Shaping Attitudes Toward Science in an Introductory Astronomy Course

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At many universities, astronomy is a popular way for non-sciences majors to fulfill a general education requirement. Because general education astronomy may be the only college-level science course taken by these students, it is the last chance to shape the science attitudes of these future journalists, teachers, politicians, and voters. Hobson recently reported on research indicating that general education requirements (often as little as a single class) are responsible for the higher measured level of science literacy in the United States as compared to Europe.

Science and society will benefit from these students gaining a deeper understanding of the process of science, rather than focusing exclusively on its results. Once outside the university, these students will find themselves in a society in which two-thirds of adults (and 38% of college graduates!) believe that humans were created “pretty much in their present form at one time within the last 10,000 years.” They should be equipped with the tools to refute or at least resist common anti-science attitudes such as “we can’t know what happened in the distant past because no one was there to observe it.” Astronomy, like evolutionary biology and geology, makes use of fossil evidence, so instructors have an opportunity to address this issue directly.

If shaping student attitudes is an important goal to us as instructors, then we should measure those attitudes before and after instruction, and consider the connection between attitude changes and classroom activities. I report here on pre- and post-instruction surveys of science attitudes in my general education astronomy course, and on classroom activities designed to influence those attitudes. The first step, well before instruction begins, is to design the attitude survey.

Measuring Attitudes

Those who teach introductory physics should be aware that several attitude-assessment instruments are readily available, including CLASS (Colorado Learning Attitudes about Science Survey), MPEX (Maryland Physics Expectations Survey), and VASS (Views About Science Survey). Each of these probes attitudes toward learning, especially problem solving, more heavily than attitudes toward science. VASS is somewhat stronger on the scientific process and the nature of scientific laws than the other two, and comes with a taxonomy that clearly lays out the motivation for each question. For example, in the epistemology section, the taxonomy states that “science is a coherent body of knowledge about patterns in physical realities (real systems or phenomena)—rather than a loose collection of particular empirical facts” and points to questions 5, 6, and 7 as specifically probing that issue. In a section labeled “Readiness to Learn,” the taxonomy states that “science is learnable by anyone willing to make the effort—not just by a few talented people” and points to question 29 as the relevant probe. Collectively, the statements in the VASS taxonomy provide an excellent summary of what is missing in the
general education astronomy course, so I wrote a set of questions specifically for my course. I started with general science attitudes such as those mentioned above in the discussion of VASS. For example, students are asked to rate the statement “Science is largely about memorizing facts” on a Likert scale (strongly disagree to strongly agree on a scale of 1-5 or (a)-(e) on a Scantron® form). I included several questions related to this attitude, because in a large lecture hall, in a nonmathematical course with no lab component (none of these parameters is under my control), it would be easy to miss the process of science and slip into merely describing the results. Another example, motivated in part by science coverage in the media that celebrates “discoveries” without considering the surrounding framework: “Scientists do experiments: (a) on what interests them the most; (e) on things that could verify or falsify theories.” This is a forced-choice type of question, in which students must choose between the two options on a five-letter scale, with (a) indicating complete agreement with the first option and (e) indicating complete agreement with the second option.

Because this is an astronomy course, I added items relating to reconstructing the past and our place in the universe, for example, “We can’t know what happened in the distant past because we don’t have any observations of that time.”

The list of 19 questions on science attitudes appears in Table I, along with the results; an electronic copy of the survey is available online. I gave the survey at the start of the first day of class and at the end of the final day. Surveys are more conveniently delivered online, but instructors should weigh this convenience against the likelihood of getting online responses from a biased sample of more conscientious students (or offer extra credit and issue several email reminders). Because there is a good deal of dropping and adding courses in the first two weeks of the term, I asked students to write their student identification numbers on the survey so that I could rigorously match pre- and post-instruction. I assured them that their attitudes would not be studied individually, but writing their ID may nevertheless have put them on better behavior compared to a completely anonymous survey.

Table I. Results of in-class survey on attitudes toward science.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Mean</th>
<th>Median</th>
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<tbody>
<tr>
<td>57%</td>
<td>4.44</td>
<td>4.76</td>
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<tr>
<td>52%</td>
<td>3.30</td>
<td>4.19</td>
</tr>
<tr>
<td>50%</td>
<td>4.14</td>
<td>4.57</td>
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<td>49%</td>
<td>3.47</td>
<td>4.22</td>
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<td>41%</td>
<td>4.24</td>
<td>4.56</td>
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<tr>
<td>39%</td>
<td>4.64</td>
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<tr>
<td>31%</td>
<td>3.56</td>
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<td>29%</td>
<td>2.87</td>
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<td>27%</td>
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<td>26%</td>
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<td>24%</td>
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<tr>
<td>21%</td>
<td>3.43</td>
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<tr>
<td>20%</td>
<td>4.06</td>
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<tr>
<td>14%</td>
<td>3.57</td>
<td>3.78</td>
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<tr>
<td>10%</td>
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<tr>
<td>9%</td>
<td>2.87</td>
<td>3.08</td>
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<td>0%</td>
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<td>3.68</td>
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<tr>
<td>-3%</td>
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</tr>
<tr>
<td>-9%</td>
<td>3.43</td>
<td>3.29</td>
</tr>
</tbody>
</table>

A bit of information is considered scientific when: (a) it is supported by evidence; (e) it is supported by eminent scientists.

Most of the atoms in your body were once inside a star.

If a scientist publishes an interesting new theory, other scientists usually: (a) compete to prove it wrong; (e) ignore it because it is not their theory.

We can’t know what happened in the distant past because we don’t have any observations of that time.

We live in a changing universe.

If a scientist publishes an interesting experimental result which is in error, the error is usually detected by: (a) no one; (e) other scientists attempting to reproduce the result.

We can’t know what happened in the distant past because we can’t do controlled experiments on it.

An experimental result: (a) should be trusted because it is scientific; (e) should be questioned as to how it fits in with other experimental results.

Science is largely about memorizing facts.

Scientists who created successful theories did it by: (a) having exceptional intelligence; (e) looking for patterns in data.

Science is largely about discovering patterns.

Anyone can understand the major themes of science if they try.

Astronomy is difficult because the physical laws that apply on Earth do not necessarily apply everywhere.

I want my tax money to help support science.

Science is fun.

Scientists do experiments: (a) on what interests them the most; (e) on things that could verify or falsify theories.
Shaping Attitudes

If writing the attitude survey helps clarify the goals, clear goals in turn guide the construction of classroom activities to further those goals. Activities and case studies are more likely to influence attitudes than simply lecturing about the nature of science, and making the nature of science a recurring theme is likely to have more impact than a single first-day activity. While I can’t prove a causal relationship between these activities and attitude changes, I offer a few examples that instructors may find useful.

The first week, I give the students “Ob-Scertainmenters®”—little black boxes whose internal structures they must deduce from the sound of a ball bearing rolling around inside. They work in groups of two to form hypotheses, then groups double up to compare hypotheses and conduct additional tests. At the end, when I am no doubt expected to reveal the correct answer, I tell them that nature never reveals the correct answer to scientists. All we can do is obtain more data and refine our hypotheses, so I ask the students to suggest additional methods of doing so. They offered many creative and enthusiastic responses to this open-ended question.

The energy source of the Sun and the age of the solar system make a nice case study. In the late 1800s fusion was not yet known, and the largest energy source astronomers knew of was the Kelvin-Helmholtz contraction, which could power the Sun for about 25 million years. Yet geologists were confident from the study of rocks that the Earth was on the order of 1 billion years old. What would you decide if this was all the information you had? Is the statement that “astronomers don’t know of an energy source that can power the Sun for 1 billion years” enough to discredit the geological evidence? On the other hand, should we just assume from the geological evidence that there must be a source of power orders of magnitude beyond what is currently known? This relates not only to the tentative nature of scientific conclusions, but also the interconnectedness of all branches of science, and the ability to recognize and mentally process the existence of large gaps in our knowledge. The fact that astronomers later radically changed their views of the Sun’s power source is an indication of science’s strength, not its inefficacy, a point that should serve students well when reading modern-day press releases that tend to overly empha-

size challenges to established scientific views.

Finding hands-on activities that work well in a large lecture hall can be a challenge. Particularly well-suited is a demonstration of why photons take on the order of a million years to travel from the core of the Sun to its surface. A balloon is placed in the center of the audience and students are first told to pass it forward; it quickly leaves the audience. The balloon is reset in the center and this time students are told to pass it in random directions. It takes much longer to reach the edge of the audience. (This is one of those rare activities where the larger the lecture hall, the better.) I use the activity not only to demonstrate the idea, but to let the students participate in making and testing models and lead them to understand that scientists do the same thing on a more mathematical level.

Another good case study is the Shapley-Curtis debate over the scale of the universe: Are the spiral nebulae small objects within our own galaxy, or are they large, distant “island universes” unto themselves? At the time of the formal debate in 1920, the evidence was conflicting, but—and this is key to the nature of science—when solid new evidence was presented, the debate was over. Furthermore, an important piece of data against the “island universe” interpretation was later shown to have been incorrectly measured. This provides an excellent opportunity to discuss how scientists reach conclusions. I poll the class after presenting the original evidence, then after retracting some of the evidence, etc. This illustrates the conditional nature of scientific conclusions.

Results

Post-instruction, I first matched the pre- and post-tests to yield a set of $n = 63$ students who had taken both. Next, I inverted the scores on questions for which the “correct” attitude was 1 or (a), rather than 5 or (e), so that a higher number is always considered better. In measuring the learning of content, it is standard to define the gain as post-test score minus pre-test score, and normalized gain as (post-test – pre-test)/(maximum − pre-test), in other words, how much the students learned as a fraction of what they didn’t already know. I adopt these definitions here, with the caveat that this survey deals with attitude changes, which is not the same as learning content. For example, expert attitudes will not always be 5.0
because of some difficult forced choices, and should be
determined by giving the same survey to professional
scientists. This is a clear advantage of using an existing
instrument such as VASS, which has been extensively
field-tested in different populations, if it is appropri-
tate to the course. However, the lack of an appropriate
field-tested survey should not prevent instructors who
care about attitudes from trying to measure them. The
results cannot be interpreted as rigorously, but the pro-
cess can lead to better teaching and learning. I list the
results in Table I in descending order of normalized
gain, expressed here as a percentage, in a recent term.
In parentheses, I list the pre- and post-instruction av-
average attitude.

The typical per-question statistical uncertainty in
gain (post-test – pre-test) is 0.12 points. Thus, the
two declines are not statistically significant. Several
attitudes improved by many times the statistical uncer-
tainty, with a normalized gain of ~50%, comparable
to the typical normalized gain for subject matter in
effective courses.

Many other attitudes individually showed a gain of only a few times the statistical un-
certainty, but collectively they represent a significant
shift.

Summary and Conclusions

It is possible to influence student attitudes for the
better. Several previous studies have shown that at-
titudes tend to decline or remain unchanged after
introductory physics and astronomy courses, with
just a few small-scale counterexamples. However,
these studies have focused more on attitudes toward
learning. Attitudes toward science may be less deeply
ingrained.

The results here are promising, but with no control
group the efficacy of the instructional approach can-
not be rigorously established. In retrospect, the process
of preparing the attitude survey was key to the entire
venture, as it forced me to reflect on and organize my
objectives with respect to student attitudes. I encour-
age other instructors to engage in this process and see
where it leads.

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statement as “definitely true” or “probably true” in
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http://www.usatoday.com/news/politics/2007-06-07-
evolution-poll-results_N.htm?csp=34. Polls do not ask
specifically about the age of the Earth, but one can take
this as a rough indicator of public attitudes. The 38%
figure for college graduates comes from a meta-analysis
of several Gallup polls with slightly varying wording:
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df

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