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Learning Astrophysics Using STEM Educational Approach: Coding and Hands-on Activities at INAF OAS Bologna

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Abstract

The paper presents some educational activities offered by the National Institute for Astrophysics – Astrophysics and Space Science Observatory Bologna (INAF – OAS) to students of the primary and secondary schools, to promote Astrophysics using the STEM educational approach. The proposed activities made students enthusiastic about science and technology, giving them the opportunity to get in touch with research staff who is daily involved in the proposed subjects: astronomy, astrophysics, and space exploration. Students are helped to develop computational thinking and skills through the Scratch tool which, by its very nature, involves not only the computational and logical-mathematical intelligence, but also the emotional and expressive sphere. In addition, they are helped to develop skills related to science and technology by creating paper circuits, making instruments, and building 3D paper models of space satellites. For students of the secondary school, educational robotics combines coding with creativity and technology: in the robot design and assembling process, students experience problem solving, building their knowledge using the science studied at school and discovering how useful and fun it is. The study of planets and moons of our solar system provides an opportunity to design robot and, during the activities, researchers and technologists of the National Institute of Astrophysics explore aspects of astronomy and space exploration. The strengths of all the proposed activities are the generation of enthusiasm and curiosity for the astronomical subjects, the solicitation to creativity, the gratification deriving from the autonomous realization of the final product, and the playful learning of advanced digital technology.

Keywords: *STEM, astrophysics, educational challenge, coding, making, Scratch*

1. Introduction

The didactic methodological approach with which the activities were designed is the metacognitive laboratory teaching, with a broad and flexible connotation mainly referred to the four STEM disciplines: science, technology, engineering and mathematics [1]. The teaching strategies and methodologies of the learning process of the STEM disciplines are perfectly integrated with the CLIL (Content and Language Integrated Learning) approach and computational thinking (coding). The proposed laboratories adopt the “Learning by doing” philosophy, which is the most suitable methodology for "hands-on" teaching, in which "knowledge" is linked to "know-how" (abilities) and "knowing how to be" (intentional and conscious action). During the activities, the emphasis is on the educational relationship, motivation, curiosity, participation, problem solving, personalized learning and use of cognitive and metacognition styles, research method, socialization, and solidarity. Also for this reason, we are used to create a collaborative synergy between teachers and researchers engaged in state of the art research in scientific and technological disciplines. This synergy represents an added value of our activities, compared to the classic STEM Lab, and represents a bridge between the school and the research world, allowing students to acquire knowledge also through the experience of the researcher closely involved in national and international research projects. In this context, the laboratory is mainly a mental place, a forma mentis, a practice of doing that enhances the student's centrality, emphasizes the learning process and puts the experimental activity of the students in close relationship with the skills of the teachers and researchers.

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2. Classroom activities

The *National Institute for Astrophysics – Astrophysics and Space Science Observatory Bologna* (INAF – OAS Bologna) implemented several educational activities suitable both for schools and the general public. Our proposals cover topics related to astronomy, cosmology, physics and space exploration. The teaching tools used include multimedia presentations, simple and fun making activities, and laboratories. In this paper we present some hands-on activities and coding laboratories we have successfully implemented, for free, in about two-hundred classes in the last two years.

2.2 Let's light the constellations

The proposed maker learning experience brings students closer to Electronics, the science of controlling electrical energy, using Astronomy as a common thread to create a final product with a great visual impact: a paper circuit in which the constellations light up, reproducing the brightness of the stars. By creating a paper circuit, students will learn easily and intuitively the basics of electricity and how the circuits work. During the activity, researchers accompany students in the creation of the electric circuit with the description of the constellation, in terms of type of stars present (brightness, color and distance from the Earth), position in the sky, presence of peculiar objects within the constellation itself, existence of planetary systems and probability of finding habitable exoplanets. In the first part of the laboratory, students will be approached to the constellations: what they are, how their component stars move in the sky and what is their usefulness in astronomy. In the second part of the lesson, students will realize their paper circuit, that is a low-voltage electronic circuit created on a sheet of paper using a conductive copper tape, LEDs and a small 3V button battery. The LEDs will be connected in parallel and students will be able to check the correct functioning of the circuit step by step. Particular emphasis is placed on how to identify and solve technical problems that often occurs in this making activity.

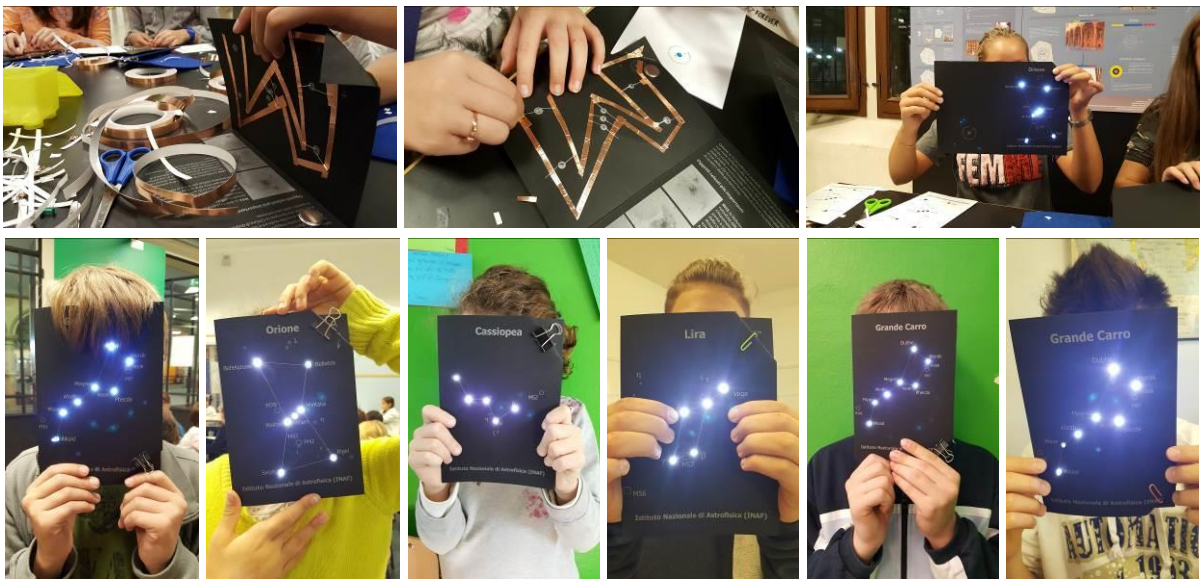

Figure 1 Let's light the constellations!

2.2 Ghost hunting

The aim of this hands-on activity is to bring students closer to the understanding of the light and to the discovery of the electromagnetic spectrum, through the construction of a simple spectroscope that allows them to discover the spectrum of the light and to appreciate the emission lines of the elements used in some light sources. In a spectroscope, the light beam passes through a slit and strikes a prism or a diffraction grating, which splits the light into the various colours that compose it, forming the so-called spectrum. By examining the spectrum, it is possible to identify the elements that produced it, that is the characteristics of the light source that generated the beam. In the proposed spectroscope, the diffraction grating consists of a CD or, better, a DVD[7]. Optical disks have a spiral of parallel and

[7] Our spectroscope was originally designed by GAPPIC (http://pedagogie.ac-toulouse.fr/gappic), CC-BY-NC-SA.

very thin grooves into which data are recorded. There are about 650 grooves per millimetre in the CD (about 1300 furrows in the DVD) and it is this grid to break the light in the colours that compose it, creating the spectrum. By using the result of their work, students can see the spectra of different bulbs we bring into the classroom: halogen bulb, led bulb, fluorescence bulb, and several calibration lamps (hydrogen, mercury, oxygen, carbon dioxide). In this way, they understand the difference between a continuum spectrum and a line spectrum produced by atoms of a specific element. Furthermore, to better explain the electromagnetic spectrum, also the other bands are presented, and using a thermo-camera they enjoy the discovery of the infrared red light.

Figure 2 Ghost hunting in a classroom.

2.3 The great adventure of Rosetta

The aim of this activity is to bring students closer to the comprehension of our Solar System, especially comets, telling them the beautiful and compelling story of the Rosetta probe and its traveling companion, the lander Philae. The activity is organised into a two-hour lesson: first, an introduction to the Solar System (Sun, planets, moons, asteroids, and comets) is made, with particular reference to comets: what they are, where they come from and why they are so important for us. The Rosetta space mission, developed by European Space Agency (ESA), is then presented through an exciting, fun, and engaging cartoon developed by ESA. At the end, each student cuts and builds a paper model of the Rosetta spacecraft and its lander Philae, using a 3D project. This laboratory not only results entertaining and useful to develop dexterity and creativity, but it also represents an opportunity to raise awareness of scientific subjects related to our local Universe. Through the narrated story and the construction of the two nice characters, children learn relevant concepts of astronomy and space exploration.

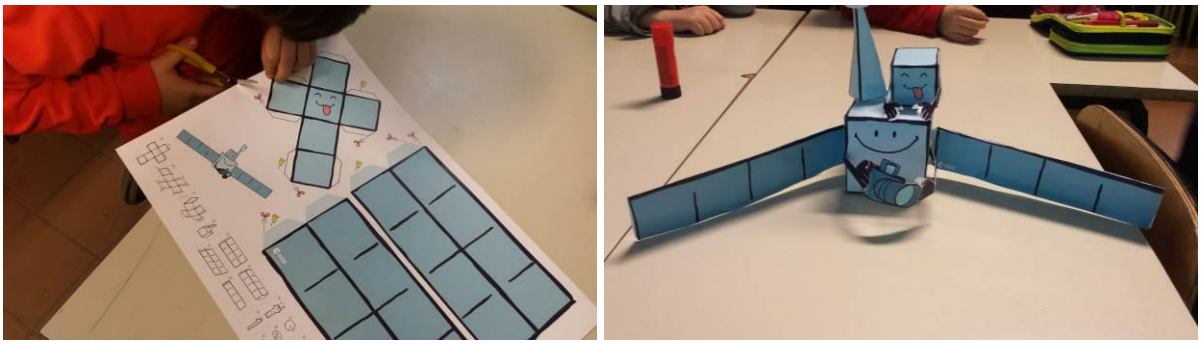

Figure 3 The great adventure of Rosetta.

2.4 Coding with Scratch

In the last two years we registered an increasing demand of activities aimed to develop computational skills and problem-solving attitude [2]. Since these are two aspects very important also in our research activities, we decided to support schools in this new path, providing primary and secondary schools with a series of simple, fun and easily accessible tools to introduce students to the coding and helping them to develop the computational thinking. In two experimental lessons, children will be approached to coding using Scratch, a free visual programming language developed by the Lifelong Kindergarten group at the MIT Media Lab to help them (ages 8 and up) to learn to think creatively, reason

systematically and work collaboratively. Students learn how to draw, how to generate, reproduce and use sounds, and how they can create stories (digital storytelling). With Scratch, children can create their own interactive stories, then share and discuss their creations with one another. Our laboratories include the presentation of the Scratch environment, the execution of a single command, the sequence of executions, the use of variables and lists, operators, multitasking and event-driven programming, as well as some examples related to astronomy and astrophysics: the animated Solar System, the life of a star, the Big Bang theory (as a digital storytelling example), and fun interactive games with spaceships that destroy asteroids to save the Earth. Finally, the Scratch portal is presented, where students are able to share their projects and work on the projects of other children all over the world. Students are guided to the use of the portal, proposing a sort of guided tour to the galleries of shared works.

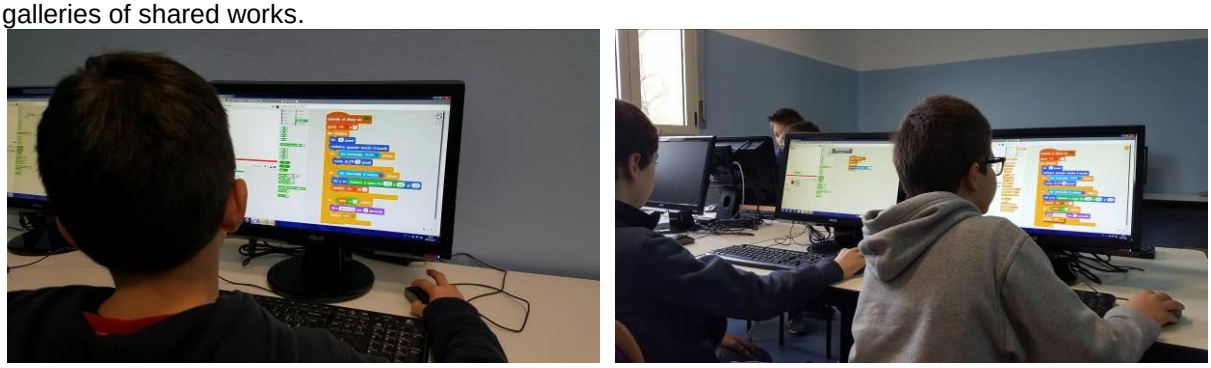

Figure 4 Coding with Scratch.

2. Activities during public events

The INAF – OAS Bologna pays careful attention to the public outreach, too. We actively participate to annual relevant events such as the European Week of Astronomy, the European Researchers' Night, and the Light in Astronomy week, just to mention some. During these events, we propose some making laboratories (such as those presented above) and, in addition, we have some exhibits very useful to introduce the general public to the gravity force: the planetary weight scale and the planetary bicycle that can be organized in conceptual paths inside a fixed argument. Furthermore, in these contests we introduce some aspects of the educational robotics, that is important both to learn how to build or use robots, and also to learn a method of reasoning and to perform experiments. Educational robotics promotes creative attitudes as well as the capacities for communication, cooperation, and teamwork. The study of educational robotics improves the attitude of interest and openness also towards canonical subjects such as mathematics and physics. It is therefore a question of directing the students toward a new method of study based on the concepts of problem solving and learning by doing. The study of planets and moons of our solar system provides an opportunity to design robot and, during the activities, researchers and technologists explore various aspects of astronomy and space exploration.

Figure 5 Left: Children remotely control a rover that is able to take and move material on a surface that reproduces the ones of the red planet (Mars), with dust, stones and small dunes. Right: the child travels among planets of the solar system using a bicycle, discovering the effects of gravity.

References

[1] H.B. Gonzalez and J.J. Kuenzi “Science, Technology, Engineering, and Mathematics (STEM) Education: A Primer”, Congressional Research Service 7-5700, R42642, 2012.

[2] Papert, S. “Mindstorms: Children, computers, and powerful ideas”, Basic Books Inc., 1980.