Teaching Astrobiology. A Scientific and a Cultural Imperative

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ABSTRACT

Astrobiology is a rapidly evolving discipline and, in order for its information to be passed on, it is urgent and necessary for Astrobiology to be integrated into the curricular domain, as well as into public and private scientific policies. The latter would contribute to the understanding of both the dynamic construction of scientific knowledge, and the spreading of science as a cultural imperative.

This paper continues our previous work on Astrobiology education and public outreach. In this sense, we will present a curricular proposal on Astrobiology, which we would like to see integrated into the scientific areas of Portuguese secondary schools. To achieve this goal, it was necessary to select the most adequate and important key ideas for teaching, and to adapt the most complex scientific language to the school context. Finally, the right tools and strategies were created and developed to attain the proposed objectives. Several examples of these ideas, tools and strategies are discussed in the present article.

Keywords: astrobiology, teaching, education

1. INTRODUCTION

As referred in the NASA Astrobiology Institute homepage, "Astrobiology is the scientific study of the living universe; its past, present, and future. It starts with investigating life on Earth, the only place where life is known to exist, and extends into the farthest reaches of the cosmos. It ranges in time from the big bang and continues on into the future"[1]. In short, we can say that this new area of knowledge tries to answer a vital question: How did life appear and evolve?

During human history there have been several thinkers who supported different opinions about the origins of life and the possibility of its existence in other worlds. But, since the 1960s, with the development of new technologies of space exploration, a new field of scientific knowledge which seeks answers to these questions emerged. As any newborn, Astrobiology is growing and maturing rapidly. In the last few years, new data has been discovered and many advances have been made.

This new subject should be integrated in the science *curriculum* of our students, as well as in public and private scientific policies. Dealing with a problem, for which there are several approaches, can lead to an adequate critical reflection on the nature of science and its inter-relations with other areas of knowledge, such as natural sciences, philosophy, theology and sociocultural studies[2]. Being an emerging science its aim is to lead students to experiment with and understand the several steps of the scientific method, also allowing to create moments of reflection, questioning and creativity.

The integration of this science into the school *curriculum* will allow the incorporation of several areas of knowledge (such as biology, geology, chemistry, physics, astronomy, etc.), which are traditionally kept apart, and contribute to explain the construction of scientific knowledge. Students will learn that this science is not an inert set of accumulated facts, but something dynamic and in constant development. At the same time, students will be introduced to a field of study that may soon yield some of the most important scientific discoveries of all time[3].

The search and the possible finding of life in other places beyond Earth will redefine our place in the Universe, which will lead students to have a different perspective in understanding both Man and Nature.

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Astrobiology is a field that raises many questions, some of them difficult to provide an answer to; at the same time as other questions can be raised and many might never be answered. The most important issue is not to achieve "the absolute truth" but to seek the path to get there. Astrobiology is meant to be a challenge in the teaching of science and in the development of thinking of our young students.

2. CURRICULAR PROPOSAL ON ASTROBIOLOGY

Our curricular proposal is the result of an accurate research and subsequent selection of the most adequate and important key ideas for teaching. We also had to adapt the most complex scientific language to the school context.
We analyzed as well several educational programs on Astrobiology[3,5,6,7] from which we selected and adapted some of the activities proposed. Finally, we created and developed the right tools and strategies to attain the proposed objectives.

The main goals of the curricular proposal are synthesized in the following points:

- To motivate the community towards scientific knowledge
- To divulge Astrobiology
- To promote critical reflection on the nature of science
- To develop reflection, questioning and creativity in the students
- To develop cooperative-learning approach for teaching Astrobiology
- To promote experimental work at school
- To develop attitudes of environmental responsibility, as a result of the understanding of the Origin of Life and the Universe
- To promote the use of new information and communication technologies

The present proposal consists of four modules:

Module I. The Birth of Astrobiology

Module II. The Origin of Life

1. Definition and Chemistry of Life
2. Theories about the Origin of Life

Module III. Earth – A Living Planet

1. Origin and Evolution of the Solar System
2. Primitive Earth
3. Palaeontological evidence for early life on Earth
4. Life on the edge

Module IV. Search for Extraterrestrial Life

1. Possible habitable environments in the Solar System
   - Mars
   - Europa and other icy bodies
   - Titan
2. Exoplanetary systems
3. SETI and the search of extraterrestrial intelligence

In the first module, students will be able to understand what Astrobiology is, what it studies, how this new science appeared and evolved throughout these past years. In this module, students will learn the construction of scientific knowledge, and the relationships between science, technology and society. To achieve these goals we propose some film[4] watching on the topic, a worksheet (a quiz with quotations on the origin of life for students to comment on) and subsequent debate.

The second module has two main ideas. The first one is to try to define life and learn about its chemistry. Students will be able to understand how surprisingly difficult it is to distinguish living from non-living systems and the best way of studying this issue is to know a list of characteristics that almost all living creatures share. In order to teach this topic we propose an experimental activity[5,6] (several samples in which students have to discover where life exists) and following discussion. To learn about the chemistry and function of entities that make up a living system we propose an activity using three-dimensional models of biological molecules.
The second topic in this module aims at the learning of different theories about the origin of life (Spontaneous Generation, Biogenesis, Oparin-Haldane hypothesis, the Miller-Urey and Fox experiments, Panspermia and Symbiogenesis) throughout activities of discussion, internet research and experimental activities (e.g. Coacervates Formation).

In the third module students, will apprehend Earth as a living planet. They'll understand the development of our planet in the context of the Universe and Solar System formation and how this knowledge is relevant to the problem of the origin of life. To accomplish this goal we suggest watching some parts of the film "Cosmos" from Carl Sagan, a worksheet and following debate.
They will also examine, through activities of discussion and worksheets, what makes Earth a habitable planet, what conditions existed on primitive Earth, and whether life in its present form may provide us with some hints on the possibility of the existence of life in other parts of our solar system or even beyond it.
This third module will provide information about palaeontological evidence for early life on Earth and students will see, through an activity of discussion with several photos, that these data are by no means definitive and are the subject of intense scientific debate[8].
At the end of this module, students will understand that life on Earth can exist in extreme environments, and that such organisms can provide useful clues for understanding how life may be able to exist in other places in the universe. We propose some worksheets[6] about this issue, an experimental activity[5,6] (using extremophiles), some film watching on hydrothermal vents (captured in the Azores by a Portuguese team coordinated by Fernando Barriga) and an educational game[3,6] (relating extremophiles, extreme environments on Earth and extraterrestrial environments that could support these organisms).

In the fourth module, students will be able to discuss the possibility of life existing elsewhere in our solar system or beyond. We will consider some possible habitable environments in the solar system such as Mars, Europa and other icy bodies and Titan. They will also look at the methods that scientists use to search for other planetary systems, signs of life and possible intelligent civilizations. To attain these goals we suggest some internet research, worksheets[5,6] and activities of discussion.

As a final activity we propose an educational game, *Astrobiotica*[7], composed of questions and tasks that will permit students to test their skills and knowledge about Astrobiology. There are four main themes in *Astrobiotica*: *History and Evolution of Astrobiology*, which includes the main landmarks in the development of this science and the principles of the scientific method; *Endogenous Model of the Origin of Life*, which deals with the Oparin-Haldane theory and the Miller experiment on the origin of life; *Exogenous Model of the Origin of Life*, related with the hypothesis that the chemical main blocks of life were originated outside of Earth, and *Cosmological Data* which includes relevant paleontological and planetological data associated with the origin and development of life[7].

This proposal would be a valuable contribution to science, in the sense that it could foster the introduction of Astrobiology in syllabus and, consequently in textbooks of Portuguese schools.

3. FINAL REMARKS

The present work is the result of our previous research on Astrobiology education and public outreach and we are convinced that it is urgent to introduce this area of knowledge in our secondary schools as well in universities. This new field of knowledge is evolving rapidly and it should be accessible to everyone, especially to our students. Its main objectives are to understand what life is, how it was originated, what it requires and where it might be found in the Universe. These are important and vital questions for which students should get the chance to reflect on and search for answers.

Astrobiology integrates several areas of knowledge and contributes to an open and therefore not compartmentalized vision of science, allowing students to understand its nature and construction. It will also help students to have a different perspective in understanding the place of Man in the complex cosmological system.

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