SAILS
Strategies for Assessment of Inquiry Learning in Science

TEACHING IDEAS SHARED FROM SAILS TEACHER EDUCATION PROGRAMME

Martian Bacteria in Alentejo?

This resource has been developed through the SAILS Teacher Education Programmes (2012-2015) but was not developed as a finalized SAILS Inquiry and Assessment Unit. These materials are shared to inspire further use of inquiry and assessment of inquiry skills in the science classroom.

Author[s]	Luísa Encarnação
Organisation	Institute of Education of the University of Lisbon
Project Coordinator	Dr. Odilla Finlayson, Dublin City University.
Website	www.sails-project.eu
Email	info@sails-project.eu

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Martian bacteria in *Alentejo*?

This activity is suitable for Secondary Education students (11^{th} grade - course of science and technology). It involves the curricular areas of Biology and Geology, specifically on the following themes "Diversity in the Biosphere", and "Classification and Taxonomy". It consists of five lessons (135/150 min each).

Inquiry skills

This activity aims to contribute to the understanding of inquiry process, namely experimentation, and to the promotion of thinking skills and attitudes and values capable of providing students an active role in decision-making.

Substantive and procedural knowledge:

- Planning experiments
- Collect and record data

Reasoning:

- Interpret data
- Make inferences

Communication:

- Use scientific language
- Presenting data, through various ways
- Present and discuss different ideas

Attitudes:

- Curiosity
- Perseverance
- Creativity
- Observation capability
- Respect for evidence
- Scientific rigor

Suggested Learning Sequence

Student's document

It is intended that you play the role of an astrobiologist, a member of the team responsible for the Phoenix mission to Mars (rover Curiosity). You are in charge of planning a research and implement an investigative procedure for detecting evidence of life on Mars. Admitting the possibility of life on other planets in the Solar System. How to procede?

A - ASTROBIOLOGY – DISCUSSION

I - Watch two *youtube* videos about astrobiology and discuss in small groups.

http://www.youtube.com/watch?v=dXwBhRkUVjA&list=PL8D00472606FEFE6F

http://www.youtube.com/watch?v=w9UrIlDaER4

I. In group work, discuss and answer the following questions:

1. Develop what could be a life definition.

   ____
   ____
   ____

2. What are the necessary conditions for life existence as we know it?

   ____
   ____
   ____

3. What are the possibilities of life existence elsewhere in the Solar System, and which places selected by NASA scientists are the most likely to have life?

   ____
   ____
   ____

4. Why did NASA scientists consider unlikely, either currently or previously, the existence of life on Mars?

   ____
   ____
   ____

5. What is the importance of Astrobiology?

   ____
   ____
   ____

B - ASTROBIOLOGISTS LOOK FOR EVIDENCE OF LIFE: *CABEÇO DE VIDE*[1] AND MARS

Mars is our closest neighbor. It is thought that in the past it was very similar to Earth. While Titan and Europa showed, respectively, a thick atmosphere rich in nitrogen, and a probable liquid ocean under its crust, Mars remains relatively accessible, and have been exploited since the 70s (twentieth century).

I - READING AND DISCUSSION

Read and discuss in small groups, the news about the work that astrobiologists are developing in *Cabeço de Vide*.

NASA INVESTIGATOR MAKES TESTS IN ALENTEJO

Steve Vance Foto © DR

The astrobiologist Steve Vance, from the NASA Jet Propulsion Laboratory, is in Portugal to study the thermal waters of *Cabeço de Vide* in *Alentejo*. The goal is to define more accurate parameters to be able to identify signs of life from geological and hydrogeological analyses. This is, after all, a work that is likely to have repercussions on rover Curiosity mission, taking place over the next two years on Mars.

"I'm trying to demonstrate that I could use a spectrometer similar to the one that is aboard the Curiosity to look for signs of active geology," explain the NASA researcher to the Portuguese newspaper Diary News. When we detect for example, gases such as methane, it is not possible to understand by naked eye if it was produced by living organisms or if it results from geological processes in a particular environment. It is necessary to take more measurements. And it is this step of the analysis that Steve Vance want to adjust. "If you can improve these measurements on Earth, it may help us to better understand the readings we will do on Mars," he states.

The work at *Cabeço de Vide* is finished. Steve Vance returns tomorrow to the United States, but the samples collected in *Alentejo* already went ahead to the laboratory. "We did some analysis on the field and preliminary results seem to indicate the presence of methane and ethane in the samples," says the researcher.

Now this is going a bit further. "I think we will be able to understand if the source of these gases are living organisms or just a result of active geology. Within a few weeks I will have an answer." Then the subsequent tests can be done on Mars.

From the Jet Propulsion Laboratory to *Cabeço de Vide*, Steve Vance followed a path, he says, is giving good results. It all started in 2008 when he discovered that the Portuguese teacher and researcher, José Manuel Marques, from the *Instituto Superior Técnico* had studied and published a paper about the type of active geology found in *Alentejo* region, where water interacts with rock in a not very common way. "I got in touch with him, we started to work and we are very pleased with the results," concludes the NASA researcher.

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[1] *Cabeço de Vide* it is a small village situated in the warm plains of *Alentejo*, Portugal. It lies on the southern slope of a hill, stretching up to the plain and then forming a square that is seen as the broadest between Tagus and Guadiana rivers. Distance 200 Km from Lisbon.

1. Enunciate the underlying scientific problem that the scientists want to explore and compare the problem formulation of your group with those from your colleagues.

   PROBLEM:

   ____
   ____
   ____

2. Indicate possible ways to address the problem stated. What could be the objectives you want to achieve?

   EXPLORING THE PROBLEM:

   ____
   ____
   ____

3. Formulate a testable hypothesis about the existence of life on Mars. What are the variables that you must consider to test your hypothesis?

   HYPOTHESIS:

   ____
   ____
   ____

II - HYPOTHESIS TESTING MODE - PREPARATION OF THE EXPERIMENTAL PROCEDURE

1. You were provided with two soil samples (A and B). What strategies would you use to test these samples for evidence of life, if they were from Mars? (Retrieve you're A.1. answer).

   ____
   ____
   ____

2. Your working group has received the following material:

   MATERIAL:
   - 1 liter chlorine free water at about 60° Celsius.
   - 1/3 cup sugar
   - 2 seltzer tablets (Alka Seltzer ® works well)
   - 7 grams of yeast
   - 6 cups of sand, fine-grained, clean or sterile
   - 3 glass beakers

   Based on the material supplied to your group, plan an experimental procedure that allows you to test the hypothesis above. Remember everything you have learned about the scientific process and the various experiments that you have examined. Be aware of the objectives and variables previously defined, the necessary resources and estimated time you will need. Justify each step of the procedure, foreseeing difficulties and predict the expected results.

PROCEDURE:

3. Discuss the procedure: compare the procedure proposed by your group with the procedures presented by other colleagues. What conclusions do you make about its correctness / errors / improvements needed?

   RECTIFICATIONS:

4. Before implementing your experiment, discuss how and what are the results you will measure / quantify and register, and how you will communicate the results to the other groups.

III - IMPLEMENTATION OF THE EXPERIMENTAL PROCEDURE

1. Resources/materials not provided:

2. Difficulties:

3. Change(s) to the procedure:

4. Observations and measurements:

5. Results:

6. Discussion of the results/conclusions:

7. Time spent:

Assessment opportunities

Students' assessment should be based on aspects such as:

- Understanding the terms and concepts involved;
- The rigor in the development of the experiments and the handling of materials;
- The accuracy of data register;
- The adequacy of the proposed Protocol, namely in terms of the possibility of being tested experimentally and to answer back the question.

Guidelines for the construction and application of an instrument for formative assessment

Purpose: It is intended with this task that students learn the scientific contents provided in the respective planning and develop Inquiry skills. This task allows students to develop several Inquiry skills; however, for the data collection about the assessment process it will be focus on planning and implementation skills.

Teacher actions

1. Before class
   a. Build an assessment instrument considering that the main focus will be in planning and implementation skills;
   b. Adapt the task to students and to the context.
2. In class
   a. At the beginning of the process clarify the assessment criteria (in particular those relating to planning and implementing skills).
   b. At the end of the process, apply a semantic differential to students for identification of their perceptions related to the assessment process.
3. After class
   a. Assess students ' productions having regard to the developed instrument and produce a written feedback;
   b. Reflect on the assessment process.

Competencies	Operations involved	Descriptors (Performance Levels 1, 2 and 3)	
Planning investigations	1. Define objectives (what?)	A. Sets objectives consistent with the problem	1 - Does not define objectives 2 - Does not define objectives consistent with the problem 3 - Define objectives consistent with the problem
	2. Define variables operationally	B. Define operationally variables that purports to study	1 - Does not define the variables that purports to study 2 - Sets the variables incorrectly 3 – Define operationally variables that purports to study
	3. Define strategies and procedures to achieve these goals (How?)	C. Define strategies and procedures which enable you to achieve the objectives	1 - Does not define strategies and procedures 2 – Defines strategies and procedures that do not allow you to achieve the objectives 3 – Defines strategies and procedures which enable you to achieve the objectives
	4. Designing an experiment that allows to	D. In experimental design makes control of variables	1 – In experimental design does not control the variables

	control variables		2 - In the experimental design makes control of the variables incorrectly 3 – In experimental design makes adequate control of variables
	5. Meet and choose the appropriate resources (with what?) (ex.: tools, materials, conditions, observe, etc.)	E. Choose appropriate resources to the goals and strategies	1 – Do not choose appropriate resources to the goals and strategies 2 – Do not choose all appropriate resources 3 - Choose all appropriate resources to the goals and strategies

Competencies	Operations involved	Descriptors (Performance Levels 1, 2 and 3)	
Implement procedures	1. Involves manipulating materials, conditions, observe, etc.	A. Respect the procedures stipulated in the planning	1 – Do not respect the procedures stipulated in planning 2 - Respect the procedures, but with handling errors or accuracy 3 – Respect the procedures stipulated in the planning
		B. Monitors the strategies and procedures, changing them as needed	1 – Do not monitor the strategies and procedures 2 – Monitors, but does not change when necessary 3 – Monitors the strategies and procedures, changing them as needed
		C. Identifies difficulties and manages to overcome them	1 - Does not identify the difficulties 2 – Identifies the difficulties, but not the demand exceeds 3 – Identifies the difficulties and seeks to exceed them
		D. Makes observations and measurements consistently with precision and correction	1 – Do not make observations and measurements consistently with precision and correction 2 - Makes observations and measurements of a consistently, but with lack of rigor 3 - Makes observations and measurements consistently with precision and correction
		E. Correctly use the necessary instruments	1 – Do not use the necessary instruments 2 – Do not correctly use the necessary instruments 3 – Correctly use the necessary instruments

SAILS Case Study – Martian Bacteria in Alentejo?

Topic:	Martian Bacteria in Alentejo?
Inquiry skills, reasoning skills, and scientific literacy:	Planning an Investigation Diagnosing problems Peer debate: communicating results
Student group:	45 science students; ages: 15-17

(i) How was the learning sequence adapted?

It was applied a specific task related with the "Martian Bacteria in Alentejo?" activity. A problem-situation was given to students, who worked in small groups (3-4 elements). The task included three inquiry skills, namely: diagnosing a problem, planning an investigation and peer debate (communicating results). The implementation involved 45 students, ranging from 15 to 17 years old, and extended over two weeks. It was built a specific rubric for each one of the skills, allowing marking student's answers.

(ii) How were the skills assessed?

For the *Diagnosing a Problem* and *Peer Debate*[1] skills were established according to three performance levels, allowing assigning student's answers with 1, 2 or 3. For the skill *Planning an Investigation*[2] were established four performing levels, and assigned a mark of 1, 2, 3, or 4. Each skill was assessed trough the examination of student's written evidence. The rubric to assess *Planning an Investigation* was decomposed in:

a) Define coherent objectives; **b)** Define operational variables; **c)** Define strategies and procedures to tackle the objectives; **d)** Conceive an experimental design with variable control; **e)** Choose resources in line with the objectives and strategies.

The rubric to assess *Diagnosing a Problem* was decomposed in:

a) Identify a specific issue; **b)** Select exploration issues; **c)** Formulate a testable hypothesis; **d)** Predictions for results; **e)** Present arguments and scientific explanations.

The rubric to assess *Peer Debate (Communicating Results)* was decomposed in:

a) Present results; **b)** Explain results; **c)** Formulate conclusions and generalizations; **d)** Propose modifications. This skill was only assessed referring to **a)** and **b),** so there aren't any students work examples to include for c) and d).

(iii) Evidence Collected:

Students' written evidence was assigned a performing level using the rubric as a guide, and will be addressed one by one. The evidence is a transcrip of students' written work (*italic black*) and teacher written observations in their work (*italic red*).

PLANNING AN INVESTIGATION

Sample student artefacts:

a) DEFINE COHERENT OBJECTIVES

2. Indicate possible ways to address the stated problem. What goals to set?
PROBLEM EXPLORATION

Example of Level 1
Investigate common characteristics to all living beings.
Teacher opinion
The student does not define any objectives. The statement doesn't make sense in the context, because the student already made a list of the characteristics common to all living being.

Example of Level 2
Find out how the geological activity influences living organisms. Discover that organisms can survive with or without intense activity.   *Already known!*
Teacher opinion
The student defines objectives, but these are not coherent with the problem, not allowing further exploration and planning experimentation.

Example of Level 3
Look for evidences of life ✓ with organic matter ✓ processing metabolism in planets with favorable environments, such as Mars. Incomplete. ✓
Teacher opinion
The student defines only some objectives coherent with the problem, referring metabolism, organic matter processing, and environmental conditions.

Example of Level 4
What is life? What gases do living organisms produce? ✓ What connection exists between active geology and living organisms? How can one distinguish life and no life from the obtained data? ✓ What is the origin of the produced gases? ✓
Teacher opinion
The student defines many objectives coherent with the problem, allowing proceeding for testable hypothesis formulation. Also mentions most of the important dimensions related to the problem.

b) DEFINE OPERATIONAL VARIABLES

3 – Formulate a testable hypothesis about the existence of life in Mars. What are the variables to be considered when testing your hypothesis?
HYPOTHESIS

Example of Level 1
If the creation of a spectrometer will be possible in the future, it will be possible to prove that living beings or merely geological activity are the source of emission of gases, which are stored in rocks, allowing to conclude on the existence or nonexistence of living beings in Mars.
Teacher opinion

The student doesn't define the variables.

Example of Level 2
If we provide a living being with components that once existed on Mars and test if the living being survives to those reactions, this will prove that there was once life on Mars, being the following variables to consider: liquid water, glucose, carbon dioxide. And what about the rest? What to do with Seltzer tablets?
Teacher opinion
The student defines the variables in an incorrect fashion, leading to difficulties in experimental procedure planning.

Example of Level 3
If… *Find excretions from living beings' metabolic activity or find CO_2 from living organisms' respiration in the atmosphere of Mars.*
Teacher opinion
The student defines the variables involved in the hypothesis, mentioning all the fundamental aspects involved in the hypothesis, but doesn't specify the control or any dependent or independent variable.

Example of Level 4
Hypothesis - *Control: -3 beakers with sand – sugar – H_2O* - *Independent variables: - Yeast – 2 Seltzer tablets* *Dependent variables: observe the gases release pattern, analyse if the origin of these gases is biological or non-biological.* *Lets test the hypothesis, observe the gases release pattern of a biological process (yeast) and of a non-biological process (Seltzer tablets) and register both release patterns, and compare them with the ones from Mars, analysing if its origin is biological or non-biological.*
Teacher opinion
The student's explains and define operationally all the important variables for the experimental procedure.

c) DEFINE STRATEGIES AND PROCEDURES TO TACKLE THE OBJECTIVES

II – HYPOTHESIS TESTING METHOD – EXPERIMENTAL PROCEDURE DESIGN

1. Two soil samples (A and B) were given to you. If those samples were from Martian soil, what strategies would you use to test them for evidences of life? (Retrieve your answer A.1.).

Example of Level 1
To test Martian soil it is necessary to understand the components of its atmosphere. In the soils A and B the strategies I would use would be to visualize temperature and density, as well as gases emission. How?
Teacher opinion
The student statement doesn't define any strategy.

Example of Level 2
The strategy we would use would be the analysis of the soils A and B, gather a sample of terrestrial soil and compare all samples of soil, looking for similarities. What similarities? How?
Teacher opinion
The student defines strategies and procedures that won't allow reaching the objectives.

Example of Level 3
The strategies used to test life evidences in those samples: if they were from Martian soil I would analyse the gases released by the soil samples.

Teacher opinion

The student defines appropriate strategies to reach the objectives, although needing more specification.

Example of Level 4

Regarding both soil samples we would have to consider the kind of effervescence, the time during which that effervescence occurs, hence gases' emission; we would have to consider the organic matter, since the definition of life has to be related with nutrition. ✓

Teacher opinion

The student defines coherent strategies and procedures that will allow reaching the defined objectives.

d) CONCEIVE AN EXPERIMENTAL DESIGN WITH VARIABLE CONTROL

Based on the material that was given to you, create an experimental procedure which enables you to test your previous hypothesis. Remember all you have learned about the scientific process, as well as the various experiences you have analyzed. Be aware of the previously defined goals and variables, as well as the necessary resources, and the time you will spend. Justify every step of you procedure, the difficulties you foresee and the expected results.

Example of Level 1

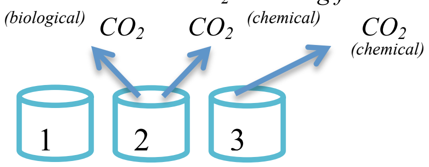
There aren't any answers marked with this level.

Example of Level 2

- Use 3 beakers.

- *In each beaker add to 2 cups of sand and 0,33l of water: one of the beakers remais with just water and sand, because it is the control.* Incomplete
- *In the second beaker add 7g of yeast and 1/3 of a cup of sugar. We use sugar beacuse it is the glucose used by yeast to carry out cellular respiration and fermentation; from this metabolic processes will result CO_2.* ✓ *To this beaker we should also add a Seltzer tablet, which will release CO_2.*

  Why? How to explain the results' causes?
- *In the third beaker just add the Seltzer tablet.* Why? What is the point?
- *With this procedure we intend to find out the difference between the CO_2 resulting from biological activities and the CO_2 resulting from chemical activities.* How will you do that?



1 – Water and sand | 2 – Water, sand, sugar, yeast and tablet X

Teacher opinion

The student makes an incorrect control of variables within the experimental design, testing simultaneously in the same device two independent variables.

Example of Level 3

Goal – verify if the produced gases are from biological or non-biological origin. ✓
Control – A glass beaker with thin grain sand. ✓ Incomplete
Independent variables – Sugar x*, yeast,* ✓ *Seltzer tablets* ✓ *and water.* x
Controled variables – Glass beakers, sand + ? ....
Experimental procedure
1º - Prepare the control beaker. With…
2º - Prepare the second beaker with sand, water and two Seltzer tablets.
3º - Observe and register the results. What do you expect to observe?
4º - Prepare the third beaker with sand, yeast and sugar (glucose).

5º - Observe, register the results. Which? How?
6º - Compare all the results (independent variables). What is the interpretation of the obtained data?

Teacher opinion

The student makes a correct control of variables in the experimental design, but with a few errors, namely confusing a control variable with an independent one.

Example of Level 4

1st Verify if we have the necessary conditions to begin the experience (necessary material in which the yeast are suspended, time and workplace) . ✓
2nd Separate three glass beakers, numbered from 1 to 3, and place 2 cups of sand in each, with equal amounts of water and sugar in each beaker. ✓
3rd Add to beaker 3 (yeast beaker) ✓,previously prepared with water, sand and sugar, 7g of already suspended yeast. ✓
4th Add to beaker 2 (beaker with Seltzer tablets), previously prepared with sand, water and sugar, the 2 Seltzer tablets. ✓
5th Compare what hapens with beaker 1 (default beaker), ✓ which already has water, sand and sugar, with beakers 2 and 3. ✓
Between steps 1st, 2nd, 3rd, 4th and 5th we intend to spend about 15 minutes. ✓
6thVerify how long it takes each beaker to release the gases and the amount of released gases using a chronometer and PH paper to determine the amount that is released in the water and by normal observation.

Teacher opinion

The student makes good control variables in the experimental design.

e) CHOOSE RESOURCES IN LINE WITH THE OBJECTIVES AND STRATEGIES

Example of Level 1

Procedure

.In the first beaker add 2 cups of sand and sugar and H_2O (control)✓

.In the second beaker add 2 cups of sand, sugar and 2 Alka Seltzer tablets. And the water? ✓

.In the third beaker add 2 cups of sand, 7 grams of yeast and sugar. And the water?

.In the three beakers add 1/3l of dechlorinated water at about 160ºC. Isolate each beaker. Why?

.Observe the results afterwards.

.In the first beaker only the suger dissolves itself in the water. Because…?
.In the second beaker there is the release of CO_2 due to the effervescence of the tablets with water (chemical reaction)✓
.In the third beaker there is also the release of CO_2
.Wait some time and observe again.
.In the second beaker one can see that there was no longer the release of CO_2. Since this was a chemical reaction the CO_2 was produced until it stoped. Because…
.In the third beaker one can still observe the release of CO_2 because we are in presence of yest bacteria, which continue to create CO_2 until they run out of nutrients.

Teacher opinion

The student doesn't choose explicitly any resources neither later indicated them, although the presented procedure contemplates not allocated resources.

Example of Level 2

Supplementary material incomplete
1 chronometer ✓
PH paper ✓
1 acetate pen or labels (to number the beakers) ✓

Teacher opinion

Some of the resources choose by student were inappropriate.

Example of Level 3
1.Unforeseen resources *A yoghurt maker was used to increase the yeast and glucose temperature.*
Teacher opinion
The student choose the proper resources, but in an incomplete fashion.

Example of Level 4
III – PROCEDURE IMPLEMENTATION 1. Unforeseen resources: *The use of a thermometer, the use of a yoghurt maker, the use of parafilm and yeast solution (instead of using yeast in grams).*
Teacher opinion
The student chooses all the necessary resources to accomplish the objectives and strategies.

DIAGNOSING A PROBLEM

a) IDENTIFY A SPECIFIC ISSUE

PROBLEM:

Example of Level 1
Is there life in other planets?
Teacher opinion
The student doesn't identify a specific question.

Example of Level 2
Where did the existing gases on Mars come from?
Teacher opinion
The student identifies an incorrect specific question.

Example of Level 3
How to identify life signs in Mars' subsoil?
Teacher opinion
The student identifies correctly a specific question, framed in the problem-situation.

b) SELECT EXPLORATION ISSUES

PROBLEM EXPLORATION:

Example of Level 1
Through the improvement of Earth's conditions we can also obtain more and better results in the researches and measurements conducted in Mars to find out if the gases that exist on Mars are originated by living organisms or just as the result of active geology. There will be the possibility to identify life signs from geological and hydrogeological analyzes.
Teacher opinion
The student doesn't select any exploration issues.

Example of Level 2
Seek evidences of life with organic matter processing metabolism in planets with favourable environments, such as Mars. Incomplete ✓
Teacher opinion
The student selects inadequate issues for exploration and limits the search for information.

Example of Level 3
What is life? What kind of gases are produced by living organisms?What kind of connection is there between

geology and living organisms? How to distinguish life and non-life from the obtained data? What is the origin of the produced gases?
Teacher opinion
The student selects adequate issues for exploration, promoting the search for information.

c) FORMULATE A TESTABLE HYPOTHESIS

3. Formulate a testable hypothesis about the existence of life in Mars. What are the variables you should consider when you test your hypothesis?

HYPOTHESIS

Example of Level 1
- The fact that there are matter, energy and gas exchanges with the external environment. Put this statement in the form of an hypothesis. *- A living being that contains DNA within himself.* X
Teacher opinion
The student doesn't formulate a hypothesis.

Example of Level 2
The field exploration is carried out by the use of specific instruments to test soil characteristics. Using this instruments soil samples are taken on Earth and on Mars, which through geological and hydrological analyzes will allow the identification of life signs on Mars, because if the existing soil and water on Mars possesses similar characteristics to the Earth's samples, it will be possible to conclude if existence of life on Mars is possible or not. This comparison between tests performed on Earth and on Mars allows the discovery of similarities and differencies between samples.
Teacher opinion
The student doesn't formulate a testable hypothesis.

Example of Level 3 (I)
By providing reagents used by living organisms, if we verify the production of organic matter resulting from a reaction to these same reagents, we verify the existence of life.
Teacher opinion
The student formulates a testable hypothesis.

Example of Level 3 (II)
It is considered that all being which carrys out exchanges with the environment has a molecule that contains genetic information and an active metabolism. This can be essential to the existance of life on a planet with active geology, because it will be a rich source of energy and matter, such as mineral gases essential to energy production. ✓ *We can distinguish life and non-life by the resulting gases of the metabolism and by the way they are released, some living beings release CO_2, ethanol and O_2. Those are the data that will allow us to distinguish biological and non-biological material.* How are you going to establish that distinction?
Teacher opinion
The student formulates an inductive and testable hypothesis, supporting it.

d) PREDICTIONS FOR RESULTS

4. Before implementing your experimental procedure, discuss how and what results you will measure, quantify and register, and how are you going to communicate them to others.

Example of Level 1
Day (date) – Time (seconds) – Temperature (ºC) – Presence of CO_2 (absence/presence) – Intensity of CO_2 release – Velocity of CO_2 release (scale) – Present the results on a chart.
Teacher opinion
The student doesn't make any predictions for expected results.

Example of Level 2
We expect to observe effervescence when Seltzer tablets are added to the samples together with water and it will be necessary to wait a few days to see if there is formation of particles in suspension. *Using beakers, measuring spoons, water, subsoil samples, Seltzer tablets and yeast it will be possible to execute the necessary experience to observe the similarities and differences on Earth's and Mars' subsoils.* *Using our definition of life we can check for the release of* CO_2.
Teacher opinion
The student makes a prevision for the expected results, but it's incomplete and some aspects are incorrect or unsupported.

Example of Level 3 (I)
Through the effervescence, the bubbles, we can see that there is the release of gases, and this is one of the evidences. According to the time spent we are calculating the amount of default bubbles, and according to that, the graphics will be different because the gases will released in the same way; what will vary is the amount of gases and velocity versus time. The speed variation and the amount of gases will indicate if the release is biological or non-biological. In the case of a biological release, the reaction will be slower and the amount will be lower. Regarding the non-biological release, the amount of gas will be higher and it will be faster.
Teacher opinion
The student makes adequate and supported previsions for expected results.

Example of Level 3 (II)
We will test the hypothesis by observing the pattern of gases release of a biological process (yeast) and a non-biological process (Seltzer tablets), and thus we will register the release patterns and compare them with those of Mars, analyzing its biological or non-biological origin.
Teacher opinion
The student makes adequate previsions for expected results.

e) PRESENT ARGUMENTS AND SCIENTIFIC EXPLANATIONS

6. Discussion of results / Conclusion

Example of Level 1
It is concluded that the yeast take longer to release carbon dioxide when in water.
Teacher opinion
The student doesn't present any argument or scientific explanation.

Example of Level 2
- In the case of yeast the release of CO_2 *does not occur because it needs time to process glucose (metabolism), therefore after 7 days yeasts have already processed glucose and released* CO_2. *- On the other hand, in the Alka Seltzer there is the immediate release of* CO_2 *due to a complete chemical reaction, not due to the processing of glucose, hence, after one week the release of* CO_2 *does not occur.*
Teacher opinion
The student present incomplete arguments with a scientific explanation.

Example of Level 3
From this experiment we can conclude that the biological processes have a pattern; this pattern is slow, progressive, because the cell cannot withstand conditions in which there is the sudden release of matter. If this happens it would lead to the lysis of the cell. We can also conclude that geological activity is rapid and sudden, however it becomes extint in a very short period of time.
Teacher opinion
The student. Presents arguments and scientific explanations correct and supported.

PEER DEBATE: COMMUNICATING RESULTS

a) PRESENT RESULTS

Example of Level 1
There are no answers marked with this level.

Example of Level 2

Scale: Null – 0 | Slow – 1 | Moderate – 2 | Fast - 3

Observations (records)	*G1 (control)*	*G2 (yeasts) 18/02/2014*	*G2 (yeasts) 25/02/2014*	*G3 (seltzer) 18/02/2014*	*G3 (seltzer) 25/02/2014*
Quantity / intensity (visual)	*0*	*0*	*Few*	*Many*	*0*
Duration and time (Chronometer)	*0*	*0*	*---------*	*47 seconds*	*0*
Velocity (scale)	*0*	*0*	*1*	*3*	*0*
Presence / absence	*Absence*	*Absence*	*Presence*	*Presence*	*Absence*

Teacher opinion

The chosen format is adequate for part of the results, not all. But, the presentation is incomplete and there are some errors in the chosen units.

Example of Level 3

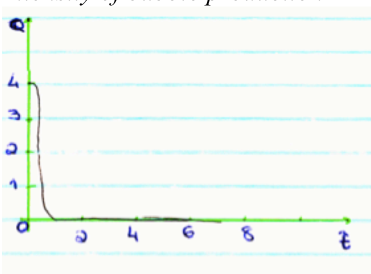
5th Observation (production or no production of bubbles and intensity versus time). Register the results.
6th Compare all results (dependent variables)
All results will be registered and interpreted through a chart and scales created by the group. The observation was made at the time the preparation was made and 7 days after.

Register table of results:

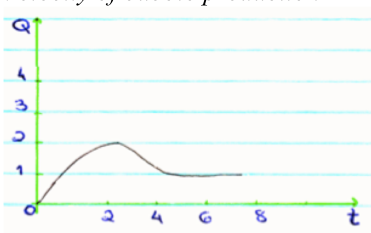
Beakers	*G0*		*G1*		*G2*	
Results	*19/02*	*26/02*	*19/02*	*26/02*	*19/02*	*26/02*
Presence/Absence (s/n)	*N*	*N*	*S*	*N*	*N*	*S*
Intensity (visual scale)	*0*	*0*	*4*	*0*	*0*	*1*
Velocity (visual scale)	*0*	*0*	*¾*	*0*	*0*	*1*
Chronometer (duration)	*0*	*7 days*	*1 13.70*	*7 days*	*0*	*7 days*

Without bubbles 0 | Low intensity 1 | + Or – 2 | Intense 3 | Very intense 4

G1
Intensity of bubble production



G2
Velocity of bubble production



Teacher opinion

The student chosen multiple and appropriate supports to present the results, with correction and adequate units, except for the second graphic.

b) EXPLAIN RESULTS

Example of Level 1

In the first beaker we can see that only the sugar dissolved itself in the water. In the second beaker there was the release of CO_2 due to the effervescence of the tablets in the water (chemical reaction). In the third beaker

there was also the release of CO_2. Seven days later we observed that in the second beaker there was no longer the release of CO_2 because we were in the presence of a chemical reaction which generated CO_2 until it stoped completely. In the third beaker we can still observe the release of CO_2. We concluded that we were in the presence of living beings because CO_2 was still being generated.
Teacher opinion
The student just describes the results not explaining them.

Example of Level 2
The beaker with continuous bubble release throughout the 7 days was G2, which contained living organisms (yeasts), the release was made steadily and at low velocity while in beaker G1 the release of bubbles was sudden and short termed. After observing these results, to find out whether the gas release on Mars has a geological or biological origin, we must take into account the release rate, the activity's processing time and intensity of the bubbles release.
Teacher opinion
The student explains the results in an incomplete way.

Example of Level 3
Through bubble effervescence we can see that there are gases being released; this is one of the evidences. According to the time spent on each release we are calculating the amount of bubbles in a pattern, and according to that pattern the graphics will be different, because the way gases are released is the same, what will vary is the amount of gases and the velocity versus time. The variation of velocity and amount of gases will indicate if the release is biological or non-biological. In the case of a biological release, this will be slower and the amount will be smaller. Regarding the non-biological release, the amount of gases will be higher and it will be faster. *In the next day we went one more time to observe the three beakers and we saw that the beaker which contained the tablet was no longer producing bubbles, and the beaker with the yeast, which in the day before had not produced bubbles was now producing them. These results lead is to believe that the origin of bubbles, whether biological or non-biological, determines the velocity and amount of gases that are produced, but in both cases the production of gases is observed. The beaker that on day 18 had produced bubbles at a high velocity and in a short period of time (the beaker with the tablet), on day 19 showed no longer the release of CO_2 and therefore the movement of bubbles in the water could not be observed. The beaker that on day 18 had no bubbles, the one with the yeast, on day 19 had bubbles slowly moving on the water, hence this beaker had production and release of CO_2. We observed that the bubbles release pattern among beakers was very distinct, this allowed us to conclude that a non-biological reaction is very fast and intense, and a release of biological origin is a reaction that takes more time and also has a reduced intensity.*
Teacher opinion
The student explains the results, supporting them with proper justification and explanation.

(iv) Criteria for judging assessment data:

The skill looked was planning an investigation: the assigned performing level to student's answers was the assessment rubric. It was only implemented by one teacher. The rubric was of easy applicability and feasible to other problem-situations. Before implementation the rubric was discussed with students, and each performing level explained. Thus, students were aware of what was expected from them.

For diagnosing a problem, although examples of performing levels to present arguments and scientific explanations are included, this dimension was assessed by looking over the student written production as a whole. The highest level of performing included aspects such as: forming coherent arguments, based in data, evidence and new scientific information, and present scientific prepositions supporting the question, the hypothesis and the prediction. For scientific explanations were considered specific aspects regarding: the articulate use of data, arguments, evidences and scientific information, involving central concepts and specific terms, the establishment of cause-effect relations and the use of inductive reasoning.

The rubric for the skill peer debate: communicating results, involved two more dimensions, forming conclusions, and generalizations, and proposing changes. These weren't assessed now, with referring to student's written work, because, after communicating results, students will continue peer debate, focusing in *Argue and Refute*, providing an opportunity to students explore their conclusions and generalizations, and consider other scientific explanations.

[1] Assessment instrument - *Diagnosing a Problem* and *Peer Debate*

SKILL	**INVOLVED OPERATIONS**	**DESCRIPTORS (PERFORMANCE LEVELS 1, 2 AND 3)**	
DIAGNOSE PROBLEMS	**1.** Identify a specific question	**1.** Identifies a specific question to be answered and frames it according to the problematic situation	**1.** Does not identify a specific question **2.** Identifies a specific question but it is inaccurate or poorly framed **3.** Identifies correctly a specific question and frames it according to the problematic situation
	2. Select topics for exploration	**2.** Selects topics to be explored valuing information research	**1.** Does not select the topic for exploration **2.** Selects inaccurate topics for exploration or those topics do not value information research **3.** Selects suitable exploration topics which value information research
	3. Formulate hypothesis	**3.** Formulates an inductive and testable hypothesis	**1.** Does not formulate an hypothesis **2.** Formulates an untestable hypothesis **3.** Formulates an inductive and testable hypothesis
	4. Formulate predictions	**4.** Formulates deductive predictions appropriate to the hypothesis and results	**1.** Does not formulate any predictions **2.** Formulates inadequate or incomplete or unsupported hypothesis **3.** Formulates appropriate and supported hypothesis
	5. Produce scientific arguments and explanations	**5.** Presents supported scientific arguments and explanations, involving data and evidences	**1.** Does not present any scientific arguments or explanations **2.** Presents inadequate arguments and explanations or those are poorly formulated **3.** Presents correct and supported scientific arguments and explanations

SKILLS	INVOLVED OPERATIONS	DESCRIPTORS (PERFORMANCE LEVELS 1, 2 AND 3)	
DEBATE AMONG PEERS: COMMUNICATE RESULTS	**1.** Present results	**1.** Presents results in an appropriate format with correction and proper units	**1.** Does not present the results **2.** Presents the results in an inadequate or incomplete format or without using proper units **3.** Presents results in an appropriate format with correction and proper units
	2. Interpret results	**2.** Explains the achieved results including the unexpected ones	**1.** Does not explain the achieved results **2.** Explains the achieved results in an inadequate or incomplete way or without including unexpected results **3.** Explains achieved results in a substantiated way, including the unexpected ones
	3. Construct conclusions and generalizations	**3.** Presents adequate conclusions and generalizations which are scientifically substantiated	**1.** Does not present conclusions or generalizations **2.** Presents inadequate conclusions and generalizations or these are incomplete or are not substantiated **3.** Presents adequate conclusions and generalizations which are scientifically substantiated
	4. Propose changes	**4.** Proposes adequate and pertinent changes considering the implications	**1.** Does not propose changes **2.** Proposes inadequate changes or does not consider the implications **3.** Proposes adequate and pertinent changes considering their implications

[2] Assessment instrument – *Planning an Investigation*

SKILLS	INVOLVED OPERATIONS	DESCRIPTORS (PERFORMANCE LEVELS 1, 2, 3 AND 4)	
PLAN AN INVESTIGATION	**1.** Define goals	**A.** Defines coherent goals according to the problem	**1 –** Does not define goals **2** – Defines coherent goals according to the problem **3** – Defines coherent goals according to the problem but does not include them all **4 –** Defines coherent goals according to the problem
	2. Operationally define variables	**B.** Operationally defines the variables of the proposed study	**1 –** Does not define the variables proposing to be studied **2** – The variables are inaccurately defined **3** – Operationally defines some of the variables proposing to be studied **4 –** Operationally defines the variables proposing to be studied
	3. Define strategies and procedures to achieve those goals	**C.** Defines strategies and procedures that enable him/her to achieve the goals	**1 –** Does not define strategies or procedures **2** – Defines strategies and procedures that do not enable him/her to achieve the goals **3** – Defines strategies and procedures that enable him/her to achieve some of the goals **4 –** Defines strategies and procedures that enable him/her to achieve the goals
	4. Conceive and experimental design that allows variable control	**D.** Experimental design includes control variables	**1 –** In the experimental design does not include control variables **2** – In the experimental design includes inaccurate control variables **3** – In the experimental design includes some appropriate control variables **4 –** In the experimental design includes appropriate control variables
	5. Know and chose adequate resources (e.g.: instruments, materials, conditions, observations, etc.)	**E.** Chooses appropriate resources according to the goals and strategies	**1** – Does not choose resources **2** – Does not choose the adequate resources according to the goals and strategies **3** – Does not choose all the adequate resources according to the goals and strategies **4 –** Chooses all the adequate resources according to the goals and strategies