Research-Based Learning: Projects of educational innovation within MUSE (Master's degree on Space Systems) academic plan

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1. INTRODUCTION

The *Instituto Universitario de Microgravedad "Ignacio Da Riva"* of the *Universidad Politécnica de Madrid* (IDR/UPM) is a **research**, **development** and **training** center oriented to space science and technology.

As a result of the European Higher Education Area (EHEA) implementation, the IDR/UPM Institute develop the **Master's Degree in Space Systems** (MUSE, from *Master Univeristario en Sistemas Espaciales*).

A pilot project based on **Research Based Learning** (RBL) is being carried out in the present academic year. RBL applies the scientific method to find solutions to the problems presented, in a search for innovation in the solutions and the processes.

Figure 1. IDR/UPM Facilities at the UPM Montegancedo campus.

2. OVERVIEW OF THE MASTER'S DEGREE IN SPACE SYSTEM

This is a two-year master's degree program with 120 ECTS (European Credit Transfer and Accumulation System) aimed to provide both theoretical knowledge and practical expertise in the space field.

A quite large part of the master's degree program is carried out through Project Based Learning (PBL), defined as a new valuable trend in the educational sector to help the students to put their knowledge into practice.

MUSE subjects are classified according to whether they are monodisciplinary, PBL or can be considered a combination of both concepts. It is important to highlight the subjects defined as "Case Study", in which the students, guided by a MUSE professor, must develop a research activity regarding a project that is being carried out at IDR/UPM Institute.

2.1. MUSE Academic Plan

Type of learning	ECTS (total)	Subject	ECTS
M	54	Advanced mathematics 1	6.0
		Advanced mathematics 2	6.0
		High speed aerodynamics and atmospheric re-entry phenomena	3.0
		Vibrations and aeroacoustics	4.5
		Quality assurance	4.5
		Space industry and institutions seminars	1.5
		Production technologies	4.5
		Space integration and testing	4.5
		Spacecraft propulsion and launchers	4.5
		Orbital dynamics and attitude control	4.5
		Communications	4.5
		Data housekeeping	4.5
M+PBL	34.5	Graphic design for aerospace engineering	4.5
		Space environment and mission analysis	3.0
		Heat transfer and thermal control	6.0
		Power subsystems	3.0
		Space structures	4.5
		Space materials	4.5
		Systems engineering and project management	6.0
PBL	31.5	Case Study 1	1.5
		Case Study 2	7.5
		Case Study 3	9.0
		Final Project	15.0

Table 1. Subjects included in the MUSE classified by type of learning

M – mono-disciplinary learning subject

M+PBL – mono-disciplinary learning subject with some load carried out by Project Based Learning

PBL – Project Based Learning subject

2.2. Research-Based Learning applied to MUSE

For the development of PIRAMIDE, five research *studies* have been proposed, in accordance with five different disciplines in the space sector, each one of them within the frame of a MUSE subject.

Subject	Previous type of learning	Type of learning within the pilot project
Systems engineering and project management (*Study* 1)	M+PBL	RBL
Data management (*Study* 2)	M	M+RBL
Graphic design for aerospace engineering (*Study* 3)	M+PBL	RBL
Power subsystems (*Study* 4)	M+PBL	RBL
Space environment and mission analysis (*Study* 5)	M+PBL	RBL

Table 2. Subjects selected for the application of RBL as main learning tool

M – mono-disciplinary learning subject

M+RBL – mono-disciplinary learning subject with some load carried out by Research Based Learning

RBL – Research Based Learning subject

3. PIRAMIDE: Research Projects carried out by Master/Bachelor Students for Innovation and Space Development

PIRAMIDE (Proyectos de Investigación Realizados por Alumno de Máster/Grado para la Innovación y el Desarrollo Espacial) is an educational innovation project based on Research Based Learning (RBL). Specifically, the project is focused on the application of the main mechanisms on which a research is based.

The main objective is to use the knowledge transference of the research activities for the students training, generating a dynamic framework encouraging the acquisition of research skills by students of the UPM.

The RBL model gives students the opportunity of learning and constructing knowledge from such research procedures as: finding information; formulation of hypotheses; collecting data; analyzing, making, and evaluating conclusions; and writing publications or reports.

3. PIRAMIDE: Research Projects carried out by Master/Bachelor Students for Innovation and Space Development

These studies have been structured in five stages of development.

Groups will preferably be created with a combination of students from both master's and bachelor's degree

To further assist in these concepts, members of two research centers, the IDR/UPM Institute and the STRAST (Sistemas de Tiempo Real y Arquitectura de Servicios Telemáticos) group, are also involved in these projects.

Phase I (February 2020): Generation of teaching material

- Generation of the didactic material necessary for the approach of studies 2 and 4.
- Allocation of resources and tutoring hours.
- Generation of necessary material for the achievement evaluations.

Phase II (March - June 2020): Implementation of Studies 2 and 4

- Implementation of Studies 2 and 4.
- Monitoring of studies and tutoring hours.

Phase III (July 2020): Analysis of Phase II results and generation of teaching material

- Analysis of results: academics, surveys and evaluation of dissemination activities.
- Generation of didactic material necessary for the approach of studies 1, 3 and 5.
- Allocation of resources and tutoring hours.

Phase IV (September - October 2020): Implementation of Studies 3, 4 and 5

- Implementation of Studies 2 and 4.
- Monitoring of studies and tutoring hours.

Phase V (Until the end of the project): Phase IV results analysis

- Analysis of results: academics, surveys and evaluation of dissemination activities.

3.1. Study 1: Design of a phase 0/A of a space mission in a CDF

Concurrent Engineering (CE) is a systematic approach to integrate product development that emphasizes the response to customer expectations. It embodies team values of cooperation, trust and sharing in such a manner that decision-making is by consensus, involving all perspectives in parallel form the beginning of the product life-cycle.

IDR/UPM Institute has his own **Concurrent Design Facility** (CDF), which includes the technology and resources needed to perform parametric studies with the objective of finding a mission solution that fulfils the technical requirements.

Students are trained to understand the mission requirements, transform them into a set of technical requirements and to propose a set of innovative solutions to comply with them. Therefore, students gain the capacity of taking technical decisions, analyzing options and reliability and using advanced technological resources.

Figure 3. Students working in a space mission preliminary design at the IDR/UPM CDF.

3.2. Study 2: Selection and study of an on-board computer for CubeSat missions

The main objective pf this *study* is to introduce them in the complexities of developing on-board embedded computers and their software, so that they can communicate with computer and telecommunications engineers in the framework of complex space projects.

Students are required to put into practice, in a transversal way, the theoretical contents of the different topics, and apply them to a real-life problem in a satellite mission. In order to do that, the students are asked to select a COTS (Commercial Off-The-Shelf) on-board computer for a given CubeSat mission.

Currently, student teams are carrying out the study. Some of them have found difficulties in applying selection criteria such as the amount of memory needed, the number and type of I/O devices, or the need of a floating-point unit. Class lectures and tutorships have been expanded in order to help them with these difficulties, expecting their understanding of the issues related to on-board computers has improved.

3.3. Study 3: Intelligent design methodologies applied to graphic engineering

This Study will allow students to be taught in **Design for Manufacturing and Assembly Integration methodologies** (DFMA). It will be developed from September to December 2020.

The development of the work is established in two complementary objectives: (i) **create** and **evaluate design alternatives**, with the aim of generating data that is used in other disciplines of the project and (ii) design and create a **model configurator** (Mock-up Configurator, MUC) for the design of space platforms.

This project involves the generation and parameterization of complex assemblies of 3D mechanical models. The data transfer for the generation of design modifications is carried out by programming design rules and laws with change control.

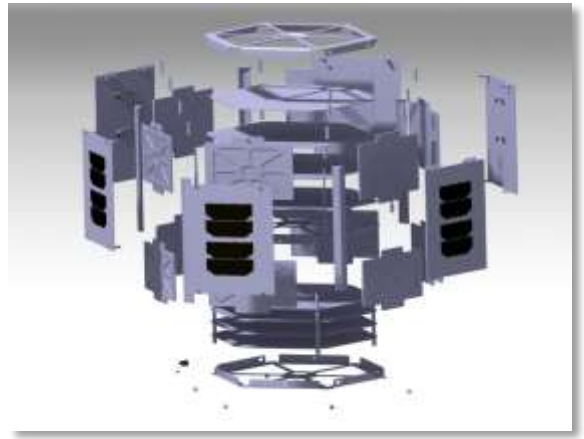


Figure 3. Spacecraft parametric CAD design.

3.4. Study 4: Analysis of power systems for space applications

This Study involves the behavioral analysis of two of the elements that conform the power subsystem of a satellite: the solar panels and the batteries (both studies based on the same type of procedure, the programming of curve adjustments).

A working group composed of six people was assembled from the end of March 2020 to the end of June 2020; supervised by a Professor of the Aerospace Engineering school from UPM.

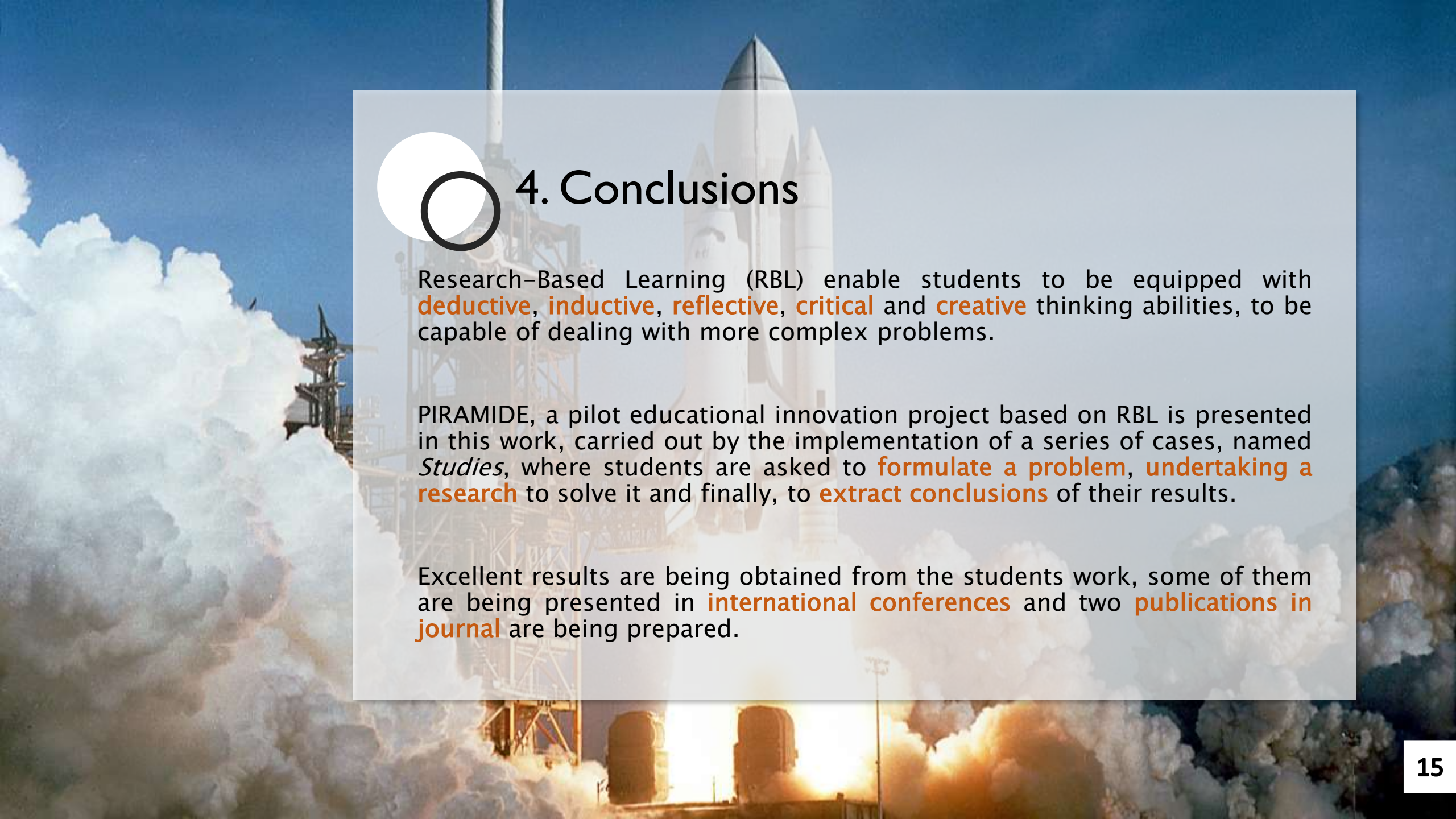
The following research lines have been developed:
(i) analysis of the best value for the ideality factor of the 1-Diode/2-Resistor equivalent circuit for photovoltaic systems modeling;
(ii) simplified expressions of the Lambert W-function applied to analytical calculations related to photovoltaic performance;
(iii) journal list and index-base classification related to solar cells/panels modeling; and
(iv) analysis of the UPMSat-2 battery performances.

3.5. Study 5: Design of an attitude determination and control subsystem

The attitude control subsystem of a satellite consists of multiple elements (sensors, actuators, computers, data acquisition boards…) to calculate and control the position of a spacecraft, and that interact with each other through control laws, filters, etc.

Students will have to develop and implement a **simulated control subsystem**. Each group will carry out the stages of assembly; design of the control algorithm; and implementation of the subsystem.

To emulate this process, the **Arduino development boards** are an ideal element, since they allow obtaining measurements, processing of results, algorithms implementation and the command of actuators. The work of the teams will be to develop the necessary **filters and algorithms** for the control and targeting of the system and implement them on the development board.



4. Conclusions

Research-Based Learning (RBL) enable students to be equipped with deductive, inductive, reflective, critical and creative thinking abilities, to be capable of dealing with more complex problems.

PIRAMIDE, a pilot educational innovation project based on RBL is presented in this work, carried out by the implementation of a series of cases, named *Studies*, where students are asked to formulate a problem, undertaking a research to solve it and finally, to extract conclusions of their results.

Excellent results are being obtained from the students work, some of them are being presented in international conferences and two publications in journal are being prepared.

Thank you all for your attention

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