Design and implementation of space educational activities to motivate young students in Catalonia

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Abstract

STEM education is a new interdisciplinary concept that fuses the learning objectives of sciences, technology, engineering and mathematics. After concluding that many undergraduate students are not interested in STEM disciplines and taking into account the admiration for space, a series of educational activities have been developed to increase their engagement in this field. The proposed project-based workshops are diverse: designing and launching High Altitude Balloons; building water rockets; protecting an egg from the impact with the ground after being dropped from a drone; designing and building paper gliders; 3D printing customzied quadcopters, etc.

One of the most impressive activities consisted of designing, manufacturing and launching a low-cost high-altitude balloon to take photographs of the stratosphere. To do so, a kit was developed and validated: this contains a GPS tracker, a camera, an EPS box, a parachute and a helium balloon. The selection of the components was done trying to minimize the operational cost and maximizing the reliability of the design; the final High Altitude balloon weights 350g and has reached altitudes around 27.000 - 30.000 m. The educational activity is a 3 to 4 days workshop in which the students go through the process of building their own HAB, launching it and eventually recovering it to obtain the photographs.

The activities have been implemented in multiple schools and high schools in Catalonia, and all of them have shown excellent results. After evaluating the reasons why the workshops were well-received, it was concluded that students were more implicated than in standard lectures because they went from a passive to an active mindset. Moreover, the workshops were designed to make them become curious and increase their eagerness to learn, while forcing them to think and to take important decisions that ultimately influence the final result, rather than observing and admiring somebody else's work.

Keywords
STEM, Space, Workshop, HAB

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Acronyms/Abbreviations

HAB	*High Altitude Balloon*
STEM	*Sciences, Technology, Engineering, and Mathematics*
UAV	*Unmanned Aerial Vehicle*

1. Introduction

STEM education is a new interdisciplinary concept that fuses the learning objectives of sciences, technology, engineering and mathematics. It is a new way of learning, usually related to the project-based methodology, which stimulates interest and creativity among students. STEM careers are growing more and more as a demand of high-technological future societies (IoT, Smart Cities, 5G…) [1]. The problem lies in the fact that STEM studies are usually not the priority among undergraduate students and this could result in a decrease in the life quality of future societies [2]. Moreover, there is an important gender gap when dealing with STEM disciplines: The majority of bachelor's degrees are obtained by women; however, STEM subjects are not attractive to them [3][4]. Increasing this interest in early phases of education such as high school can reduce the gender and social class gap [5].

On the other hand, in many countries, it is very common to divide the disciplines into mathematics, technology, engineering and sciences when killing the creativity among students and making the learner lose generality whilst being close-minded [6]. This can be improved by applying a project-based methodology - to increase creativity and interest - with a STEM framework. As can be seen, new ways of teaching need to be put on the table in this new era: the learning procedures need to adapt to the new world.

Most of the programs and activities that use space to motivate young students to increase their interest in STEM disciplines use an admiration-based methodology: They consist of showing examples of big achievements of difficult challenges (outreach strategies of Rosetta mission and Apollo program) [7]. Usually, in this kind of outreach strategies, the student does not have the opportunity to create anything. This is a logical approach since access to space is, in the majority of cases, expensive and technologically difficult. By doing so, most of the potential of space and its attractiveness to motivate high-school students to start STEM careers is lost because they adopt a passive attitude rather than an active one.

In order to solve this shortcoming, a non-profit organization called GoSTEM was created. This is a project born in the International Space University to motivate students from all over the world to pursue STEM careers. The goal of the organization is to find an educational project for each interested school, association, or group of students considering their needs and their desire to enter the world of space and STEM.

2. Workshops and activities

Currently, several workshops and project-based activities are being proposed by GoSTEM. These are:

1. "High-Altitude Balloon: photographs from the stratosphere".
2. "Saturn V: Fragile launch".
3. "Opportunity: Landing in an unknown planet".
4. "Wright Brothers' challenge".
5. "3D-printing your own drone".

All workshops are composed of the stages depicted in Figure 1.

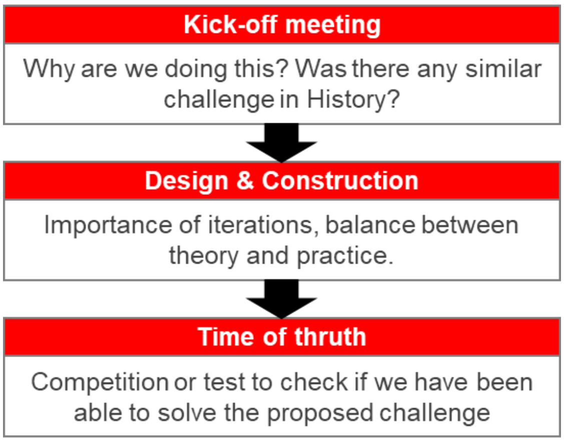

Figure 1. Workshops and activities architecture

Follows a small description of the activities and workshops. Note that all the workshops have been designed to be done with several students working simultaneously. In some cases, the motivation and capabilities among them vary and this may cause difficulties when trying to maintain a uniform flow when doing an activity. To solve this problem, all the workshops described hereunder have different layers of complexity and guidance. This allows the students to adapt to different rhythms and to feel comfortable within the educational activity.

2.1. High-Altitude Balloon: photographs from the stratosphere.

This is, without any doubt, the most impressive activity done by GoSTEM. The educational workshop consists of a 3-4 days project, whose ultimate goal is to take a photograph of the

Earth, from the stratosphere as the one shown in Figure 2.

Figure 2. Photograph of the Earth at 36.000m altitude (Taken by GoSTEM).

To do so, the students receive a kit designed by GoSTEM containing the following items: A sports camera, two independent GPS Trackers, all required components to do the platform for the High-Altitude Balloon, the parachute, and the weather balloon with helium [8].

Figure 3. GoSTEM High Altitude Balloon kit

2.1.1. Camera

To select the most appropriate camera for the HAB, five different properties were considered: weight, cost, image quality, temperature resistance, and battery duration. The final selection was an Apeman A80, which has an image resolution of 20 MP, a maximum visual angle of 170º, a minimum self-timer shooting mode of 2s, and a battery that has proved a duration of 120min @ -18ºC [9].

For this component, the students have to do a trade-off between the battery duration in low temperatures, image quality, and the rate at which the photographs are taken.

2.1.2. GPS Tracker

For the tracking system, 2 redundant devices are included in each kit. Both trackers are GPS-based but differ on the way of transmitting their position to the ground station: A SPOT Trace is used to transmit the position of the HAB via satellite (Iridium-based) [10]. An Invoxia GPS does the same function but transmits its position via the SigFox network [11].

2.1.3. Platform

The Platform is composed of three different components: an EPS Box (internal dimensions 160 mm x 95 mm x 35 mm), cross-linked polyethylene for the interior of the box, and methyl methacrylate to cover the hole for the camera.

The students are in charge of cutting, gluing, and preparing the platform to accommodate all other components.

2.1.4. Parachute

The parachute is built from scratch using nylon fabric. This is one of the most interesting designs that the students have to develop. From a basic equation that represents the static equilibrium between weight and drag, the students have to derive the parachute diameter from a given HAB mass and drag coefficient. Moreover, they have to do a trade-off to select the terminal velocity of the HAB. If the terminal velocity is too high, the components inside it such as the camera or GPS can brake down. On the other hand, if the terminal velocity is too low, the HAB can travel too much horizontally during its descent and this increases the probabilities of landing in remote areas.

2.1.5. Weather Balloon and Helium.

After many iterations, it was concluded that is was highly recommended to use an over-dimensioned weather balloon. This allows the HAB to ascent very quickly (which is favorable given the low battery durations in low stratospheric temperatures).

Moreover, online calculators such as the one presented by Habhub [12], are used to predict the flight of the HAB. Since these online tools require inputs in the form of parameters that describe the HAB, students are usually motivated to do tests and calculations to estimate properties such as the ascent and descent velocity.

2.2. Wright Brothers' challenge

This is one of the most complex activities proposed by GoSTEM. The challenge proposed to the students consists of designing and building a carboard airplane following all the design guidelines of a real airplane.

The concepts explained to the students include static and dynamic stability of an airplane, Lift,

Drag, Center of Gravity, etc. This is presented in a simplified way that allows the students to understand the basic concepts without overwhelming them.
After going through structural and dimensional tests, the airplanes are thrown using a dedicated launch pad.
The structural tests consist of supporting the airplanes by their wingtips and hanging a mass from the airplane center of gravity.

Figure 4. Wright's Brother's challenge

2.3. Saturn V: Fragile launch & Opportunity: Landing in an unknown planet

These two activities are very similar and share the same architecture: a challenge is presented to the students consisting of designing, building, and testing a capsule capable of protecting an egg against its fall to the ground. For the first activity (Opportunity: Landing in an unknown planet), the capsule is launched with a water rocket and, with the second one (Saturn V: Fragile launch), the capsule is launched with a quadcopter UAV or by other analog means.
As all engineering challenges, a set of requirements constraints the design of the students:

- Maximum mass
- Maximum quantity of tokens used to buy materials to construct the capsule. *(Each student starts the activity with the same amount of tokens and the non-compliance of requirements supposes the removal of them)*
- Design envelope

This makes the students to work with a clear objective and the activity forces them to retrofit the design in order to meet the requirements.

Figure 5. Opportunity: capsule launch from UAV.

2.4. 3D-printing your own drone

The majority of educational activities consisting of building drones are limited to building a pre-designed UAV. GoSTEM has proposed, for this activity, the following: the students receive all electronics required to build a standard quadcopter, a set of 4 motors, and a flight controller. The challenge consists of designing and 3D-printing the frame (platform) of the quadcopter. The final drone contains a camera to transmit real-time images and a wifi-based comms system.
The activity also deals with concepts such as stability vs maneuverability by proposing different challenges to the students and making them adapt the design for each situation. An example of this is how the students have to adapt a drone prepared for an obstacle course to a drone capable of carrying a mass. The driver of the first design is maneuverability, hence, it has to be designed with short legs and low mass. The second one, on the other hand, has to have long legs to maximize stability.
The educational activity is complemented with simulators to practice how to fly a quadcopter.

3. Results and Discussions

In total, 698 students have participated in different activities, distributed as follows:

Table 1. Results [1]

Project	Students	
	M	F
"High-Altitude Balloon"	13	17
"Opportunity: landing in an…"	201	247
"Wright Brothers' challenge"	49	32
"Saturn V: Fragile launch"	68	55
"3D-printing your own drone"	10	6
TOTAL	**341**	**357**

In summary, all the activities were a success: all the students had a great time developing their creations. As a reminder, the main objective was to motivate young students to engage in STEM disciplines by using the attractiveness of space. Their motivation during the activities was obvious since the vast majority of them were extremely engaged during all the workshops. This could directly imply a growth in the number of students engaged in STEM careers. After surveying all the participants, they declared that they increased their comprehension of the STEM concepts treated during the activity. Furthermore, they emphasized that the proposed workshops allowed them to have a first-hand experience with the theoretical concepts that the teachers explained to them in class.

In terms of gender equality, 51% of the participants were female students and no difference was appreciated between the motivation and performance between female and male students.

4. Conclusions

The educational project has proved to be an excellent platform to fulfill the objective of popularizing STEM disciplines.

The next steps would be to reach more and more schools and associations to continue motivating young students to engage in STEM disciplines.

As an example of this, two measures have already been implemented:

1. The creation of a website to present the project and spread it among all the schools in Catalonia:

   www.gostemspace.com

2. The creation of a summer camp that encompasses all GoSTEM workshops:

   www.spacecamps.cat

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