☐	☐	☐	☐
There are phenomena that physical science and the laws of nature cannot explain.	☐	☐	☐	☐	☐
The positions of the planets have an influence on the events of everyday life.	☐	☐	☐	☐	☐
UFOs are real and should be investigated	☐	☐	☐	☐	☐
It is almost certain that there are intelligent lifeforms in other parts of the Universe.	☐	☐	☐	☐	☐
Some people possess psychic powers.	☐	☐	☐	☐	☐
Nuclear power is an important energy source and its use should be expanded.	☐	☐	☐	☐	☐
There are some circumstances when medical science should not be used to prolong life.	☐	☐	☐	☐	☐
The Universe was created in an enormous explosion billions of years ago.	☐	☐	☐	☐	☐
Some ancient civilizations were visited by extraterrestrials.	☐	☐	☐	☐	☐
Computers will eventually be intelligent enough to think like humans.	☐	☐	☐	☐	☐
Technology has too much control over our lives.	☐	☐	☐	☐	☐
Scientists should take responsibility for the bad effects of their theories and inventions.	☐	☐	☐	☐	☐
The government should strongly support the manned space program.	☐	☐	☐	☐	☐
Genetic engineering is a good idea.	☐	☐	☐	☐	☐
We should devote more of our money and scientific resources to repair damage done to the environment.	☐	☐	☐	☐	☐

Pure science should be funded regardless of its lack of immediate benefit to society.	☐	☐	☐	☐	☐
Science will come up with a way to dispose of toxic waste.	☐	☐	☐	☐	☐
We should exert more control over the nuclear weapons developed by scientists.	☐	☐	☐	☐	☐
Faith healing is a valid alternative to conventional medicine.	☐	☐	☐	☐	☐
We should make a concerted effort to search for life on other planets.	☐	☐	☐	☐	☐
Scientists should be allowed to do research that causes pain to animals if it helps solve human health problems.	☐	☐	☐	☐	☐
Some numbers are especially lucky for some people.	☐	☐	☐	☐	☐

References

Antonellis, J., Buxner, S., Impey, C., and Sugarman, H. 2012, "Surveying Science Literacy Among Undergraduates: Insights from Open-Ended Responses," *Journal of College Science Teaching*, 41, 82.

Bransford, J., Brown, A., and Cocking, R. 2000, *How People Learn: Brain, Mind, and Experience & School*, Washington, DC: National Academy Press.

Buxner, S., Antonellis, J., and Impey, C. D. 2010, "A Long-Term Study of Undergraduates' Science Literacy: Exploring Responses to Policy-Driven Survey Items," Paper presented at the Annual meeting of the National Association for Research in Science Teaching (Philadelphia, PA).

Buxner, S. R.,Impey, C. D., and Antonellis, J. 2012, "Analysis and findings of 22-years of science literacy and attitudes towards science and technology data," (unpublished).

College Board, 2012, http://www.collegeboard.org/.

Donovan, S., and Bransford, J. D. 2005, *How Students Learn: History, Mathematics, and Science in the Classroom*, Washington, DC: National Academies Press.

Ecklund, E. H., and Scheitle, C. P. 2007, "Religion among Academic Scientists: Distinctions, Disciplines, and Demographics," *Social Problems*, 54, 289.

Edwards vs. Aguilard 862, U.S. 578 (1987)

Fraknoi, A. 2002, "Enrollments in Astronomy 101 Courses," *Astronomy Education Review*, 1, 121.

Gauche, H. G. Jr. 2003, *Scientific Method in Practice*, Cambridge: Cambridge University Press.

Goode, E. 2002, "Education, Scientific Knowledge, and Belief in the Paranormal," *Skeptical Inquirer*, 26, 24.

Gould, S. J. 2002, *Rock of Ages: Science and Religion in the Fullness of Life*, New York: Ballantine Books.

Hafner, A. W. 1993, *Readers Guide to Alternative Health Methods*, Chicago: American Medical Association.

Hobson, A. 2008, "The Surprising Effectiveness of College Science Literacy Courses," *The Physics Teacher*, 46, 404.

Hobson, A. 2000, "Teaching Relevant Science for Scientific Literacy," *Journal of College Science Teaching*, 30, 238.

Impey, C. 2010, "Science Education in the Age of Science" in *Organizations, People and Strategies in Astronomy*, ed. A. Heck, New York: Springer Science, 70.

Impey, C. D., Buxner, S., Antonellis, J., Johnson, E., and King, C. 2011, "A Twenty Year Survey of Science Literacy Among College Undergraduates," *Journal of College Science Teaching*, 40, 70.

Kunda, Z. 1990, "The Case for Motivated Reasoning," *Psychological Bulletin*, 108(3), 480.

Lindeman, M., and Aarnio, L. 2007, "Superstitious, Magical, and Paranormal Beliefs: An Integrative Model," *Journal of Research in Personality*, 41, 731.

Lord, C. G., Ross, L., and Lepper, M. R. 1979, "Biased Assimilation and Attitude Polarization: The Effects of Prior Theories on Subsequently Considered Evidence," *Journal of Personality and Social Psychology*, 37(11), 2098.

Losh, S. C., Tavani, C. M., Njoroge, R., Wilke, R., and Macauley, M. 2003, "What Does Education Really Do," *Skeptical Inquirer*, 27, 30.

Martin, M. 1994, "Pseudoscience, the Paranormal, and Science Education," *Science and Education*, 3, 357.

National Science Board 1979, *Science and Engineering Indicators*, Washington, DC: National Science Board.

National Science Board 2006, *Science and Engineering Indicators*, Washington, DC: National Science Board.

National Science Board 2012, *Science and Engineering Indicators*, Washington, DC: National Science Board.

Pew Research Center for People and the Press 2009, "Public Praises Science; Scientists Fault Public, Media: Scientific Achievements Less Prominent Than a Decade Ago," Retrieved from http://people-press.org/report/528/.

Resnick, D. B. 2000, "A Pragmatic Approach to the Demarcation Problem," *Studies in History and Philosophy of Science Part A*, 31(2), 249.

Scheitle, C. P. 2011, "U.S. College Students' Perception of Science and Religion: Conflict, Collaboration, or Independence? A Research Note," *Journal for the Scientific Study of Religion*, 50(1), 175.

Shermer, M. 1997, *Why People Believe Weird Things*, New York: W. H. Freeman.

Sugarman, H., Impey, C., Buxner, S., and Antonellis, J. 2011, "Astrology Beliefs among Undergraduate Students," *Astronomy Education Review*, 10, 010101.

Thagard, P. R. 1978, "Why Astrology is a Pseudoscience," *Philosophy of Science Association, Volume 1*, edited by P. D. Asquith and I. Hacking, East Lansing, MI: Philosophy of Science Association.

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