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To Hear Ourselves as Others Hear Us

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Abstract

The American Astronomical Society has recently developed an ambitious set of goals for introductory astronomy courses. How well does an introductory astronomy course based firmly on these goals actually do? In this article, an education student enrolled in such a class and the professor who taught it present an unvarnished analysis of one course designed to meet precisely these goals. How do the students judge the goals? Can a one-semester course actually meet these goals realistically? In addition to examining these questions, we include data on student course evaluations and student performance as measured by the Astronomy Diagnostic Test.

1. GENESIS OF THIS PAPER

As each semester begins, professors enter their classrooms with goals in mind for their courses. How well do we meet those goals? Are we moderately successful, or do we fall woefully short? There is an instructive *Far Side* cartoon (which unfortunately we were not given permission to reproduce here) with two panels. The upper panel shows a man issuing firm, clear instructions to his dog, Ginger. The lower panel shows what the dog hears: "Blah, blah, Ginger, blah, blah..." Can we be sure that we are not replicating that hapless man’s experience? Typical course evaluations tell us less about our success in meeting goals than about how students liked our course. Tests, including the Astronomy Diagnostic Test (see Zeilik 2002; Hufnagel 2002; Deming 2002), can measure student mastery of some material in "Astro 101," but we often have goals that extend beyond the knowledge of astronomy. Here, we explore a different way of assessing how others hear us in the classroom.

The professor in Haverford College's introductory astronomy course, Bruce Partridge (second author of this article), learned early on this past fall semester that an enrolled student, Nathaniel Lippert (first author), had a deep interest in pedagogy and a background in educational psychology. The two of us agreed that an unvarnished critique of the course made by the student after completing the course would provide a useful gauge of how well the course had met its goals (see Tobias 1990). Moreover, because the goals adopted for this course were exactly those advocated for Astro 101 in national meetings of astronomy department leaders and educators (Partridge & Greenstein 2003), we believe that the student's reaction will be of interest to the wider astronomical community. This article lists the goals, assesses student interest in each of them, provides a student evaluation of the success in meeting the goals, and finally presents an analysis by the student of the goals and the course structure. The article is offered as an opportunity for professors to "hear ourselves as others hear us." Although both professor and student read and approved all sections, those marked (BP) were written primarily by the professor, and those marked (NL) primarily by the student. No attempt was made to mute or modify the student's opinions; instead, the professor was asked to write a brief coda (section 7).

2. THE PROFESSOR'S GOALS FOR ASTRO 101 (BP)

2.1 The Nature of Haverford's "Astro 101"

Astronomy 101 is taught at Haverford College as a one-semester survey specifically intended for non–science majors. It has been taught by BP for more than 30 years with little structural change, save updating of course content. The course description (from the *Haverford College Catalog*) is:

> *Astro 101*: **Astronomical Ideas**
> Fundamental concepts and observations of modern astronomy, such as the motions and surface properties of the planets, the birth and death of stars, and the properties and evolution of the Universe. Not intended for students majoring in the physical sciences.

(The full syllabus is at http://www.haverford.edu/physics- astro/course_materials/astr101a/astr101a.html.) As the course description indicates, course content is clustered around several major astronomical ideas, starting with a historical focus on how we came to understand the large-scale properties of the Solar System, and ending with cosmology. The material on stars is consciously abbreviated and focuses mainly on stellar evolution.

Like most science courses at Haverford, the course is taught in three weekly lecture sessions. Over the past six years, BP has consciously introduced in-class exercises modeled on the techniques developed by Mazur (1997). Starting some 15 years ago, BP added weekly small class sections of approximately 15 students each. These small group meetings led by the course instructor allow time either to conduct or set up laboratory exercises, discuss astronomical topics of social significance, such as uncertainty in science or NASA's newest programs, and answer student questions about homework and/or tests (and coincidentally, to work on math skills).

A graded semester-long exercise asked students to make weekly records of the time and position of sunset, and brief sketches of the phase of the Moon every clear night. From these observations, the students were asked to estimate the lunar synodic period, then to project forward to find the phase of the Moon and the time and position of sunset on their graduation day. Because of the weight placed on this observing exercise, relatively little class time was spent on the detailed exploration of the daily and yearly motions of the Sun and Moon (see section 4.2).

2.2 Overt Introduction of Goals for Astro 101

In the spring and summer of 2001, the American Astronomical Society sponsored a pair of national meetings on the goals of courses like Astronomy 101 (see Partridge & Greenstein 2003). The 13 goals are listed in abbreviated form in Table 1 (see http://www.haverford.edu/physics-astro/course_materials/astr101a/astr101a.html for the detailed list of goals and arguments for them). In the fall of 2003, BP decided to adopt these 13 goals in their entirety and without change for Haverford's Astronomy 101 course. Early in the course, the students were informed of these goals, and an abbreviated copy of the AAS-sponsored report was distributed to them. The format and approach of the course were adjusted slightly to bring them into better agreement with the goals. The course content, however, was not substantially altered. Thus, the course description remained the same, and the course continued to focus on the same set of overarching astronomical ideas.

Table 1. Goals adopted by AAS-sponsored national workshops and adopted verbatim for Haverford's Astro 101.

Goal		**Brief "Tag"**
1	A cosmic perspective--a broad understanding of the nature, scope, and evolution of the Universe, and where the Earth and Solar System fit in.	Cosmic perspective
2.	An understanding of a limited number of crucial astronomical quantities, together with some knowledge of appropriate physical laws.	Crucial quantities and laws
3.	The notion that physical laws and processes are universal.	Universality of laws
4.	The notion that the world is knowable, and that we are coming to know it through observations, experiments, and theory (the nature of progress in science).	Progress in science
5.	Exposure to the types, roles, and degrees of uncertainty in science.	Uncertainty in science
6.	An understanding of the evolution of physical systems.	Evolution
7.	Some knowledge of related subjects (e.g., gravity and spectra from physics) and a set of useful "tools" from related subjects such as mathematics.	Related subjects
8.	An acquaintance with the history of astronomy and the evolution of scientific ideas (science as a cultural process).	History of astronomy

9.	Familiarity with the night sky and how its appearance changes with time and position on Earth.	Night sky
10	Student exposure to the excitement of actually doing science, and to the evolution of scientific ideas.	*Doing* science
11.	An introduction to progress in science for students: training in the role of observations; analyzing evidence; critical thinking, including appropriate skepticism; and testing hypotheses.	Critical thinking, etc.
12.	Training for students in quantitative reasoning; in the role of uncertainty in science; and in how to make spatial/geometrical models.	Quantitative reasoning and modeling
13.	Increased student confidence in their critical faculties; increased student interest in science and inspiration from science; enhanced ability and interest in following scientific arguments in the media.	Student confidence

3. STUDENT GOALS FOR THE COURSE (NL)

3.1 Student Evaluation of the Professor's Goals

The 38 students in the course were given an evaluation at the end of the semester. This evaluation listed each of the previously introduced course goals and asked students to rate both their interest in each goal and the professor's effectiveness in meeting each goal. These questions used a Likert-type scale ranging from 1 to 5, with 1 being *not important or effective* and 5 being *very important or effective*. The wording of the questionnaire is provided in the Appendix.

Students rated their interest in the goals slightly above the midpoint, with average importance of 3.3. As shown in Table 2, students ascribed the lowest importance to goals 6, 7, and 12, which centered on physics and quantitative reasoning. They found goals 1, 9, and 13 to be the most important; these goals focused on gaining a broad understanding of astronomy and building a positive self-image as natural scientists. Student interest in course content, demonstrated in such evaluations, has been shown to influence the quality of students' attention, the ability of students to set independent learning goals, and student performance on traditional assessment models (see Renninger, Sansone, & Smith 2002). Thus, student interest is important because it may directly correlate with student self-concept and performance.

Table 2. Ranking of Goals

Goal	Brief "Tag"	Students' Ranking of Their Interests	Students' Ranking of Astro 101's Success in Meeting Goals
1	Cosmic perspective	4.3	4.3
13	Student confidence	4.3	3.6
9	Night sky	4.1	3.4
10	*Doing* science	3.5	3.5
4	Progress in science	3.4	4.1
8	History of astronomy	3.3	4.0
11	Critical thinking, etc.	3.1	3.6
3	Universality of laws	3.0	4.3
5	Uncertainty in science	2.9	3.5
2	Crucial quantities and laws	2.8	4.2
6	Evolution	2.7	3.8
12	Quantitative reasoning and modeling	2.7	3.2
7	Related subjects	2.6	3.7
The standard deviations of these means ranged from 0.15 to 0.2.			

With these survey responses, students showed that they were much more interested in gaining a sense of what astronomy is, and of how it involves and informs their lives, than they were in specific laws and quantities. These student responses concur with the AAS's skills, values, and attitudes goals and their encouragement to professors to integrate these goals into course content. In practical terms for the professor, trying to meet such goals means "coming up for air" more often when the course gets into specific technical content. It involves being direct in the way that professors "narrate" specific topics by providing contexts in which the concepts are easily understood by the students (e.g., connecting them to students' lives; see Tobias 1990). Professors should also heed student goals when constructing tests. While traditional methods of assessment center on an objective body of knowledge, tests that connect course content to student interests may help students internalize course content better (Tobias 1990).

The AAS-sponsored meetings on Astro 101 endorsed tests that speak to student interests. It was concluded that any effective assessment should be consistent with the themes and methods of the course. For example, if a teacher structures the class around research experiments in which students themselves make the observations, students may respond better to action-oriented questions about their data as compared with essay questions about cosmology or other abstract ideas (Partridge & Greenstein 2003).

3.2 NL's Comments on Student Goals

If professors adopt the AAS goals, they should keep in mind that student conceptualizations of the goals will inevitably be different from their own. This becomes an issue of communication and "translation." For example, in goal 6 (evolution of physical systems), students may think it sufficient to recognize that physical systems evolve, while professors deem it necessary to understand *how* individual systems evolve and *why* different systems evolve differently. Perhaps more important are difficulties in translating the goals that deal directly with student values and attitudes. In goal 13 (student confidence), a professor may underestimate the amount of confidence that non–science majors need to gain a positive self-image as natural scientists. In this case, even if a professor notes an increase in student confidence, students may have hoped for (and needed) a greater change. These issues of translation should encourage professors to validate multiple meanings of course goals and to discuss their progression over the course of the semester.

Just as students build their own conceptions of the goals presented to them, they also establish their own goals for the course. Professors surely hope for classes full of motivated students who are eager to cover each topic, but student goals may be as basic as fulfilling a natural science credit, earning an acceptable grade, or gaining an overview of astronomy. Until students have a more complete knowledge of the subject, their interest in the material will likely be very different from that of their professors. To close this gap in interest between professor and students and to foster an individual interest in each student that inspires increasing curiosity about the subject, professors need a combination of "modeling, opportunities to apprentice, and interaction with others and text" (Renninger 2000). Because individual interest is driven by both background knowledge and values, professors should strive to impact both of these, first by giving students enough knowledge to pique their curiosity, and second by supporting students' self-concepts and working to counteract the stereotype that science is "not for everyone" (see Schiefele et al. 1983; Renninger 2000). Although it may seem an arduous task for a professor to ensure that students are learning enough to be curious and also "to feel okay" about astronomy, the payoff of increased individual interest in students may be outstanding.

One way to find out about independent student goals is to ask the students directly. In the first week of the course, professors could have students write down and submit their own goals for the course. The students could then evaluate *their* own goals at the end of the course, along with those suggested by the professor. This is one way to encourage the idea that it is the students themselves who own and shape their learning, not just their professors (see Blumenfeld et al. 1991; Adams & Slater 1998).

3.3 NL's Comments on AAS's Goals

The goals outlined at the two AAS workshops should be commended for their focus on creating scientific thinkers rather than simply consumers of information. The goals are intended to help students gain a broad perspective on what it means to study astronomy, and to provide students with a reference point to return to when the focus of the class becomes more specific. Although all goals are groundbreaking in their focus on student learning rather than facts and figures, the skills, values, and attitudes goals have added importance for two reasons. First, these goals align best with the students' perceived and indicated goals, and thus are links between students and professors. Second, as stated in the AAS report, Astro 101 has the "potential to serve as an ideal way of introducing students to science in general and to the scientific method" because of its popular appeal and the sheer number of students who take the course each year (more than 250,000 in the United States and Canada). This gives vitality to those goals that address student attitudes toward the natural sciences. The goal of Astro 101 at many schools is not to recruit majors--as there are often more advanced introductory courses for students pursuing a science major--but to build a stronger affinity toward the natural sciences within the general population.

Goal 10 (*doing* science), goal 11 (critical thinking, etc.), and goal 13 (student confidence) warrant individual attention for their crucial roles in an introductory course such as Haverford's Astro 101. Goal 10 (*doing* science) is fundamental to the success of Astro 101 because of its inherent value and because it is a means of attaining other goals when put into practice. Having students actually *do* science is inherently valuable because it promotes the idea that scientific thinking is not limited to a select few "geniuses," but is a tool that all people can use in their lives. Furthermore, the merits of project-based learning are widely understood by experts in pedagogy. As Phyllis Blumenfeld and her colleagues (1991) put it, "it is through this process of generation that students construct their knowledge--the doing and the learning are inextricable."

Having students *do* science is also very important because it is an avenue toward attaining goal 11 (critical thinking, etc.) and goal 13 (student confidence). When students facilitate their own experiments and analyze their own hypotheses, they are *forced* to think critically, not just asked to do so. Similarly, having students *do* science by conducting and analyzing their own experiments can build student confidence by directly challenging notions that students are not capable of such scientific endeavors.

Although the value of critical thinking is quite apparent as a life skill, educational researchers underscore the importance of "thinking about your own thinking" (see Schoenfeld 1987). Alan Schoenfeld suggests that metacognition, a specific type of critical thinking, is a key element in improving students' memory, study skills, problem-solving skills, and self-management skills. The fundamental importance of these life skills encourages teachers to facilitate the growth of students' metacognitive abilities. As a teacher, Schoenfeld does this in part by asking students questions while they work on astronomy problems: What exactly are you doing? Why are you doing it? How does this help you? Professors may also model this self-reflective behavior when solving problems in lecture.

Finally, when exploring a new field of study (astronomy in this case), students need to have positive feelings about the subject matter with which they work, and a sense that they can be successful (see Renninger, Sansone, & Smith 2002). Students' sense of their own possibilities as learners enables them to dictate their own learning by asking curiosity questions that push their own boundaries. This lessens the need for professors to spoon-feed information to students (Renninger 2000).

4. HOW WELL WERE THESE GOALS MET? (NL)

4.1 Student Evaluations

Student ratings of the professor’s effectiveness are displayed in the right column of Table 2. In general, students rated the professor’s effectiveness in meeting the goals higher than their own interest in the goals. This is a positive indicator that the course was effective in teaching to the student interest level, regardless of whether student interest was high or low for a given subject (most were relatively high). Although student interest in a goal and a professor’s effectiveness in meeting that goal are slightly different measures, to make a useful comparison of the two, we assume that when students claim that the professor successfully met a goal, this professor also successfully met student interest in that goal. Such a comparison may be important in developing future curricula because it provides a chance for professors to see which goals they need to spend more time on, and which goals may be less important.

Students rated the professor’s effectiveness lower than or equal to their interest level on four goals. Students rated the professor’s effectiveness in reaching goal 1 (cosmic perspective) and goal 10 (*doing* science) to exactly match their level of interest, while they rated the professor’s effectiveness for goal 9 (night sky) and goal 13 (student confidence) 7/10 of a point below their interest level. The professor should give the most attention to these goals when planning his next offering of the class. Again, the guiding principle for this practice of self-evaluation is to be most effective in those areas about which students are eager to learn.

4.2 Implications of Student Ratings for Individual Goals

The importance of meeting goal 9 (night sky) is a point of contention for many astronomers, depending on their personal philosophy and methodology. For students, actually seeing astronomy from the Earth’s perspective might be a concrete way of *doing* astronomy, and they may have more interest in it than the professor does. In this situation, where professor and student interests may not directly align, professors would ideally adjust their curricula slightly to meet student interest. Professors cannot be expected to completely alter their plans for the semester, but for a successful classroom experience in which students are given agency in shaping the course, professors need to continually gauge student interest and factor that into their pedagogy.

What is more important in the case of Haverford’s Astro 101 is that students’ interest in goal 13 (student confidence) was not sufficiently met. As stated earlier, students’ confidence in their own ability to do scientific work and to be scientific thinkers is a determinant in their motivation. Furthermore, because the vast majority of students in Astro 101 will not take any other courses in astronomy (and many will not take any other courses in the natural sciences), this one-time shot at fostering a general respect for and interest in the natural sciences relies largely on the success in meeting this particular goal. The low student rating can therefore be seen as a major weak point in the class. Unfortunately, adjusting to meet skills, values, and attitudes goals is not as simple as adjusting to meet content goals. A professor may need to consider revising the structure, tone, and content of the course if he or she is interested in cultivating student confidence (see section 6 for specific suggestions). However difficult this may be, it is worth the effort of Astro 101 professors to have interested, inspired, and motivated students.

Haverford’s Astro 101 matched student expectations exactly for goal 1 (cosmic perspective) and goal 10 (*doing* science). These goals should also be considered because they are arguably more important than some of the content goals in the way that they transform students into scientists. The merits of meeting goal 10 have been discussed in section 3, but goal 1 is also significant because a "cosmic perspective" is fundamental to understanding the more complex concepts of astronomy. Goal 1 should also be given priority because it was rated highest in student interest, tied with goal 13 (student confidence). Student ratings of goals at the outset of class will only be effective if the professor adjusts his or her pedagogy to fit those ratings.

A final set of goals (specifically, goals 2, 3, 6, and 7) offers a complication for the interest-effectiveness comparison. For these, students rated far above their own interest level the professor's effectiveness in meeting goals. On the surface, this may seem to be a positive indicator for the professor, but one may also question why student interest in these goals didn't increase with the professor's effectiveness in meeting them. Recall that these ratings were done at the end of the semester, so why didn't students see the importance of the goals that the professor successfully met? This may be an open question, but these results suggest that professors should work not only to achieve the AAS goals but also to help students understand *why* they are important, and eventually to "own" them as vital aspects of the course.

5. WHAT WE LEARN FROM THE ASTRONOMY DIAGNOSTIC TEST (BP)

NL's material above allows us to examine student attitudes and expectations. But what about student *performance*? One means to assess that is to use a standard survey, particularly the Astronomy Diagnostic Test (http://solar.physics.montana.edu/aae/adt/). Because we are specifically interested in the connection between student performance and the goals adopted for the course, we begin by noting that the ADT focuses primarily on a restricted number of goals, with goals 1, 2, 7, 9, and 12 all heavily emphasized.

5.1 The ADT in Haverford's "Astro 101"

The ADT was given as a pretest at the end of the first week of a 14-week semester. That was necessary because some of the material tested by the ADT was covered in lecture at the very end of the first week of the course, and BP wanted to reach a truly "naïve" group with the pretest. The consequence of giving the test early was that some of the students who eventually took the course were not able to take the pretest, and some students who took the pretest dropped out of the course after the first week. The posttest was administered just after the next-to-last lecture in the course, after all material of relevance to the ADT had been covered.

5.2 Results and Analysis

On average, after one semester in this class, Haverford students (N = 29 responding) improved their performance on the ADT by 5 points on the 21-point test, a 53% improvement over the average pretest score. These figures compare well with results for a much larger sample found by Deming (2002) or tabulated on the ADT Web page (see http://solar.physics.montana.edu/aae/adt). Deming reports an average improvement of 3.1 points for 3,900 students surveyed, an average percentage increase of 46%. A 5-point improvement (formally, 5.0 ± 0.5) is also statistically higher than the average improvement of 3.7 ± 0.4 points found by BP in previous versions of Astro 101. The pretest scores of Haverford students, on the other hand, have varied imperceptibly from year to year. The pretest scores of women in this (small) class averaged to 9.3, versus 9.7 for the men. Using Student's t test, we find that this difference is significant at the 80%-90% level. The improvements in ADT scores, again for this small group, were 4.9 and 5.9, respectively (see Note 1). Although both men and women improved their scores by more than the average for Deming's large sample, the discrepancy between male and female improvement is bigger than found for a much larger sample by Deming (2002); she finds a discrepancy of 0.3, versus 1.0 in Haverford's class. This gender difference in improvement was highly significant (< 99%, again using Student's *t* test), even given the small samples involved.

Because the enrollment in Haverford's Astro 101 is not large, we do not have a large statistical sample. We do, however, have the advantage that Haverford students are a trusting lot. Many were willing to use their names on both the pretest and posttest, having been assured that neither test would count in any way toward their class grade. Thus, we were able to plot individual and aggregate changes in performance. We can also correlate both pretest performance and improvement on the ADT with course grade--at least for the 60% of the students who took both tests and attached their names to both. We present some of the results in graphical form, in part to provide a profile of this group of students.

First, there is no correlation between a student's improvement on the ADT and his or her pretest score. The correlation between improvement and final grade in the course is also weak but positive, as shown by the R^2 factor of 0.228. In Figure 1, we show the rather similar plot of posttest performance versus student grade for the 23 students who used their actual names on the pretest and posttest. Again, we see a similar weak correlation. Given the small number of students and weak correlation, we did not pursue more elaborate statistical tests.

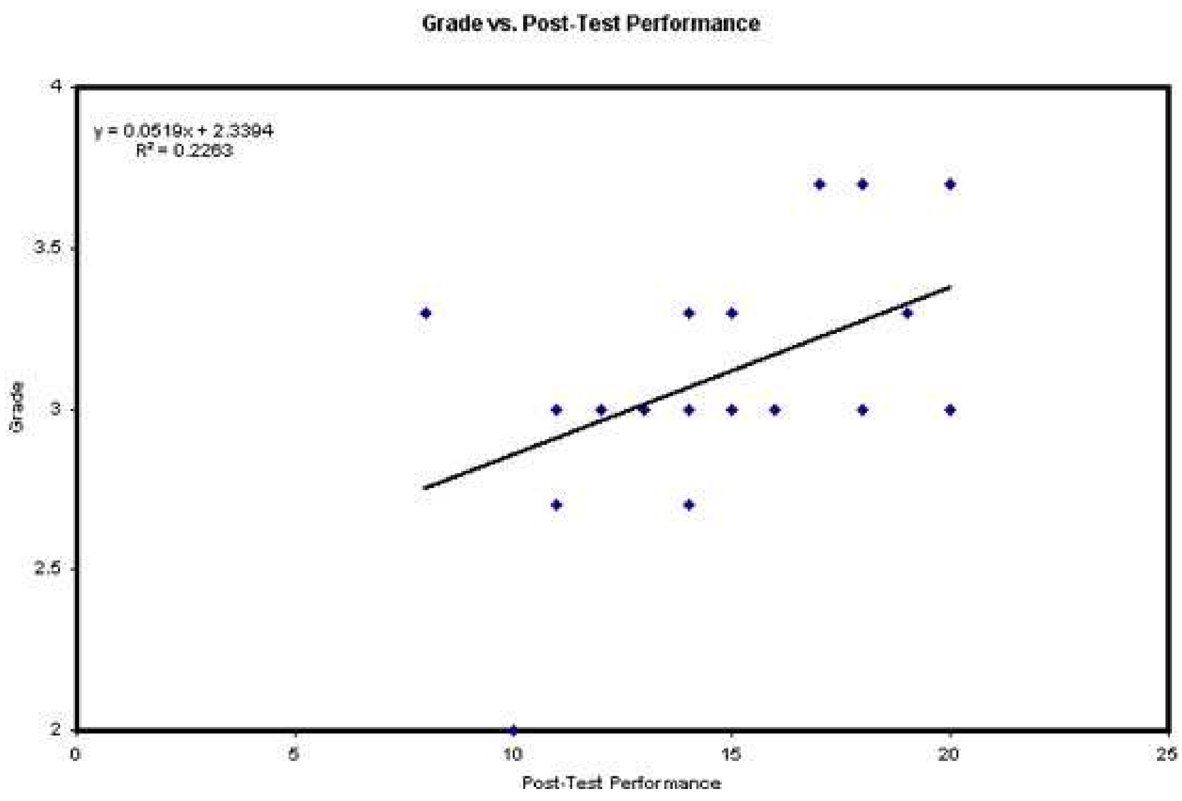

Figure 1. For the 23 students who supplied their names, we plotted student grades in Haverford's Astro 101 (on a 4.0 scale, with 4.0 = A) vs. posttest performance on the ADT (a 21-point test).

The ADT also asks for the students' own judgments on how confident they were in their answers. In aggregate, the level of confidence (as measured by a 5-point Likert scale) went up, suggesting that goal 13 (student confidence) on the AAS list was partially met. We found it interesting to correlate increase in confidence level with improvement in performance on the ADT; Figure 2 shows essentially no correlation. In these responses, there was a small difference between the self-assessed level of confidence of male students (N = 12) and that of female students (N = 11). We quantify this by assigning a value of 1 to a student response, *Not at all confident*, to the ADT question, "In general, how confident are you that your answers to this survey are correct?"; assigning a value of 2 to *Not very confident*, and so on. Over several years, women students in Astro 101 have rated their confidence at 2.2 - 2.5 on this scale, and men generally at 2.7. These pretest values match very well those for the much larger sample compiled by Deming (2002). The change in confidence, however, was slightly higher for the women (1.4) in the class as compared with the men (1.3). Women ended the class at 3.8 on this scale, and men at 4.0 (*Confident*); both figures are significantly above the results tabulated by Deming (2002).

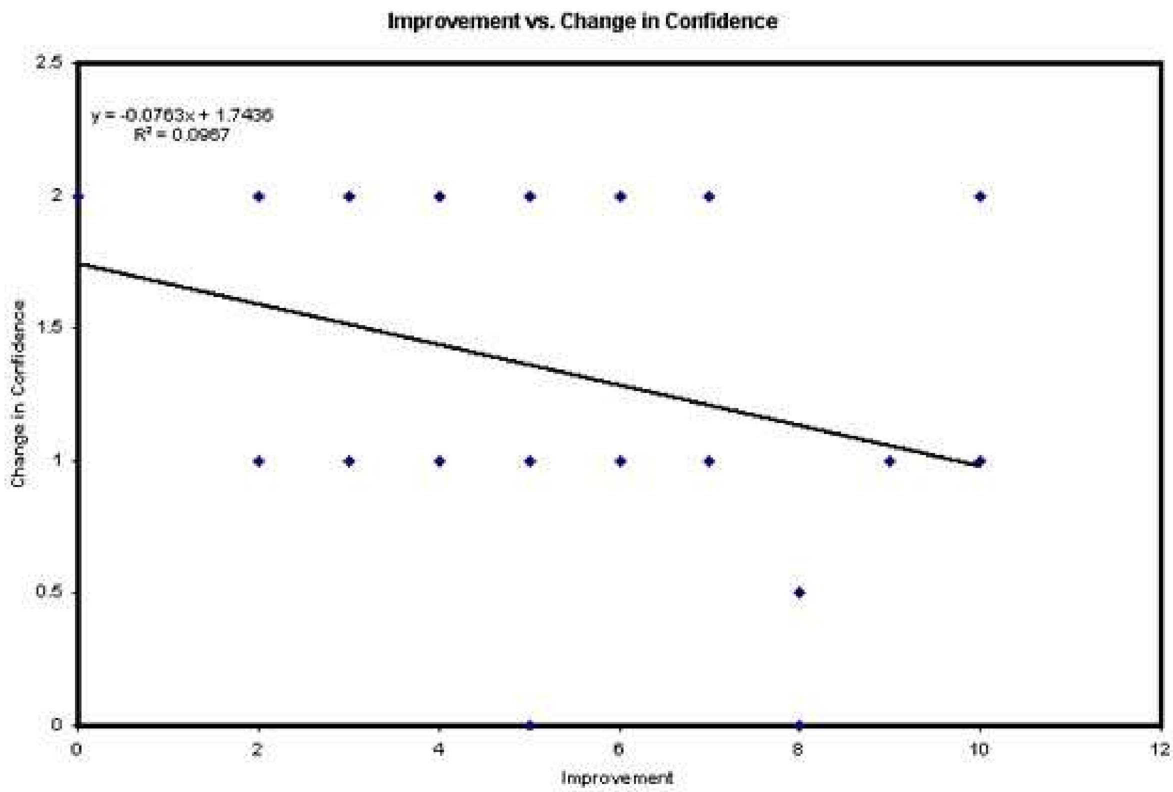

Figure 2. Change in student self-assessment of confidence on the ADT (on a 5-point scale, 5 = *very confident*) versus improvement in ADT score (a 21-point test).

5.3 A Few Specific Issues

Several patterns in student responses to the ADT caught BP's eye. First, the ADT asks about the speed of radio waves compared with light waves. In the pretest, 93% of the students got this question wrong. Very upsetting to a radio astronomer! So BP was very careful to specifically state in at least two lectures that *all* electromagnetic radiation, including radio waves and X-rays, travels at the same speed. On the other hand, this material was not mulled over much by the students, was not discussed in the small class sections, and did not appear on any of the homework or tests. Perhaps as a consequence, posttest performance showed only modest improvement by the students on this question: 76% of the students still got it wrong (in one case, it was the *only* question the student got wrong!). There is a take-home lesson here: Simply *telling* students that the speed of electromagnetic radiation is independent of its frequency isn't good enough. We suspect that the independence of c is embedded in virtually all of the students' notes, but apparently not in their minds. Their preconceptions prevailed.

Now let us look at the set of questions that involved the phase of the Moon (numbers 18 and 19 in the ADT). In the pretest, 40% of the student answers were wrong. During the course, however, students were charged to do their own observations, keep notes on them, and think through the consequences of the various patterns they observed. In the posttest, only 12% of the responses to these two questions were wrong. These more positive results--albeit with a small sample of students--back up the assertions made by NL in section 3.3.

6. NL's ANALYSIS OF THE COURSE

6.1 Did the Course Work Overall?

The *Far Side* cartoon described in section 1 serves as a good metaphor for many classrooms in which the professor thinks that he or she is communicating clearly, and the students have simply given up trying to understand. This is a concern for all professors of introductory astronomy, and a thorough analysis of Haverford's course as a case study can provide insight into how one can avoid this situation. The value of the following recommendations lies in the fact that only minor changes are necessary to make courses like Haverford's very effective in focusing on student needs, and that these changes may be universalized as supplements to other introductory astronomy classrooms.

First, the small class sections, all led by the professor, are fundamental in personally involving students in the course, and hence in reaching some of the key AAS goals. Although it is easy to sit through a lecture without absorbing much material, it is much more difficult to sleep through a class with only 15 students, especially if the activities are engaging and interactive (see remarks on strategies later in this section). For large lecture classes of 100 or more students, incorporating these small class sections will obviously require many more human resources. However, the value of these sections cannot be overestimated because they provide students with an opportunity to discuss the issues involved in the course, ask questions, and become "owners" of astronomy.

A second aspect of the course that can encourage the idea of "ownership" is the lab portion. As stated earlier, students in Haverford's course were asked to observe the Moon phase daily, and the sunset or sunrise weekly, in order to make predictions about the seasonal motion of the Sun and the phase of the Moon. These exercises emphasized that students were to "do" astronomy, not just learn it. Although students grumbled some about this aspect of the course, it resisted passive learning by holding students accountable for work outside the classroom. In these types of activities, professors need to be comfortable acting simply as providers of basic tools, guidance, and support while students set out on their own discoveries in a heuristic approach (see Lindfors 1991).

A third aspect that can help make the course more student centered is the format of the exams. In Haverford's course, three take-home exams were given, with the third acting in lieu of a final exam, but valued equally with the other two. These exams were open-book and open-notes with a three-hour time limit, and they required that students answer three of the five given questions. They stressed that students be familiar enough with the material to back up their claims with evidence, but memorization of a series of facts or figures was not required. This format aligns exactly with the AAS goals, and it may help to overcome the pervasive student prejudice that the natural sciences are built on memorization. Although take-home tests may be harder to administer in larger settings, in-class tests can easily be adjusted to follow an open-book and open-notes model that focuses more on content than on memorization.

A fourth aspect of the course that worked toward student ownership was a nontraditional teaching method used in lecture, in which the class breaks into small groups and discusses a problem together before coming back to the large group. This helped to interrupt the sometimes wearing pace of the lectures, and succeeded in engaging students more directly in the material. Making the classroom more social at times can help the class dynamic and aid the organization of students outside class for things like homework groups (Adams & Slater 1998; Hemenway et al. 2002).

6.2 Employing "Reporters"

At certain points in Haverford's Astro 101 lectures, it was clear that students were confused about the material that was being presented to them, but they did not feel it appropriate to ask questions. These troublesome spots in lectures can be identified easily with the help of students. I recommend recruiting 5-10 students in the first few weeks to meet with the professor semiregularly as the course progresses. This is a way of receiving constant feedback about the effectiveness or ineffectiveness of different areas of the course, such as specific points in the lectures. These students should be chosen at random to ensure various levels of interest and motivation. Although it may seem rudimentary, checking with students directly about how the course is going is probably the best way to gauge one's own effectiveness (see Trumbore 1978; Hemenway et al. 2002).

6.3 Structural Suggestions

A number of other structural suggestions may help make introductory astronomy courses more student centered. First, I advise giving students direct input in the course curriculum (see Trumbore 1975). Students should be sufficiently prepared by the midpoint of an introductory astronomy course to intelligently elect the remaining themes of the course by preference and interest. This would require professors to prioritize their content and "frontload" their courses with the material that they deem most important. Professors would then split the remainder of the course into a limited number of major themes that they felt comfortable covering either inside or outside lecture. Students could then vote in class for the few topics that they would like to study in lecture. The remaining topics that turn out to be less popular for lecture could be moved to the small class sections to be covered in a different format. This strategy of narrowing the scope of the material covered in lecture is fully consistent with the "less is more" philosophy that astronomers at the AAS workshops advocated. In addition, giving students such agency in shaping the course content helps to build their identities as participants in a collective learning experience, rather than simply consumers of information.

The small class sections have the potential for added impact. These meetings are useful in managing the logistics of the course and clarifying uncertain material, but they must also be used to personally involve students in their work. First, the topics that students elect to move to the small class sections could be turned into individual or group projects. These projects would serve as an opportunity for students to be creative in expressing their knowledge of the material. Each of the topics could be broken into subtopics to be assigned to either individuals or groups. At each small class section, one or two of these subtopics could be taught by the student(s) in creative five-minute presentations. These presentations could take the form of a mural, a ballad, a skit, a PowerPoint presentation, or any other format that students choose, as long as they accurately and sufficiently convey the given material. These projects fulfill many different prerequisites for a good learning experience: they validate students' talents outside astronomy; they offer an opportunity for students to use different "forms of intelligence" (see Gardner & Walters 1993); and they make students owners of material by putting them in the position of teacher (see Brown & Campione 1996). In this process, students should be held accountable for the material covered in all of their classmates' projects; this provides the incentive to attend and pay close attention in the small class sections.

Small class sections should also be a place where students feel free to ask questions and are helped accordingly. In other words, the "classroom culture" needs to be adjusted to accommodate inquiry, skepticism, and debate, with professors not only accepting student skepticism toward the material but also encouraging it (see Tobias 1990). One way to ensure that students are processing the material is to have them come to the small class section each week with a question about the lecture or the reading from that week. This practice can serve the dual purpose of holding students accountable for their work and providing a starting point for conversation about the material (a "hook" in teaching terms). Finally, with this much emphasis on the small class sections, the TAs who lead them must be carefully chosen and trained properly, and they must be in close contact with the professor as the course progresses.

A third and final recommendation for the course is the addition of institutionalized homework groups. Many students in these introductory natural science courses find the work to be not just challenging but also isolating. Many students fight this isolation by getting together with friends in the class to work on homework, but not all students have this opportunity. Therefore, professors can do a great service to students by placing them in assigned homework groups. These groups should not be mandatory (that could be difficult logistically), but they could serve as a starting point for student collaboration. Although it is impractical for most professors to collect student schedules and coordinate meeting times, professors can place students into groups, keeping gender dynamics in mind, and count on them to find times to meet. One possible way to initiate this process is to get these groups together at least once early in the semester for an in-class activity. Ideally, positive working relationships built in class will translate into those outside class. Regardless of the approach, students will likely feel more confident about and perform better on homework if they collaborate with other students (see Tobias 1990).

With these additions, Astro 101 has the potential to engage students, use multiple intelligences, encourage ownership of learning, and give students agency in affecting the classroom. To return to the AAS report, introductory astronomy courses are well positioned to create either an affinity for or an aversion to the natural sciences as a whole. These structural changes, coupled with a dedication to continual reform and self-reflection, may help guarantee the former.

7. THE PROF RESPONDS AND REFLECTS (BP)

In general, I fully support all of the observations and suggestions made by NL. They are both instructive and perceptive. Although in some ways they are specific suggestions to me on how to improve a particular Haverford course, I believe that many of them would be beneficial to anyone teaching Astro 101. NL's general support for the goals adopted by the AAS-sponsored meetings is heartening, and his emphasis on a certain set of goals is a useful message to all Astro 101 teachers.

Let me begin a more detailed response by endorsing NL's suggestion (from section 3.1) that we instructors pay attention to student ranking of our goals for our courses. If there is a disjuncture between what we as professors hope to achieve and what the students are expecting, the course won't succeed. Although my own priorities for the 13 AAS goals at the beginning of the semester more or less matched student rankings, I ranked goals 4 (progress in science), 6 (evolution), and 12 (quantitative reasoning) higher than the students did, in part because the course was underpinned by the theme of evolution in astronomical systems. On the other hand, I ranked goal 13 (student confidence) lower, assuming that that goal would be met more or less automatically. I was mistaken. My failure to meet student expectations on goal 13, as NL noted in section 4.2, is a worrying failure in a course designed both to meet all AAS goals and to contribute to science literacy. Clearly, I (or, may I say, all of us) should pay more overt attention to this goal. On the other hand, as Figure 2 shows, there was some improvement in students' rating of their confidence in answering the ADT questions. These two results perhaps can be reconciled by recognizing that Haverford's Astro 101 has a reputation as a tough course (to quote one student, "Baby science courses aren't supposed to be this hard!"). So students may rate themselves more confident on the ADT after a semester of Astro 101, but nonetheless be sufficiently shaken by the course to give a low rating to my performance in meeting goal 13.

Next, I welcome NL's comments on and support for the small class section (see 6.1). If anything, I'd like to make the Sun/Moon observing lab more integral to the course, and spending time in the small class section to discuss the student observations might provide a good means to do so. It might even reduce the number of students who think that the phase of the Moon changes in its daily motion across the sky.

One technical remark: I doubt that many of you teaching 600 students in institutions without Haverford's well-established honor code would hand out take-home tests to Astro 101 students. But NL does raise the point that the tests we do give, whatever their format or locale, should be consistent with our course goals and should emphasize conceptual understanding and not mere memorization.

In 6.2, NL suggests the use of "student reporters." Something like this has been tried by Dick McCray in his introductory course at the University of Colorado, using undergraduate TAs (see his site, http://cosmos.colorado.edu/cw2/courses/astr1020/text). At some level (though evidently not successfully), the small class sections in Haverford's Astro 101 allowed me to judge what lecture material was getting across, and what was, to refer to the cartoon, just "blah, blah, blah."

I agree that the small class sections could have been used better, particularly in the year that NL took Astro 101. In years when I am less distracted by off-campus events, I do encourage student projects. One that has been quite effective is to have individual students or small groups of students select a world (planet or moon) in the Solar System for detailed study, then present their findings back to their small class section. To emphasize the uniqueness of the various worlds of the Solar System, I sometimes have students prepare tourist brochures for their worlds. The students own their worlds, and can generally be more enthusiastic about them than I can. And their colleagues enjoy the informality of student presentations. There’s no reason not to extend this model to topics other than the planets. In addition, I very much like his idea of having every student bring a question to each small class section. I’ll start that next year.

Appointing student homework groups (see 6.3) rather than letting them assemble may work in small classes on largely residential campuses. I’m not sure that the idea could easily be scaled up to larger classes or institutions (but see Shipman & Duch 2001). I’ll try a modified version next year: assigning students who have not quickly formed their own groups to study groups that I "appoint," again with attention to gender dynamics.

One suggestion that I don’t much like is to give students more voice in the curriculum (as opposed to the goals) for the course. I believe that this would focus student attention too much on content ("let’s talk about Black Holes and ETI") at the expense of a healthier focus on student goals for the course. Furthermore, a naïve audience, even halfway through Astro 101, might vote to drop or downplay topics like stellar evolution and the cosmic microwave background, topics that I as a professional astronomer consider too beautiful to omit.

Despite the last comment, I have very much profited from a chance to "hear myself as others hear me," and I believe that the student’s eye view may help all of us embarking on introductory science courses that are aligned with the AAS goals. And I’m glad that Haverford’s Astro 101 wasn’t all "blah, blah, Kepler, blah."

Appendix

Appendix

Haverford College

Astronomy 101
2003
Course Evaluation

Early in the course, I mentioned a set of goals for this fall's version of Astro 101. These were derived from a list of goals drawn up by the American Astronomical Society (see http://www.aas.org/education/).

I'm interested in *your* views of how well the course met this (admittedly ambitious) set of goals, and also your reaction to the goals themselves.

A. Let's start with the latter:--

For each of the many goals listed below, give a mark that represents *your interest* in each goal (what you were looking for in the course). For instance, if learning more about the night sky and its appearance was a high priority for you, rate goal #9 ("familiarity with the night sky") very highly.

Scale:		
	5	very important to you
	4	somewhat " " "
	3	average importance
	2	low importance
	1	little or no importance to you

[Then the 13 goals as given in Table 1 were listed.]

B. Now, how did this year's course do in meeting the 12 goals listed above? Rate the course using the following scale:

5	this goal was fully met by the course
4	" " " substantially met
3	" " " partially met
2	" " " occasionally met
1	met not at all or just barely met

[Then the 13 goals were repeated.]

Note

Note 1. These figures differ from the overall result for the class (5.0 ± 0.5 improvement) because not all students used their names, so we could not determine gender for some students.

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