Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

Implementing the Astronomy Education Research

Leonarda Fucili
Teacher of Science and Mathematics
Supervisor in the Teacher Development School "SSIS Lazio", Rome, Italy
E-mail: l.fucili@itaca.com

I think there is nothing like the study of astronomy to capture the imaginations of our students, to make them understand phenomena, and to introduce them to the fundamental ideas and methods of science and mathematics. In my presentation, I will examine my research on effective teaching and learning of astronomy at the elementary school level, and how I have implemented my research in my work with students, teachers, and curriculum.

1. My Research on Effective Teaching and Learning of Astronomy

For several years, in Rome, I have carried out research on Astronomy Education with the Educational Co-operative Movement (MCE) association, co-ordinated by N. Lanciano, University "La Sapienza". The main topics are:

- the dynamics of the individual cognitive process in developing basic astronomical concepts
- the conditions for effective teaching and learning of astronomy
- misconceptions in astronomy

We create educational contexts in which participants – students and teachers – observe, experiment, build instruments and models, and discuss. We investigate mental images and conceptions, with attention to the significant questions and answers, to misconceptions and mistakes, and to the elements that facilitate or block understanding. The results of my research made me think over the conditions for teaching Astronomy at the elementary school level: short activities and lessons inside the classroom, following a fixed curriculum and textbooks, do *not* improve the students' understanding and appreciation of astronomy; rather, they sometimes create a negative impression of it, and intensify misconceptions.

2. Teaching Astronomy

First, I will examine how I have implemented my research in my work with students in order to improve the students' awareness, understanding, and appreciation of our subject. The context: I teach in "Scuola Media" to students of all abilities, aged 11-14 years, in the same full-time class for three years, 6 hours a week in Math and Science, and 2 hours a week in an integrated project. This situation gives me the opportunity to develop long-term astronomical activities and lessons, as well as the mathematical knowledge, skills, and concepts which students need for the understanding of Astronomy. I developed an introductory

Astronomy course for grades 6-8, founded on the belief that effective learning of astronomy at a primary level is strongly related to observations of real phenomena, and requires a direct involvement and an active body. It is an integrated interdisciplinary course, with a flexible, modular, and in-progress curriculum.

The main goal is to encourage the enthusiasm of my students, and increase their familiarity with astronomy, their understanding of science, and their appreciation of its role in making sense of the world. A significant aspect of my course is its emphasis on hands-on activities. I want students to discover the ideas of astronomy for themselves, not just to read about them passively. An active body renews emotions, curiosity, and effective learning. The act of discovery, of experiencing insight or understanding, produces a thrill of victory, and its memory lasts forever.

Students spend a long time outdoors, making observations and constructing instruments, before developing theoretical explanations and models. The sky becomes a scientific laboratory, "a lab within everybody's reach", always available, free and fully equipped. Students have to be guided in "knowing what to look for", because usually they don't observe much more than things they are already familiar with. They will discover that a surprising abundance of observations is possible. They are guided:

- to find in the sky the same fascination and wish of knowledge that has always led mankind to observe astronomical phenomena, and organize space and time;
- to follow humanity in its discovery of the shape of the Earth, reference systems, celestial motions, distances in the universe, measures of space and time
- to see connections between the scientific disciplines and the humanities, as well as between what they learn in school and in the real world
- to become aware: *to perceive as Ptolemy did, to think as Copernicus did*

3. Looking at What Happens in Class

I will give some examples of astronomy activities and methods that have been tested in my class.

- Investigating students' pre-knowledge makes explicit misconceptions, *epistemological obstacles* and gaps, and turns them into a problem which students want to work on. The workshop *A Round World* is an example which is focused on the shape of the Earth and gravity. Everybody knows that the Earth is a sphere, but the majority of people don't use the concept of an earth-sphere and are not able to connect the spherical form with its geometrical and physical properties. By showing how the human mind has evolved throughout history, I give students the elements of a critical look.
- Using significant or *upsetting* questions: common-sense rules and scientific knowledge don't provide answers any more and, in this uneasiness, new knowledge links with old knowledge in a more conscious way.

https://doi.org/10.1017/S1539299600018049 Published online by Cambridge University Press

- Caring about linguistic aspects before concepts are expressed by words; often, one word has several meanings.

- Spending a long time in observations before developing models and theoretical explanations. In search of reference systems, we make observations from our local horizon and meridian.

- Collecting data in order to discover simple general laws, for instance the mid-day height and declination of the sun. Creating a complete record of data would take one year but, in just six months, students can foresee the further results.

- Building and using models: hand-made of common materials and manipulated by students, in order to develop geometric and spatial imagination, and link celestial phenomena to terrestrial analogies.

- Enacting dynamic human models: students enjoy a model in which they co-operate with others, and the retention of concepts is enhanced. These models need a long time to arrange, and this time helps students to reach the spatial visualization required in many astronomical concepts. Demonstrations in which students represent the Earth, Sun and zodiac, the Sun and planets, and lunar phases are well known. Some more examples: (a) *The planetary week and the "week's dance"*: an active body, with rhythm and movement, can help to re-discover and understand the sequence of the days of the week. This model enacts the explanation of the origin of the planetary week made by Abraham ba Hiyya from Barcelone, called Savasorda, in "Sefer ha't'bbur" (The Book of the Calendar) in the 12th century. (b) *Walking with solar steps*: this model helps students to understand the rhythm of the sun's motion over one year; how and why days stay long (and nights short) for several weeks near the summer solstice, and shorten quickly before the winter solstice. Students work with a monumental sundial in St. Peter's Square in Rome; the gnomon is a giant Egyptian obelisk, and the local meridian is lined with zodiacal signs.

- Measuring the human body in order to discover proportions and laws. In accordance with Galileo's method, the human body and nature become an open book, understandable with the language of mathematics.

- Practicing mathematical skills: calculating, ordering, classifying, comparing, measuring, recording, graphing, reasoning, inquiring, are essential skills for studying astronomy.

- Starting nearby and moving further out, using simple principles, historical methods, and data gained by observations, in order to make deductions about the scale of the universe. Gaining knowledge about distances in space was and still is long and hard work for students, and a step-by-step process from earth to moon, sun, planets, stars, and galaxies.

4. An Interdisciplinary Approach

Among the most distinctive aspects of my course is the interdisciplinary approach to astronomy. A deep emotion and desire for knowledge emerges from the sky: physics, mathematics, geometry, science, art, religion, literature, music, without separation into different disciplines. This integration has to be emphasized at the elementary school level.

- *Anthropology*: we investigate the astronomical roots of our culture, the astronomical phenomena at the basis of our calendar, customs, and feasts.
- *Mythology*: myths describing the origin of the universe, planets and constellations help to organize the space of the sky. Myths are the first sky maps.
- *The history of astronomy* has an appropriate place in my course. We trace back the origins of the early astronomical observatories. In Rome, they are connected with the history of the Jesuits, who were in charge of astronomical research until the last century. We do workshops and lessons in the Collegio Romano, and in places visited by Galileo.
- *The sky and the cities*: the social and ritual foundation of a city has always been related to the sky; we research how ancient architects organized *place and time*, observing astronomical phenomena. In Rome, the Pantheon, Domus Aurea, and Villa Adriana are examples of suggestive places in which the history of a city, the project of an emperor, astrological symbols, and astronomical data fuse in geometrical architectural structures. Monuments, historical buildings, and squares become our laboratories, sundials, and calendars to register astronomical phenomena, and to be reproduced at school.

5. The Method

- Inducing students to take an interest in the content, to see something meaningful, and to become engaged in the search for it.
- Exploiting and making maximum use of students' pre-knowledge.
- Giving time for understanding from observations and experiences before working on more theoretical explanations.
- Giving preference to questions over answers, in order to develop an inquiring attitude.
- Focusing on "concept maps", the essentials of the discipline, and the connections between concepts, goals, and topics.
- Making students aware of the path that they are following.

Students sometimes work alone, sometimes in co-operative groups. Not only classrooms are used, but also the outdoors and the city, not only for short

https://doi.org/10.1017/S1539299600018049 Published online by Cambridge University Press

lessons, but also long activities. At the same time, we look for connections between the scientific disciplines and the humanities, as well as between what students learn in school and the real world.

6. The Results

At the end of every year, an interactive exhibition documents and focuses on the main significant concepts that students have worked on. Students train other students in the same activities and learning situations they have experienced. It is a summary as well as a test of the effectiveness of their understanding and learning. *Knowledge becomes culture* when it is useful for understanding reality, and for acting on that. It happens when teaching connects with the individual process of learning by significant aims, methods, and subjects. By studying astronomy, basic concepts such as space and time – essential for understanding the world – are addressed. This is the great contribution of astronomy to education; let's use this opportunity!

References

Davidson, N. *Astronomy and Imagination*, Routledge & Kegan Paul, London and New York

Fucili, L. & Lanciano, N. 2000, Il Cielo a Scuolo, Naturalmente Anno 13, #1, 56-58

Fucili, L. 2001, Astronomical Terraces: Space Labs between the Earth and Sky, ESA Teach Space

Lanciano, N. 2002, Strumenti per i Giardini del Cielo, Edizioni Junior (BG)