

Teaching Astronomy via the Internet

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Abstract.

In the framework of a partnership between the Astronomical Observatory of Padova and Telecom Italia, the most important Italian Internet and Intranet provider, we are experimenting with the educational possibilities of the Internet. A Web site *entirely* devoted to the teaching of Astronomy to secondary school students has been designed and realized. Graphics and animations are widely used to introduce the concepts, and special care has been devoted to the language used in the text.

A group of junior and senior high schools (8-12 grades) will be connected to a server located in the Observatory, and the server will in turn be a gateway to the whole Net. Access will be given to a selected number of external astronomical Web sites.

The actual use of this tool in the selected classrooms will be followed up in the next scholastic year (October 97–June 98). A strong and continuous interaction with the teachers is also, obviously, foreseen to ensure a strong positive feed-back. On one hand, this project will give us important suggestions for the further development of a specific educational method suitable for the Web. On the other, it will give the students basic astronomical knowledge and the possibility to become familiar with the Internet environment.

1. Guidelines for this Project

There are several reasons why astronomy is an appropriate choice for a project like this. Astronomy and astronomical images have immediate appeal to a large number of young people, so they can be used to attract people to science in a general sense. Moreover, images are an obvious way to build an attractive Web site, and a search on the Web does indeed reveal that there is a huge amount of astronomical information available. On the other hand, there are no comprehensive projects which lead a student through astronomy from the very basics, particularly among Italian Web sites. Furthermore, the information that one can find is also sometimes wrong or misleading. The aim of our project is therefore first to provide introductory and *reliable* astronomical material to 8-to-12 grades students, and, as a second step, to be an informed guide through the existing external Web sites.

With regard to the first point, the new medium allows one to overcome the limitations of traditional textbooks: the students can establish by themselves the pace of their 'lessons', and they can experiment in real time with the

concepts they have learned, interacting with the environment that we provide. Furthermore, the Web site also contains a guided first contact to the Internet and explains how to exploit its wealth of astronomical information.

We must also point out that teachers themselves are not always aware of the possibilities of the Net, and textbooks are generally lacking in topics suitable for effective hands-on activities. Another important task of our project is therefore to assemble a complete database of reference hands-on activities to be performed in the classroom. Guidelines for their usage and simulations of the results are also given.

2. Theoretical Approach to the Educational Method

It is now widely accepted that the best strategy to introduce new knowledge to students is the so-called Karplus' cycle (Atkin & Karplus 1962; Karplus et al. 1976). It consists of three steps. First, the students are given some 'environment' where they can explore a given phenomenon, make their own observations and draw some first conclusions. Second, these preliminary conclusions are discussed with the teacher and incorrect interpretations are removed. Finally, once the new and correct explanation is acquired, new concepts are used in the exploration of a new situation, and the *learning cycle* repeats itself.

We also bear in mind that new knowledge should be introduced after the students' misconceptions have been removed. If this task is not performed, it is possible that no actual change in the individual reasoning will happen. Her/his knowledge is not *restructured* (see e.g., Vosniadou & Brewer 1987). The new information will be somehow adapted to the old mental schemes, so that distortions and misunderstandings will result. Moreover, the knowledge is never incorporated into one's vision of the world and soon forgotten (Ausubel et al. 1978).

Once the educational method has been defined, the contents must be selected and organized. The basic approach is to put the subjects in a hierarchical structure. To this aim, several methods can be devised in order to identify which concepts are prior to the others, and conceptual pyramids can be built. We followed the results of the project STAR, which are discussed in by Sadler (1996, see his Figure 6).

After this first learning phase, another approach to the educational material can be given, which is that of unifying concepts. It is useful for the students to see how the same principles and methods are at work throughout all the subjects they have encountered.

Educational content and unifying concepts are now briefly discussed.

2.1. Educational Content

The subjects have been selected from a standard list (see e.g., Schatz 1996) and organized in a multilevel structure. The starting points are the concepts of the Earth's shape and motion, then we move on to gravity and its consequences, periodic phenomena and orbits, the laws of planetary motion and the Solar System. Radiation properties are introduced before studying the Sun and the stars. The masses, luminosities, radii, temperatures and distances of the stars are discussed, and care is always used to supply all data in a comparative way.

At the higher levels, our current vision of the structure of the Universe is given, emphasizing the role of galaxies as the fundamental components of the large scale structure. Finally, the Big Bang theory is introduced and the past, present and future of our Universe are discussed.

During a normal school year only a few themes can be explored in depth, so the teacher will have to select a subset of all the subjects, which should be consistent with the actual level of her/his students.

2.2. Unifying Concepts

After introducing the fundamental idea of science as inquiry, other conceptual structures are highlighted, such as energy balance and conservation, the equilibrium and evolution of a physical system, and the clustering properties of the Universe. It is shown how the Universe is ordered and organized from micro to macro worlds. The relation between distances and time scales is emphasized, and between the mass, radius and luminosity of stars and galaxies. The concept of order of magnitude of physical quantities is also explored.

3. Application to the Internet Environment.

The misconception removal phase and the learning cycle have been reproduced by means of tests. In the first case, the questions reproduce the ones used in many experimental investigations on the children's learning processes and are connected to a list of answers which contains the most common misconceptions. If a wrong answer is selected, then its consequences are shown to the student, and eventually he will get to the point of self-contradiction. From this point he will get back to the initial test, and when the right answer is chosen the correct explanation is reinforced by means of other examples, images, films etc.. This process makes the student interested in the forthcoming material and prepares him/her for the next subject.

When the test is connected to the Karplus' cycle, it is used to perform the three phases. First, the exploration of a phenomenon is proposed by means of introductory text and images, and some observations and/or hands-on activities are suggested. These observations are usually possible with very simple aids, and the teacher is expected to guide the students through the various steps. If for some reason the observations cannot be made, or the user has no time for them, then simulations are provided. The simulations are also useful as a guide to the correct interpretation of the observations. Java scripts are widely used in this phase.

The students are then requested to give their interpretation of the observations and/or simulations. A set of alternative explanations for the phenomenon is listed and the students are required to choose one. When the student's choice is incorrect, they are led to a self-contradiction.

The third phase (application of new concepts) is performed when the correct answer is chosen. The phenomenon is further discussed and its consequences highlighted, and it is then used to introduce the next subject in the hierarchy. CGI scripts have been devised in order to manage the tests and the related actions, and to take care of the user database and access log.

The site is organized in a multiple level structure. The single levels can be accessed either from a general table-of-contents or through an ordered path. A log of all the user's accesses is kept. If the user wishes, his/her performance can be evaluated using the number of correct vs. wrong answers. In that case, access to the single levels is given with a password and is flagged in the log file.

4. Conclusions and Future Developments

This project allowed us to establish a template in the teaching of Astronomy via the Internet. The most effective educational strategy has been identified and it has been adapted to the new medium. The key feature of this medium, i.e., interactivity, has been fully exploited.

The educational contents have been carefully selected and organized in a hierarchical structure. Therefore, we ensured both that the basic astronomical knowledge is provided and that no previous elements are needed to fully exploit the Web site. The basic unifying concepts have also been identified and are stressed throughout the various levels.

Browsing through this material, the students will encounter a new way to learn things. A lively way which overcomes the traditional static textbook limitations, and which gives the students the chance to wander around along their preferred path at a pace they will establish according to individual capabilities. They will learn by doing things themselves, which is the best way to learn.

At the same time, the Web site provides a starting point to become familiar with the Net environment and to establish a minimum set of astronomical concepts. Using this background astronomical knowledge and the basic navigation skills, they will be able to access the available material on the Web with full awareness.

In the near future, we will extend the database of interactive experiments by means of a Java laboratory, and VRML will be implemented. The response of real classes will be tested and we will take advantage of the students' and teachers' suggestions in order to improve the site (a 6 month phase is expected). The Web site can be reached via the Padova Astronomical Observatory¹.

References

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¹<http://www.pd.astro.it/>