4.1 Case study 1 (CS1 Portugal)

Concept focus	The effects of microgravity
Activities implemented	Activities A-D
Inquiry skills	Planning investigations
Scientific reasoning and literacy	Not assessed
Assessment methods	Student devised materials (investigation report)
Student group	**Grade:** 11th grade, upper second level; two classes **Age:** 15-16 years **Group composition:** co-ed, groups of 3-4 **Prior experience with inquiry:** Yes

In this case study, the teacher focused on assessment of students' skill in *planning investigations*. The teacher designed a three-level rubric that detailed success criteria for a) defining goals in accordance with their research question, b) identification of variables, c) proposed experimental plan and d) identification of potential limitations. The teacher evaluated students' written artefacts for assessment of these skills.

(i) How was the learning sequence adapted?

The **Up there... how is it?** unit was developed by a physics teacher during the 1st SAILS inquiry workshop. It explores issues related to the effect of microgravity and the activities developed aboard the International Space Station. The unit was implemented in two 11th grade classes, with 32 students aged 15-16. Students worked in groups of three or four. The lessons were carried out according to the suggested lesson sequence in the unit, as follows: a) students read a text about the International Space Station (ISS). Afterwards they were asked to imagine some of their daily routines and how it would be to do it in the ISS (microgravity environment) and they discuss their ideas with all class; b) students watched a video about everyday life in the ISS. Classroom discussion: connect new ideas with the prior ones; c) students, in groups, raised a question to be investigated in a microgravity environment, brainstormed possible solutions, selected statements to test and designed an experimental plan; at the end they d) presented, shared and communicated their experimental plans to the class.

The unit, although suited for upper second level, may also be implemented in lower second level, in particular in the 7th grade within the study of gravity. Furthermore, it is suggested to develop this task in collaboration with the curricular area of natural sciences (biology and geology), as the research questions to be drawn by students at the stage "Going further" may also be in the domain of these curriculum areas.

(ii) How were the skills assessed?

The element of inquiry that this activity assessed was *planning investigations*. In order to assess the selected skill, the teacher designed an assessment tool formed by identifying three levels of performance (Table 1). Students' written evidence was examined and assigned a mark of 1, 2 or 3 using the rubric as a guide.

Table 1: Assessment of the inquiry skill planning investigations

Assessment criteria	Performance level		
	1	2	3
Do students define the goals of the experience clearly and in accordance with their initial research question?	Goals of the experience are not clear or aligned with the initial research question.	Goals of the experience are aligned with the initial research question, but are not clear enough.	Goals of the experience are clear and aligned with the initial research question.
Do students identify involved variables that should be measured and controlled?	Manipulate responding or dependent variables are not identified at all, when applicable.	One or more of the manipulate responding or dependent variables are not identified or are irrelevant for the research.	Identifies manipulate, responding and dependent variables for measuring relevant for the research, when applicable.
Is the proposed process adequate for collecting relevant data, written in a clear language and easy to reproduce?	Proposed process is not adequate: a) Students do not know which data to collect or they do not know how to proceed in order to collect data. b) They develop a process for collecting irrelevant data.	Proposed process is adequate, but it still requires reformulation, as students know which data to collect but they do not know how to proceed in order to collect the data.	Proposed process is adequate: students know which data to collect and they know how to proceed in order to collect the data.
	It is difficult to understand the written proposed process. It will be difficult to reproduce it.	The written proposed process is clearly written. Nevertheless, it lacks some detail and so it will be difficult to reproduce it.	The written proposed process is clearly written and it presents enough details for being reproduced later on.
Do students foresee possible limitations of their experimental plan?	Students only consider some possible limitations of their plan or students point out incorrect limitations	Students consider possible limitations of their experimental plan.	Students consider possible limitations of their experimental plan and they reveal understanding of those limitations.

(iii) Evidence collected

The data collected were students' written documents. These documents consisted of their written answers to the activity. The students written work transcription is presented with *italic black* characters. Each of the three performance levels will be addressed separately below.

Example 1: performance at level 1

1. Question: *With how much acceleration does a body move on an inclined plane according to the time that body take to travel the rail under microgravity?*

2. Goals: *Calculate the final velocity and acceleration of the bodies.*

3. Materials:
- Closed rail with 1 meter
- Solid spheres with 30g/40g/50g
- Measuring tape
- Several objects

4. Experimental procedure

1. *Put the rail at a 30-degree angle with the plan (in order control this variable and the height).*
2. *Pile several objects in order to have a certain height and pin the rail.*
3. *With each sphere, place the sphere at the top of the rail and record the time that the sphere takes to travel the rail.*
4. *Calculate the final speed and afterwards the acceleration for the different spheres.*

5. Used equations

$v = \Delta x/\Delta t$ $\Delta v = v$ *because* $v_i = 0$

$a = (\Delta x/\Delta t)/\Delta t$

$a = \Delta v/\Delta t^2$

6. Table

Mass	*Angle*	*Time*	*Final v*	*Ax*	*Acceleration*
20g	*30 degrees*	*?*	*?*	*1 meter*	*?*
20 cm		*?*	*?*		*?*
10 cm		*?*	*?*		*?*
55 cm		*?*	*?*		*?*

Teacher opinion

The work of the group in example 1 represents performance at level 1. Here students wanted to study the motion of a body on an inclined plane in a microgravity environment. However, the research question is not clear, for example, when students refer to "the time that the body takes to go through" clearly no acceleration will be determined as a function of time, because students will not control this variable. Variables are not clearly identified. They arise throughout the procedure and as the problem (hypothesis) was not clearly defined, it is difficult to identify what physical quantities students intend to measure and control. In the material, one realises that the mass will be a variable (because students mention three masses), which was not made known from the research question and objectives. The procedure is acceptable, but requires reformulations, noting the difficulties faced by students in deciding about the kind of data that they would need to collect. There are still some details missing, for example, are the bodies with different masses released with initial velocity or do they start from a resting position? Finally, the equations are incomplete for calculating the magnitude of variables proposed by students, a table built for data collection introduces inaccuracies, particularly in the unit of mass, and students did not consider any limitations of the experimental procedure presented.

Example 2: performance at level 2

Question: *How does a mixture of two substances with different densities behave in a microgravity environment?*

Goals: *The goal of this experience is to compare the mixture of two substances with different densities on Earth and on a microgravity environment, such as ISS.*

Hypothesis:

- *The olive oil clearly separates itself from the water, although it does not become evenly distributed.*
- *The liquids separate originating a heterogeneous mixture.*
- *One of the liquids is distributed around the other.*
- *The water floats on top of the olive oil, such as the olive oil floats on top of the water.*

Necessary materials to execute the experience:

- *1 bag of 250 ml of water*
- *1 bag of 250 ml of olive oil*
- *1 bottle of 550 ml*
- *2 researchers*

Procedure:

1. *The first researcher simultaneously squeezes both bags to make the liquids move towards the bottle opening.*
2. *The second researcher grabs the opened bottle, gathers the liquids and the closes the bottle.*

	Earth	***Space Station***
Does separation occurs?	*Yes*	
Does the olive oil float on top of the water?	*Yes*	
Does the water float on top of the olive oil?	*No*	
Do they mix evenly?	*No*	
Does the water become evenly distributed around the olive oil?	*No*	

Teacher opinion

These students start by defining a research question and the goals of the experience are clear and aligned with the initial research question. The materials required to perform the experimental plan were identified, and correctly explained by students, and an adequate procedure was designed for collecting the data for responding to the hypothesis raised. However, the second point of the procedure is not clear or reproducible, because it refers to an open bottle, containing liquids; that cannot happen in a microgravity environment. If this point is not revised, the completion of the experiment is compromised. However, after reviewing, the procedure could be acceptable and, therefore, the assignment of the level 2 is appropriate. However, this work did not consider any limitations to the proposed experimental procedure.

Example 3: performance at level 3

Research Question:
Does the firing of a gun cause the same damage on the surface of the Earth and on the ISS?
How much time takes the bullet to do the same trajectory on the Earth's surface on the ISS?

Objective:
Analyse the damage caused;
Checking the depth reached by the bullet on the ballistic gel moulds used as the limit of the trajectory;
Measure the time that the bullet takes to do the same trajectory, between the gun and the ballistic gel moulds;
Compare the results on the ISS with the results on Earth.

Variable:
Initial velocity (constant)
Distance (50 m) (constant)
Time (Δt) (responding)
The depth of the bullet in the ballistic gel moulds (x)
Damages (qualitative variable – observed)

Material needed to carry out the investigation:
Gun | 4 Identical bullets | Stopwatch | Ruler | Laser | Support for gun | 4 Ballistic gel moulds |Calipers | Rope

Procedure:
Install the gun support;
Place the gun on the support;
Place the roper at the gun trigger;
Place the bullets in the gun;
Install the laser and connect it to the stopwatch;
Place the ballistic gel moulds (material used as target) to 50 m from the shooting point;
Pull the rope to shoot;
Record the time;
Measure with a caliper ruler the depth that the bullet enter in the ballistic gel moulds;
Replace the gel and repeat the procedure

Data collection table

On ISS				***On Earth***			
d/m	*t/s*	*x/mm*	*Photo of damage caused*	*d/m*	*t/s*	*x/mm*	*Photo of damage caused*
50							
50							
50							
50							

Limitations
Because the impulse caused by the shooter shooting the gun could affect the results, we used a support

Teacher opinion

Students define objectives consistent with the proposed question. With regard to the variables, they indicate and demonstrate what they intend to control, manipulate and measure, because not only the variables are indicated but also the kind of variables. The procedure is adequate for collecting relevant data, clearly indicating what data they want to collect; the table for data records is an evidence of this. The procedure is written clearly and is reproducible, however, is too synthetic. With regard to limitations, students consider some possible limitations but they aren't relevant and didn't consider other relevant limitations; this example demonstrates that students didn't understand the possible limitations of the experimental plan. Although the work of the group presents some points

that are closer to a performance level 2, such as clarity, reproducibility, and limitations of the procedure, level 3 has been assigned to this planning because students managed to define objectives and maintain consistency with the proposed question, identify variables, and design an adequate procedure for collecting relevant data to answer to the proposed goals.

(iv) Criteria for judging assessment data

The assessment instrument was built before the task implementation in the classroom. After completion of the task, students' work was collected and assessed according to the rubric. This instrument allowed the teacher to assess the students' performance regarding the skill of *planning investigations*, particularly in defining a research problem and its objectives; identification of variables to measure and control; construction of a proper procedure with the data to be collected, clear and reproducible and predicting possible limitations to the proposed procedure. The use of this instrument, organised by criteria and performance levels, decreased the subjectivity of qualitative assessment, such as assessment of skills and analyse collected information from students' work, facilitating provision of oral feedback after completion of the implementation.