Challenge-Based Learning and the Barcelona ZeroG Challenge: A Space Education Case Study

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Abstract

Challenge-Based Leairining is a STEM Education methodology that has been used as a collaborative and hands-on approach to encourage students to put their knowledge in practice by addressing real-life problems. Space Education is a field particularly suited to apply it, with hands-on research projects which require students to take actions and communicate their efforts in a multicultural, international scenario in order to produce an optimal response a specific goal. We herein present a successful Challenge-Based Learning Case Study which involves designing, implementing, and actually flying a microgravity experiment in parabolic flight. The Barcelona ZeroG Challenge is an international competition addressed to University students worldwide. It challenges students to build a team with a mentor, propose, design, build and fly their experiment in microgravity and finally communicate their findings. The experiment has to meet the requirements of a unique microgravity research platform available in Barcelona for educational and research purposes.

More than fifty students have flown their experiments on board an aerobatic CAP10B aircraft in Barcelona in previous educational campaigns; having published their results in relevant symposiums and scientific journals. These campaigns have always attracted media attention. The current edition is underway with the winner team expected to fly their experiment before the end of 2022. This edition is jointly organized by Universitat Politècnica de Catalunya, the Barcelona-Sabadell Aviation Club and the Space Generation Advisory Council. Up to fifteen projects have been submitted to this edition, an unprecedent number so far. A panel of experts from the European Space Agency Academy conducted the selection of the winner team, who receives a 2500 euros grant to develop its experiment, aside from the opportunity to fly it in parabolic flight. Furthermore, students from our own University have also the opportunity of designing and testing their microgravity experiments during their studies.

Principles of Challenge-Based Learning are herein described as well as how this methodology is applied to this Case Study. Results from our experience are very satisfactory as most of the students who have been involved in it perceive this experience as a boost for their careers. Three key factors to success have been identified: a strong involvement from students' associations, a need for international cooperation and the quality of the students' mentoring. The experience can be of interest for other organizations to conduct a successful CBL educational project.

Keywords

Aerobatics, Challenge-based learning, Microgravity, Parabolic flight, Space education.

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Acronyms/Abbreviations

CNES *Centre National d'Études Spatiales*

EASA *European Aviation Safety Agency*

ESA *European Space Agency*

HEI *Higher Education Institute*

IAF *International Astronautical Federation*

ISU *International Space University*

SSP *Summer Space Program*

SEMA *Spanish Society of Aerospace Medicine*

SGAC *Space Generation Advisory Council*

STEAM *Science, Technology, Engineering, Arts and Mathematics*

UPC *Universitat Politècnica de Catalunya*

VFR *Visual Flight Regulations*

1. Introduction

Parabolic flights have been conducted for a long time as a way of performing short-time duration experiments and technical demonstrations [1, 2]. Aircraft parabolic flights provide up to 25 seconds of reduced gravity. They are used for conducting short investigations in Physical and Life Sciences, both for senior researchers and for international student experimentation and motivation, and public outreach.

We report on educational experiments conducted in the Barcelona parabolic flight platform (Sabadell Airport, Barcelona, Spain) with single-engine aerobatic aircraft such as the CAP10B (Figure 1), achieving up to 8.5 seconds of microgravity in its cockpit.

The flight profile results coming from a steady flight profile an introductory pull-up maneuver is performed at increased acceleration (roughly 3-3.5g for these aircraft), pilot reduces thrust and, with throttle or idle engines the airplane follows the parabolic trajectory of a free-flying body. As a consequence, after a short phase of transition, microgravity is obtained for 5-8 seconds.

After the recovery maneuver at increased acceleration (2.5-3g), the airplane flies again horizontally to the ground level for some minutes before introducing the next parabola. During one flight mission typically 10-15 parabolas are performed. Larger aircraft provide between 20-25 seconds of microgravity thanks to a more powerful engine.

The European Space Agency (ESA) has used since 1984 six types of aircraft to conduct its parabolic flight campaigns [3]: the KC-135, the Caravelle from CNES, the Russian Ilyushin Il-76 MDK, the Cessna Citation II, the Airbus A-300/A-310 'zero-g' from Novespace, all of them with 2 or 4 engines. An important number of physical and life sciences experiments have been conducted showing the success of this kind of access to microgravity.

Our approach is different from the successfully previously reported parabolic flights as we propose the use of a small single-engine aerobatic plane. This kind of aircraft (Figure 1) is certified to conduct this manoeuvre and could also be used for professional experiments, testing technology and educational and outreach campaigns as well. Hypogravity is experienced within the cockpit for about 8 seconds with a flight profile significantly different from that of larger aircraft [4].

Figure 1. Mudry CAP10B aerobatic aircraft used for educational parabolic flight campaigns. (Credit: Barcelona-Sabadell Aviation Club)

Parabolic flights have been used very successfully by the space agencies to conduct student campaigns with the aim to motivate the youth to take part in aeronautical and space research. This project is inspired by the ESA Academy hands-on educational projects and, in particular, by the very successful ESA Fly Your Thesis Program [5].

2. Objectives

The objectives of parabolic flights with an aerobatic single-engine aircraft are as follows [4, 6]:

2.1. Scientific & Research

-To study different processes in which abrupt changes of gravity workload are applied. In particular hyper (3 – 3.5g) to hypogravity (0.05g), and hypo to hypergravity periods.

-To analyse transient phenomena that may occur after short periods of hyper and hypogravity.

-To allow experiments for testing the equipment in a real parabolic flight, with the opportunity to manually interact with the equipment and provide a proof-of-concept before accessing other microgravity research platforms.

-If the experiment can be run in less than 8 seconds of exposure to hypogravity, and the residual acceleration of 0.05 g is acceptable, then quantitative and qualitative measurements can be made, thus providing meaningful data. The parabolic flight can provide up to 20 parabolas in a single flight, and weather permitting the procedure can be repeated in a single day.

-In regards to human physiology or physical experiments in which and the hypo and hypergravity environment plays a role, the facility enables different experiments to be tested inside the cockpit, one by one on board (Figure 2). More information can be found at our laboratory website (CSmicrogLab.upc.edu)

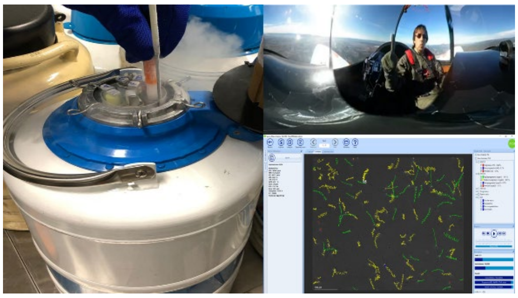

Figure 2. Human reproduction studies conducted in this platform [7]. (Credit: Institut Dexeus, UPC & Barcelona-Sabadell Av. Club)

2.2. Technological

- Assessment of technological equipment behaviour in a hyper and hypogravity environment with abrupt changes in a tiny environment.

- Safety assessment of experiments and technological demonstrations within a parabolic flight aircraft cockpit.

- Training of wannabe or future astronauts for foreseen private or public space missions.

2.3. Education & Outreach

- Allowing students to conduct hands-on experiments in a real weightlessness experience.

- Increasing their interest for studying Science, Technology, Engineering, Arts and Mathematics (STEAM) syllabus, in particular in the aerospace field.

- Providing students from different backgrounds and nationalities with the opportunity of working as a team with a common goal, while interacting with space professionals.

- Raising public interest in space research.

- Creating the opportunity for students to write and present their space research in relevant journals and congresses, and also to further apply to the space agencies educational programs building up their curriculum.

3. Challenge-Based Learning

Challenge-Based Learining (CBL) is a STEAM Education methodology that has been recently introduced as a collaborative and hands-on approach to encourage students to put their knowledge in practice by addressing real-life problems. In 2008, the concept CBL was first named by the technology enterprise Apple® as a methodology to meet the XXIst Century demands [8]. Higher Education Institutions (HEIs) have seen in the recent years how their role had to adapt itself to the arising changes in our society and in particular, STEAM Universities [9]. Our colleges are becoming facilitators for the students' training, including in their syllabus competencies (such as teamwork, creativity or innovation skills) to be acquired, which are required in nowadays' scientific endeavours. Space Education is a field particularly suited to apply CBL, with hands-on research projects requiring students to work with teammates, mentors and experts. They are expected to take actions and communicate their efforts in a multicultural, international scenario in order to produce an optimal response a specific goal.

We herein present a successful CBL Case Study which involves designing, implementing, and actually flying a microgravity experiment in parabolic flight.

4. The Barcelona ZeroG Challenge

The Barcelona ZeroG Challenge is an international competition addressed to University students worldwide (Figure 3). It requires the students to build a team with a mentor, propose, design, build and fly their experiment in microgravity and finally analyze the results and communicate their findings.

Figure 3. Barcelona ZeroG Challenge announcement. (Credit: SGAC)

The experiment has to meet the requirements of a particular platform of microgravity research available in Barcelona for educational and research purposes [10].

More than fifty students have already flown their experiments on board an aerobatic CAP10B aircraft in Barcelona in previous educational campaigns; having published their results in relevant symposiums and scientific journals [4]. These campaigns, inspired by the well-known ESA Student's Parabolic Flight campaigns, have attracted media attention and have promoted public awareness on STEAM studies as well. Four previous editions of the Barcelona ZeroG Challenge have taken place since 2010, with a significant number of the International Space University (ISU) students being involved [11,12, 13, 14,15]. Three workshops had been held in the Summer Space Program and in the Master Space Program of ISU. A new edition of this contest is underway [10], with the winners expected to fly their experiment in 2022. This edition is organized by Universitat Politècnica de Catalunya (UPC), the Barcelona-Sabadell Aviation Club and SGAC, the Space Generation Advisory Council well-known students association. Multidisciplinar, diverse and minority teams of students were encouraged to apply. An independent panel of experts from the European Space Agency (ESA) Academy conducted the final selection of the winner team. In the current edition, the selected students' team receives a 2500 euros grant to develop its experiment, as well as the opportunity to fly it in parabolic flight. An unprecedent number of 15 proposals have been received. Students from 23 different countries submitted their proposals (60% life sciences experiments; 40% physical sciences). Among the participants 63.3% came from Europe, 14.3% from America and 13.4% from Asia. The winner team consists of four female students from the University of Antioquia: Luisa Fernanda Mendoza (spokesperson), Paulina Quintero, Oriana Mejía and María del Pilar Monsalve. The team is called 'Vera Gravitas', which in Latin means 'true gravity', and it also refers as well to Dr. Vera Rubin, a famous astronomer who made important contributions to science [16]. They are part of the Colombian Association of Women in Aerospace, which aims to arise women's interest in this science. The team also has a mentor, Professor Liliana Marcela Bustamante Goez, from the Department of Mechanical Engineering at the University of Antioquia (Figure 4). Their proposed experiment is entitled "Deposition of tin droplets on electronic components in the absence of gravity."

Figure 4. 'Vera Gravitas' Team, winners of the Barcelona ZeroG Challenge 2021.

The experiment seeks to study how soldering electronic components is affected by microgravity, a research topic that may have many applications in the near future. Currently, this team is working with the advice of researchers from UPC and experienced pilots from the Barcelona-Sabadell Aeroclub in order to develop their experiment, adapt it to the cockpit of the plane and fly it this year 2022 at Sabadell Airport. The team is also engaged in an outreach project to diffuse their findings [17].

Furthermore, students from our own University, have also the opportunity of designing and testing their experiments during their studies with a singular hands-on training and an introduction to space research [4, 11]. Master and Doctoral Thesis are good frameworks to include students' advances and contribute to their graduation with a singular experience.

5. Discussion

We first reported a successful series of parabolas performed with a light single-engine aerobatic plane with a life sciences experiment on board. Between 5 to 8.5 seconds of microgravity were achieved with a limited operational cost. The optimization of the manual piloting has made possible to provide a quality of g between 0.05g and 0.005g with a g jitter reduction depending on the strength of wind gusts. Very limited time is needed to prepare and perform the experiment so this approach is specifically suited for those kind of rapid prototyping technology tests, or simple experiments that do not need huge or sophisticated equipments. These parabolic flights are not designed to compete with those from space agencies requiring larger aircraft, instead, they rather extend the range of possibilities available to the researchers and students interested in microgravity research. Among the limitations of small aerobatic aircraft are: limited cockpit size, reduced hypogravity time, no electricity plugs available, only one experimenter at a single flight, higher g jitter sensitivity and a more aggressive flight profile. However, from the point of view of providing a hands-on experience to students it has proven very successful at a reasonable cost.

Educational activities have been from the beginning an essential part of our motivation, and have provided meaningful results and a number of flight opportunities for students' experiments, as well as tutorials after data collection.

Only two mild episodes of motion sickness have been reported in more than 10 years of eductional activities. The visual flight configuration of this platform allows the participant any inconvenience during the flight, and following the pre-established protocol, he or she would be safely held on ground in less than 15 minutes with specialized medical care available on site. Mandatory safety briefings are conducted pre and post-flight.

Students' associations such as the Space Generation Advisory Council (SGAC), are currently involved in this endeavour. Some of the prior participants have declared their excitement for having the opportunity of actually making space research in microgravity, providing outreach to the public, and later publishing the results in selected conferences and indexed journals.

Three key factors to success have been identified from our years of experience: 1- A strong involvement of students' associations, 2- International cooperation and 3- Quality of students' mentoring.

Space students associations are one of the most valuable assets in the astronautical field to promote motivation, mentoring and a meaningful career for their members. They spread the word of the opportunities that eventually arise, and provide an important contacts network which are essential to build up a diverse team such as that requested in this singular challenge. International cooperation involves making use of the professional societies such as IAF to reach the necessary stakeholders for starting and mantaining an educational endeavour.

Last but not least, in the cases that a highly involved mentor was engaged with their students project, there was a unique boost to the quality of their research product. Some mentors even attended all briefings, supervised the experiment in a particular field in which they were recognized experts and researchers, and contributed substantially to the success of their students.

6. Conclusions

We have reported on the educational and outreach activities of an innovative microgravity platform based on single-engine aerobatic planes in Barcelona (Spain) which is ongoing, making a significant impact and inspiring students around the world to get an interest on space medicine and research. Therefore, we plan to continue these activities and expand them in the near future. Among the lessons learned, the students' involvement and international cooperation have been the most important factors that have led this platform successful. Good mentoring is a key factor for the success of students involved in complex Challenge-Based Learning activities.

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