Moon Rover Challenge. An educational space robotics resource to teach programming and promote space careers at secondary education levels

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Abstract

Nowadays, space educational activities are essential in schools, in order to show the importance of space research and exploration in our daily and future life. Space related activities provides teachers tools and a fascinating context to get students involved in different disciplines which are 'difficult' for them. In addition, programming is one of the most important skills in technological areas. Space technology is full of programming, algorithms, and code. However, students' perception is different because they think coding is difficult and they will not be able to program a satellite or a rover, so they are not very interested and motivated to learn to program.

A widely useful tool to motivate students to learn programming is educational robotics, which uses physical robots and block-based programming interfaces to attract their attention. However, these robots are not accessible for all schools, and it is difficult to use robots in the online environment created by COVID-19. Therefore, online tools are becoming more and more important in education, because they make activities more flexible and accessible for schools and students.

In this paper, we show an educational resource that used space robotics as a context achieving two main objectives: to promote space careers and teach and motivate high school students to learn how to program. We also show our conclusions and lessons learned, after implementing this project in two different situations. The students' challenge is to control a Moon rover, which is on the Moon surface in order to fulfil a space mission. The activities can be performed completely online using an online simulation tool and block-based programming language.

We tested the educational material in an online event with many high school pupils and also in a face-to-face lesson with pupils studying a technical module. The experiences and feedbacks were positive and allowed us to improve the initial activities. Moreover, the results show students are more interested in space careers after completing the challenge. Space robotics give us a perfect opportunity to introduce subjects such as programming, robotics, and technology to students. These areas will be essential in the future and we have to change perception of the space industry because it is fundamental for the development of space exploration and our society.

Keywords

Block-based programming, Educational resources, Outreach activities, Robotics, Space context.

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Acronyms/Abbreviations

ESA	*European Space Agency*
ESERO	*European Space Education Resource Office*
STEAM	*Science, Technology, Engineering, Arts and Mathematics*
ORL	*Open Roberta Lab*

1. Introduction

Space industry and exploration are essential for the technological and scientific development of our society. For most people, to work in the space industry just means being an astronaut, but behind a space mission there is a lot of work and different specialists who work as a team: programmers, engineers, astronomers, mechanics, doctors, welders, etc.

The Space industry involves technical disciplines which seem as 'difficult', such as coding, robotics, technology and electronics. Young people have the perception that these disciplines are very complicated. For this reason, teaching these subjects to primary and secondary pupils using an educational context is essential. Students are more easily involved and engaged if the learning activities are set within an interesting context [1]. That is because they are more interested in learning when they can relate the theory to the real world [2].

The European Space Education Resource Office (ESERO) provides a direct link between the European Space Agency (ESA) and teachers [3]. The ESA Space Missions are multidisciplinary as they involve programming, simulating, engineering, etc. As a result, school activities based on ESA's Missions allow students to interact with STEAM (Science, Technology, Engineering, Arts and Mathematics) disciplines in the classroom [4]. In accordance with this, ESERO offices have developed a long list of educational resources, based on ESA's Missions, called "Teach With Space collection" [5], for teachers. These resources use space as a context, to engage students to be more motivated to study disciplines like physics, biology and science.

Educational robotics is commonly used as a multidisciplinary tool to teach programming, because it materializes the abstract behaviour of algorithms [6]. The clearest example is LEGO Mindstorms [7]. Another important fact is most educational robots have a programming interface which uses block-based programming language, interactive structures and graphics to catch students' attention. This is due to the fact that programming with blocks permits students to forget the technical problems and they can focus on the structures and logist [8]. Students who programme in blocks are not quicker learners, however they have the perception that it is less complex [9], and this is directly related to the learning context.

So, one question is clear: learning coding in a real context attracts students to technology and programming, because it changes the perception and makes coding more interesting for students [6]. Also, the context plays a determining role in girls' perception of programming. Girls, who are often not interested in traditional approaches to robotics and programming, become motivated when programming activities are introduced as a story or connected with other subjects and areas of interest [10]. Space robotics is the union of two great backgrounds, robotics and space, and it involves motivation, programming, space careers and a long list of multidisciplinary disciplines.

Despite the fact that space robotics is a fantastic context, it is not always possible to have a robot to program and a table simulating Moon surface in the classroom. Educational robots are usually a bit expensive and schools cannot afford them for all students. Moreover, programming a robot in an online class is not possible. In 2020 and 2021, the educational system became to totally online because of COVID-19. Online tools have been essential to help learning in this situation and makes it more accessible.

In this paper, we present an educational resource for secondary education levels. The main goals are to teach programming and to promote space careers, taking advantage of block-based programming language and Space robotics as a context. Presenting the learning activity as a Space robotics Mission, motivates students to consider a Space career as a good career choice. At the same time, using block-based programming tools makes coding more attractive for them. Moreover, we used an online tool to program and simulate robot movements, so we do not need a physical robot to do the activities. Students can easily see if the robot is performing well, doing the simulation. Furthermore, performing

simulations is one of the most important phases in a technological project development. In any space mission, millions of simulations are carried out before the spacecraft is tested [4], especially if it is manned.

The challenge is based on the ESA 'teach with space' resource 'Mission to the Moon' [11], which is contextualized in the ESA Heracles robotic mission. Students work as ESA programmers who are developing a program to remotely control a Moon rover. Our rover goal is to take some surface samples and bring them to the Earth. Students have to complete a set of activities to fulfil the challenge.

All educational materials developed have been tested in two learning situation involving secondary school students. We did these activities in the framework on ESERO Spain. In both cases, resources were easily adaptable to the situations, learning rates and classroom formats. More than 80 % of students showed more interest in space careers and coding after completing the challenge. In addition, using a totally online platform made it possible to forget all problems associated with the use of physical materials and software installation.

2. Methodology

The software we used to complete the activities is Open Roberta Lab (ORL) [12]. This online tool has a block-based programming language and allows robots' movement simulation in a configurable online environment.

ORL is an open-source platform to programming and simulating robots. It was developed by Fraunhofer Institute for Intelligent Analysis and Information Systems and financed by Google Germany inside the initiative 'Roberta- Learning with robots' [13]. It is so easy to use, through any web browser. In the main interface you can see the programming area and the simulation tab. The simulation environment makes it possible personalizing the backgrounds, color areas and obstacles [Figure 1]. This is essential to keep the space context all the time, because the robot will stay on the Moon surface all the time.

The educational resources we have developed include all the materials that teachers need to complete the challenge in their classroom: a teacher's guide, taking into account curricular contents, with all important aspects in the educational planning, and practical guides for students using a scaffold-type methodology. This implies instructions to complete little milestones, in order to achieve the final challenge.

The title of the first mission is 'Back to the base!' where students have to program the robot to go to the base camp. Students have to use action programming blocks and calculate the angle to turn. This mission has lots of solutions. The second Mission is 'Searching Moon surface samples!' The robot has to take four samples, which are spread over the entire surface. Students have to use colour sensor and action blocks. The last Mission is 'Let's race on the moon!', where students have to program a Rover to follow a line. They have to use loops and sentences to fulfil the mission.

Apart from performing simulations, ORL is prepared to load programs in different educational robots and development boards. Moreover, it allows account configuration options, save programs, share programs and manage user groups.

3. Results and Discussion

All educational materials developed have been verified in two learning events involving secondary school students [Table 1]. These activities are part of the ESERO Spain awareness-raising events during the year 2021.

Table 1. Experiences Summary

	Engineering fair	Technical module
Date	21 April 2021	26 May 2021
Students	291	10
Time	1 hour	2 hours
Format	Online	Face-to-face

We designed a simple form with two questions to get some feedback from students:

- Question 1: after doing these activities, do you think space careers are more interesting?
- Question 2: Would you like to work at the European Space Agency?

Also, we asked them how many missions had been completed [Table 2].

3.1. Engineering Fair

We developed the first version of our resources to do an outreach activity in the engineering fair

2021, so the material we used to participate in this event, was the first draft of the challenge, and it can be seen in the platform with the other activities [14]. The first edition of this fair was in 2019. In the year 2021, due to the pandemic situation, this event became online and it was in April.

Table 2. Students form Results Summary (percentages)

		Engineering fair	Technical module
Q1	Yes	82	74
	No	12.8	17.6
	DK	5.2	8.4
Q2	Yes	88.4	90.8
	No	8.8	4.8
	DK	2.8	4.4
Percentage of students who have completed the mission	M1	97.5	100
	M2	62	90
	M2	31.5	70

The Engineering fair is an event organised by the University of Granada. The objective is to introduce engineering areas to secondary school pupils and its professional outings. This programme is especially for girls, to show them engineering is for everyone and they are as capable as boys of studying a technological degree. During one-week, different schools visit university laboratories and equipment to do different activities like workshops, talks, experiments, etc.

The format was a live online connection with schools [Figure 2]. Classrooms from six different secondary schools connected to do the workshop simultaneously, in total 291 students and 13 teachers. Results were as good as we expected, more than 88 % would like to work at ESA. Moreover, during the workshop students were enthusiastic to get to know the next challenge.

After this experience we realised the activities were so useful, flexible and engaged students in programming and knowing more about the Moon and space exploration. However, only 31.5 % of the students finished the third mission. As a result, we have developed new introductory activities to help students to fulfil this last challenge.

3.2. Technical module

In this case, the format was face-to face with pupils who were specializing in microcomputer systems and networks module. These students are usually not motivated to learn, and they do not have any future expectations regarding becoming programmers, engineers or workers of a big company like ESA. They did not have any experience in programming,

For this time, we had the updated material, with two more introductory activities to program loops and sentences. We had two hours instead of one as well. All these facts helped students to complete all the challenges. As they did not have any experience in programming, 70 % completed the last mission.

The space context was the key to catch their attention. Space robotics motivated them to do the activities and they showed a lot of interest in space missions and exploration rovers. ‘How many rovers are there in space? Who designs the rovers? How can I apply to work at ESA?’ were some of their questions. 90.8 % of them wanted to work at ESA in the future.

4. Conclusions

We have developed a space educational resource which puts three key elements into practice: space robotics as a context, block-based programming language and online simulation tool. Contextualizing activities inside space robotics which seems ‘unreachable’ from the outside, is a way to change this perception and show that anyone can be a space programmer.

In both cases we obtained the similar results, the interest for space careers and industry were higher after completing the challenge. From our point of view and experience, girls have some ‘fear’ of technological areas, and it is necessary to change this. Introducing activities with the mysterious space context can help to attract them and increase their motivation. We have improved the material, including more activities and taking into account the students’ feedback. Also, we plan to put this challenge into practice again with new modifications and improvements.

Education is the base of a society and teachers are essential in this process. They teach us to develop our skills, to know our environment, its characteristics and possibilities, and this knowledge makes us free to choose our future.

Apart from the main goals of this challenge, we wanted to show with this educational resource that the limits are only in our minds and the space industry is waiting for the new generation.

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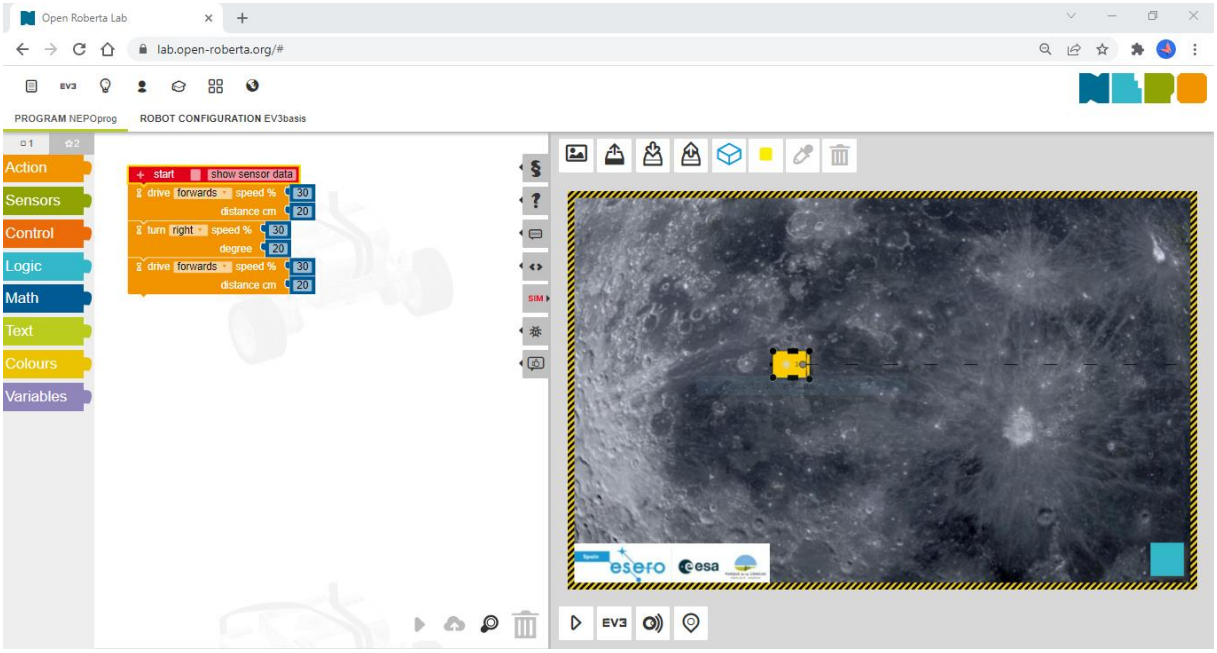

Figure 1. Open Roberta Lab environment with Moon surface simulation background [12]

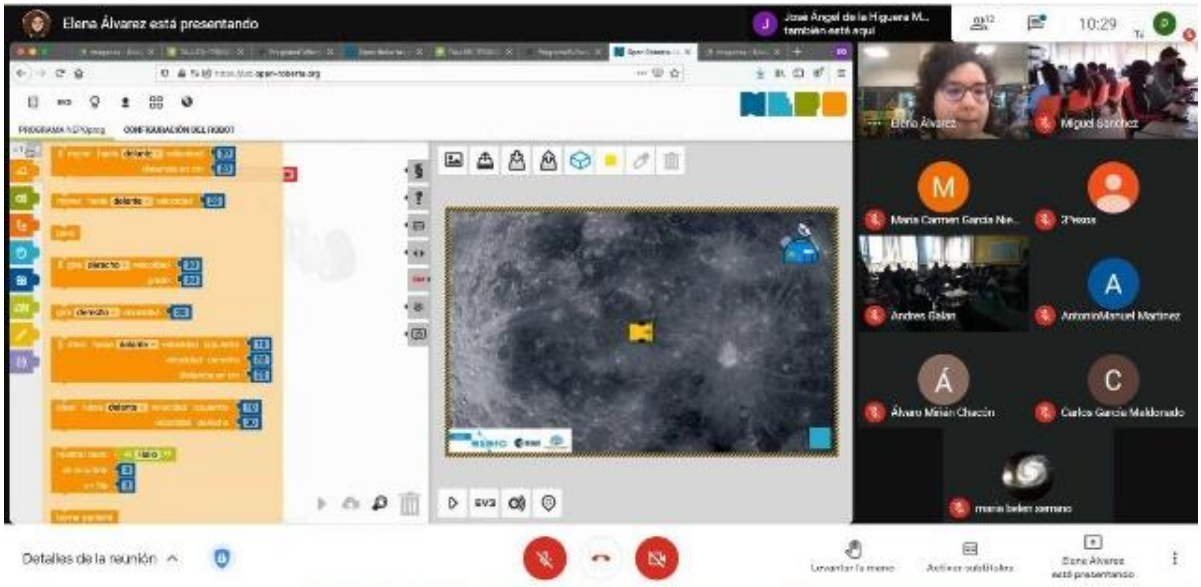

Figure 2. Live connection at engineering fair (21/04/2021)