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# Using Literacy Techniques to Teach Astronomy to Non-Science Majors

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## Abstract

We discuss an introductory-level college astronomy class that significantly relied on reading and writing assignments to deliver basic content knowledge and provide a basis for deeper analysis of the material. As opposed to the traditional problem-set method of homework, students were required to read popular articles from magazines and newspapers related to the content presented in class, and then prepare responses. These responses ranged from methodological analyzes to using the readings to create original science journalism. Additional forms of assessment indicated that students benefited from this type of course design. We propose that given the background of students in this type of course, our course design is better suited to engage students in the material and provides a valid alternative method of assessment.

## 1. INTRODUCTION

Improving the college-level "Astronomy 101" course has been a goal of many astronomers for a number of years. A significant amount of effort has been expended redesigning this class to benefit the large course enrollments (e.g., Partridge & Greenstein 2004.) Through these efforts, a number of "new-model" Astronomy 101 courses have been developed, often featuring active learning techniques and the introduction of educational technology (e.g., Alexander 2005; Bailey & Slater 2004.) Research (e.g., Prather et al. 2005) has shown that these types of classes do improve conceptual understanding of selected astronomy topics, typically assessed with the Astronomy Diagnostic Test (ADT; Hufnagel 2002). Although these classes show gains in conceptual understanding when compared with "traditional-model" courses, we suggest that increasing students' conceptual understanding should not be the only objective of Astronomy 101. It is in the interest of the astronomical community to continue to develop the Astronomy 101 class based on additional needs, such as increasing students' scientific literacy. We present a different take on the new-model Astronomy 101 by grounding our class development in literacy techniques.

## 2. LITERACY CAN DRIVE ASTRONOMY EDUCATION

The use of literacy techniques to drive science classes is not new. Epstein (1970) proposed the use of primary literature--original writings such as journal articles--as a central feature in science classes. By using primary or secondary literature (writings based on primary literature such as reviews or popularizations), science educators can move beyond the "initiate-respond-evaluate" methodology of the typical science class and begin to explore the "habits of mind" of the practicing scientist (El-Hindi 2003; Glynn & Muth 1994). For example, Glynn and Muth see literacy activities as tools to help students analyze and communicate scientific ideas. Caton (1996) described his use of astronomy news items to drive the content and sequence of a college-level introductory astronomy course. Both Ratay et al. (2003) and Yarden, Brill, and Falk (2001) discussed examples of how primary and secondary literature, respectively, can be used to further science education in a high school biology classroom.

We suggest that learning through literacy is one of the best ways to bring science to introductory classes of nonmajors because it builds on the typically stronger skills of reading and writing. One of us, Garland, teaches at Castleton State College, a small regional state college in Vermont. In that state, roughly half of 10th-grade students are at the Standard or Honors level of state tests in reading comprehension and analysis, and roughly 10% are at the Little or Below Standard levels. However, up to 40% of Vermont 10th graders are at the Little or Below Standard levels in mathematics (Vermont Department of Education 2005.) Therefore, we expect that the language skills of many Castleton students will be much stronger than their mathematical skills and will serve as a door through which science knowledge can pass.

There have been few long-term controlled studies of science classes that use literacy as a primary teaching tool. Several studies, including Ratay et al. (2003), Bandoni Muench (2000), Yarden and Brill (2000), Janick-Buckner (1997), and Epstein (1970), reported anecdotal evidence of student interest and curiosity being piqued by such a class design. However, long-term standardized data are lacking. An understanding of students’ views of science, of views of their capacity to understand science, and of conceptual understanding is critical in evaluating the effectiveness of literacy-based science classes. We present a preliminary view of data from such a literacy-based Astronomy 101 class and plan to continue this study longitudinally.

## 3. CLASSROOM DESCRIPTION

Garland teaches an introductory astronomy course, Astronomy: Exploring the Universe, every fall in the Natural Sciences Department at Castleton State College. The class meets three times a week for a 50-minute lecture, and once a week for a two-to-three-hour lab during a 14-week semester. Garland teaches both the lecture and lab. The class enrollment is small, with no more than 20 students. There are no prerequisites, and this course counts toward the Scientific and Mathematical Understanding distribution requirement. Therefore, most students are enrolled to fulfill part of that requirement as "painlessly" as possible.

Students range from high school students taking a few college credits to college seniors. Few students are science majors. Most students are from Vermont or the adjoining states. Many are nontraditional students and/or the first in their family to attend college. Most students are full time.

Castleton State College is a small, public liberal arts college located in rural Vermont. It offers two- and four-year degrees in a variety of majors, and a limited number of graduate programs. One of Castleton's strongest areas is its preparation of students for licensure in elementary and secondary education. Many of the students enrolled in Garland's astronomy classes are preservice elementary teachers.

## 4. CLASS METHODOLOGY

The course is organized by time, beginning with the Big Bang and ending with life on our planet, plus the search for other life. Although a textbook--either Seeds's *Horizons* (2004) or Hester et al.'s *21st Century Astronomy* (2002)--is used to supplement material covered in class, newspaper and magazine articles are the main vehicle used to present and reinforce the material. The goal is for students to gain a better understanding of the astronomical concepts and to increase their scientific literacy and comfort with reading science-themed popular articles. By scientific literacy, we mean the "knowledge and understanding of the scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Academy of Sciences 1995). It is also hoped that students will be inspired to continue reading in a scientific vein after completion of this course.

Articles are chosen from a variety of sources, ranging from the *New York Times* to *Scientific American*. A good starting point is the collection, *Cosmic Dispatches: The New York Times Reports on Astronomy and Cosmology* (Wilford 2002). Garland also finds it helpful to save astronomy-themed articles throughout the year for use in the subsequent year's class. Examples of articles that the students read are:

- *Before the Big Bang, There Was . . . What?* (Overbye 2001)
- "The First Stars in the Universe," *Scientific American* (Larson & Bromm 2001)
- "Scientific Savvy? In U.S., Not Much" (Scientist at Work: Jon Miller), *New York Times* (Dean 2005)

After reading such articles, students are assigned various questions, ranging from "What was the main point of the article?" to "What was not explained well?" or "What were some good analogies used by the author?" After reading three or four articles, students are then instructed to write their own astronomical articles suitable for the general public. Students have chosen topics such as

- Coronal mass ejections
- Special relativity
- Annie Jump Cannon
- Stellar evolution

At the end of the semester, the students publish their own astronomy newspaper as a class project. This newspaper is distributed campuswide.

This work is assigned within the framework of a class taught as part lecture, part small-group activities, and part hands-on exploration. Students are regularly given the assignment of bringing in astronomy news articles for classroom discussion and debate.

When researching their articles or searching for astronomy news articles, students are provided with a list of suggested resources in the college library. They may also choose to use Web sites. At first, the use of Web sites is limited to those approved by Garland, such as http://www.nasa.gov or http://hubblesite.org. However, throughout the semester, the students work with a college librarian to learn how to discern the scientific appropriateness of Web sites. By the middle of the semester, students are permitted to choose their own Internet sources.

# 5. RESULTS

This is only the second year that the course has been taught in this format at Castleton. Anecdotal results are excellent, with the vast majority of students successfully completing the course, voicing enthusiasm about learning "astronomy news," signing up to come out for voluntary astronomy nights, and some even changing their major to include a science concentration.

Some preliminary diagnostic testing has been performed during the time that this course has been offered. The ADT 2.0 (Hufnagel 2002) has been used to measure conceptual gains made by the students. However, because the class was not designed to follow the standard presentation offered in an Astronomy 101 textbook, several concepts covered by the ADT were not addressed in the class. Because of this incomplete coverage and the small numbers of students involved, we present a small sample of the student results in Table 1. We also asked students additional questions regarding material not tested in the ADT; some of these questions are also included in Table 1. (Refer to the appendix for the choices provided to the students for each question listed in Table 1.)

We found, in general, that the student responses improved over the course of the semester and that this improvement is similar to other classes' experience with new methods of astronomy instruction (Alexander 2005; Zeilik & Morris 2003). Note that we do not provide "g" and "effect size" calculations because of the small sample size in this class.

**Table 1.** Results of selected questions from the ADT 2.0, plus our own additional questions. See the appendix for possible student choices.

| **Question** | **Pretest % Correct (*N* = 20)** | **Posttest % Correct (*N* = 16)** |
|---|---|---|
| 1. According to the latest astronomical observations, approximately how old is the universe? | 75% | 100% |
| 2. Where is the center of the universe? | 37% | 93% |
| 3. What determines how long a star lives? | 62% | 86% |
| 4. Where does the Sun's energy come from? | 37% | 66% |
| 5. Why do astronomers put telescopes, such as the Hubble Space Telescope, in space? | 65% | 100% |
| 6. A spiral arm in a galaxy is: | 75% | 33% |

We found significant improvement in questions related to cosmology and the early universe. We suggest that this is due to the alignment of the course with the temporal evolution of the universe. The initial topics that students were exposed to were related to the early universe, and these topics were covered in more detail than others closer to home. Thus, it makes sense that student understanding improved most in these areas.

On some questions, such as Question 6 in Table 1, student understanding appears to have diminished. We attribute this to incomplete coverage of these topics. For example, galaxy formation and distribution were discussed, but the finer details of galactic structure were not explained.

The demographic questions of the ADT 2.0 also produced some interesting results. Table 2 presents the student responses to a question regarding their confidence in answering questions on the ADT. Table 3 presents the student responses to a question regarding the students' self-assessment of their science abilities.

**Table 2.** Student confidence levels in answering questions on the ADT 2.0, plus our own additional questions.

| | % Very Confident | % Confident | % Not Sure | % Not Very Confident | % Not at all Confident |
|---|---|---|---|---|---|
| Pretest (N = 20) | 0% | 16% | 36% | 32% | 16% |
| Posttest (N = 16) | 7% | 73% | 13% | 7% | 0% |

**Table 3.** Student self-assessment of science ability on the ADT 2.0, plus our own additional questions.

| | % Very Poor | % Poor | % Average | % Good | % Very Good |
|---|---|---|---|---|---|
| Pretest (N = 20) | 5% | 0% | 45% | 45% | 5% |
| Posttest (N = 16) | 7% | 0% | 40% | 40% | 13% |

We found that the confidence level of students on the ADT improved greatly over the course of the semester, perhaps because a test that students had already taken would appear easier the second time around. However, the students' opinion of their own ability to do science was unchanged. This result is similar to that found by Zeilik and Morris (2003), who found that the "astronomy attitude" among students in introductory astronomy classes did not change statistically over the semester. Zeilik & Morris's (2003) "astronomy attitude" included feelings toward astronomy, plus attitudes about astronomy knowledge, skills, usefulness, relevance, and difficulty. Note that the students' immersion in science is still very limited. Our demographic questions revealed that 40% of the class had previously taken one college-level science class or none at all. A mere 56 class meetings with these students is not enough to change their perception of how well they do science--there simply is not enough time.

We had hoped that our approach of adding popular writing to standard astronomy pedagogy would improve the students' self-perception regarding science. This did not appear to be the case. We propose studying the students in our class longitudinally to determine if additional science classes change their opinions.

## 6. CONCLUSIONS AND FUTURE WORK

We are encouraged by the initial success of this astronomy course. We feel that the use of popular writing is an effective addition to the Astronomy 101 pedagogy. We suggest that a class designed to follow the aging of the universe can be just as effective as the traditional textbook-designed class. However, because Castleton only offers one section of Astronomy 101 per year, it was impossible to have a control class taught using the traditional sequence of topics. Garland is currently searching for another astronomer at a similar institution to provide such a control. Castleton students, however, perform similarly on the ADT as compared with other astronomy classes studied (e.g., Alexander 2005; Zeilik & Morris 2003), which are not all taught with the same sequence of topics. Although diagnostic tests such as the ADT are effective at capturing student conceptual learning gains throughout a semester, literacy activities provide insight into other facets of learning. For example, the publication of an astronomy newspaper allows the assessment of scientific communication, scientific literacy, and synthesis of astronomy concepts and content.

We recognize the limitations of our small sample size in this initial view but hold that with so little data present for alternative Astronomy 101 classes, these early trends are useful for sparking a larger conversation. We look forward to collecting more data in the upcoming semesters and comparing our results with those of other institutions.

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# APPENDIX

Student choices for questions listed in Table 1. The best response is indicated with an asterisk (*).

1. According to the latest astronomical observations, approximately how old is the Universe?
   a) 1 million years
   b) 1 billion years
   c) *10 billion years
   d) The Universe has always existed.
2. Where is the center of the Universe?
   a) The Earth is at the center.
   b) The Sun is at the center.
   c) An unknown galaxy is at the center.
   d) *The Universe does not have a center.
3. What determines how long a star lives?
   a) Stars never die.
   b) *The mass of the star.
   c) Where the star was born.
   d) What the star is made of.
4. Where does the Sun's energy come from?
   a) *Light elements are combined into heavier elements.
   b) Heavy elements are broken apart into lighter ones.
   c) Molten rock, like in a volcano.
   d) Heat left over from the Big Bang.
5. Why do astronomers put telescopes, such as the Hubble Space Telescope, in space?
   a) They can see better because the telescope is closer to the stars.
   b) *The Earth's atmosphere interferes with observations.
   c) To escape the Earth's gravity.
   d) They are too big to use on Earth.
6. A spiral arm in a galaxy is:
   a) A place where all the stars are located.
   b) A solid structure made of gas, dust, and stars.
   c) *A place where stars are forming because of a spiral density wave.
   d) The only region of a galaxy that is emitting light.