A High School Astronomy Course for a Wide Range of Student Abilities

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1. Introduction

Astronomy is, inherently, a high-interest subject. However, at the high school level there is a tendency to teach astronomy using higher- level abstractions and complex mathematics. This teaching approach thus eliminates a large number of students who have difficulties with abstractions and complex mathematics, thereby restricting the study of astronomy to a rather select group of students.

The astronomy course offered since 1976 at Wauwatosa West High School was developed to reach a wide range of students with differing abilities. The prerequisite for this one-semester elective course is the successful completion of one year of high school science. Most of the students enrolled in this course are high school juniors and seniors, ages 16-18. Since algebra is not a prerequisite, the "math phobic"students have been attracted to the course. The higher ability students enjoy the challenges posed by astronomy and often take this course as a supplement to their physics classes. Students who normally have difficulty with science suddenly discover that they can succeed in astronomy, and we have introduced a whole new group of students to this high-interest subject.

2. Activities

Our astronomy course focuses on hands-on activities, which can illustrate higher-level abstractions in a more concrete manner. In particular, we use Project STAR activities, which were developed at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. Our text is also the Project STAR textbook (Coyle, et al, 1993). The following subsection will illustrate some of these hands-on activities.

2.1. *Orientation: Celestial Sphere*

[Slide: exterior of Wauwatosa West High School] Wauwatosa West High School is located in a suburb of Milwaukee, Wisconsin, on the western shore of Lake Michigan. As a public school, we serve a wide range of students. Thus, as we begin the astronomy course, orientation (both on Earth and on the celestial sphere) become important. [Slide: student assembling globe] Students plot star maps on the inside of two plastic hemispheres. [Slide: student assembling globe] An ecliptic strip is added, and the two hemispheres are joined together on a shaft made from a surplus coat hanger. [slide: student measuring horizon collar] A horizon collar is added. [Slide: student using celestial globe] A map pin is placed onto the ecliptic to represent the Sun, thus making it possible to simulate the Sun's daily motion for any day of the year. The globes are tilted at an angle equal to our latitude of 43° North. These globes can be duplicated for other areas of the Earth, although there was a bit of a dilemma when we constructed celestial globes with American and Australian students in Wollongong, Australia at latitude 35° South. We resolved this dilemma by "inverting"the globes, so that south was at the top.

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2.1.1. *Diurnal Path of the Sun*

[Slide: student using sun-tracking hemisphere] We also plot the diurnal path of the Sun directly with these Sun-tracking hemispheres. First the students draw their predicted daily path of the Sun on the hemisphere. A common misconception is to show the Sun's path passing through the zenith, which never happens at our latitude. Then the students plot the actual path of the Sun, with the tip of a pen acting as a gnomon. When the pen's shadow falls on the center of the hemisphere's base, the Sun's current location can be plotted on the outside of the hemisphere. At least five points are plotted, and when joined to the sunrise and sunset points for that day, it is possible to plot the diurnal path of the Sun.

2.2. *Earth-Sun-Moon*

2.2.1. *Ratios and Proportions*

[Slide: students with spheres] Ratios and proportions are very important, especially in our unit on the Earth, Sun, and Moon. One of our activities involves the students in choosing from a series of assorted sizes of spheres everything from lead shot to basketballs. Students work in pairs, with the first student selecting a sphere to represent the Earth. The second student selects a sphere to represent the Moon in its correct proportion to the Earth on the same scale, with the Earth-Moon ratio being roughly 4:1. Then the students move to the correct proportional distance between the Earth and the Moon, using 30 Earth diameters as the proportional distance.

2.2.2. *Lunar Phases*

[Slide: student with styrofoam sphere] Moon phases are simulated by using a light bulb to represent the Sun, a student to represent the Earth, and a styrofoam sphere, held at arm's length, to represent the Moon. A second student observes the changing "phases" of the Moon as the first student slowly rotates 360° while holding the "moon" at arm's length. [Slide: student using lunar phase dial] These lunar phases are recorded on a chart, and the names of the phases and a time-of-day dial are added. With this lunar phase dial, students can determine the time of day when a given phase of the Moon rises, sets, or when it is highest to the south.

2.2.3. *Lunar Surface Features*

[Slide: students working with lunar maps] Inexpensive lunar maps can be used to locate and describe lunar surface features. [Slide: student observing lunar rocks] The National Aeronautics and Space Administration (NASA) loans out samples of lunar rocks for study in the classroom. Here a student is observing lunar rock samples under a stereoscopic microscope.

2.3. *Pinhole Tubes*

[Slide: student with pinhole tube] Students construct pinhole tubes from empty paper towel tubes. Aluminum foil is placed over one end of the first tube, a pinhole is made in the foil, and tracing paper is placed over the end of the second tube. The pinhole tube is aimed at a light bulb, and an image of the light bulb is formed on the tracing paper. By making a series of calculations, this activity can be used to illustrate similar triangles, among other uses.

2.4. *Refracting Telescopes*

[Slide: student constructing telescope] The pinhole tube is then converted into a simple refracting telescope. The tracing paper is replaced by an eyepiece and the aluminum foil is replaced by a 16-cm focal length lens. [Slide: student testing telescope] Students check out their telescopes in the classroom and often fear that they have done something wrong when they see an inverted image. [Slide: student calibrating telescope] The telescope can be calibrated to determine width of field of view.

2.5. *Three-Dimensional Constellation Models*

[Slide: students measuring strings for three-dimensional constellation model] Students construct three-dimensional constellation models. A photograph of a constellation is attached to a piece of cardboard. Beads are threaded onto strings suspended from the cardboard. [Slide: students attaching strings to washer] Then the strings are fastened to a washer at a distance of 56 cm from the cardboard, since the camera that photographed the constellation had a 56-cm focal length. The washer represents the Earth, and the beads, representing stars, are adjusted for their correct scale distance from the Earth, using a scale of 1 cm = 100 LY. Constructing these three-dimensional constellation models can be quite tedious and involves a great deal of teamwork and cooperation.

2.6. *Observational Astronomy*

Observational astronomy is enhanced by the plotting of constellations, use of star finders, regular observation in the planetarium, and direct observation whenever possible. Five major constellation groups are studied: circumpolar, the summer triangle, autumnal constellations, the winter hexagon, and the spring diamond.

3. Course Content

The astronomy course is divided into seven units as follows;

- **Astronomy and the Beginning of Science**: the origins of science through astronomy, interpreting sky phenomena, methods of astronomical inquiry, including the uses of technology.
- **Solar System Dynamics**: measuring size, distance and scale in space, modeling the solar system, and observing the planets.
- **Observing Earth Motions**: apparent daily motion of the Sun, timekeeping systems, time zones, revolution of the Earth, the seasons, and precession.
- **Earth-Sun-Moon**: scale of Earth-Sun-Moon system, lunar phases, solar and lunar eclipses, the Apollo moon voyages, and lunar observation.
- ***The Sun and Stars in General**: measuring and observing magnitudes of stars,* magnitude scales, physical properties of the Sun, and solar activity.
- **Stellar Evolution**: spectral classification, the Hertzsprung-Russell Diagram; energy production in stars; and evolution of low mass, medium mass, and supermassive stars.
- **Galaxies and Cosmology**: observing the Milky Way and deep space objects, types of galaxies, large-scale structure of the universe (the Bubble Theory), and theories of cosmogeny.

4. Basic Skills

Application of basic skills is another major thrust of the course. As new vocabulary terms are introduced, their use is integrated into laboratory, audiovisual, planetarium and other observational activities. Scientific notation and unit conversion activities are used extensively throughout the course. The use and understanding of time zone changes is studied thoroughly in the unit on Earth motions. Use of outside reference material is integral to each unit. Interpretation of charts, graphs and coordinate systems facilitate basic understanding of potentially complex material. Models are used extensively. Computer technology is used on a classroom basis, particularly to study constellation maps. There are provisions for students to do independent study, and even for a separate independent astronomy course.

5. Assessment

Formative assessment includes regular quizzes on constellations and basic skills. Summative assessment is based on unit tests, a constellation unit test, a final examination, as well as written homework and laboratory procedures. The grading scale is deliberately widened at the C and D range to accommodate those students who truly work hard, but have difficulties in academic situations.

6. Conclusion

Astronomy has become a very popular course in the Wauwatosa high schools, but it is not widely taught in high schools elsewhere. Perhaps the present model could be used to provide an incentive for more widespread teaching of astronomy at the high school level.

REFERENCES

Coyle, H. P. et al, 1993, "Project STAR: The Universe in Your Hands," Kendall/Hunt Publishing Company, Dubuque, Iowa.

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