4.3 Case Study 3 (CS3 Portugal)

Concept focus	Development of inquiry skills
Inquiry skills	Developing hypotheses Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (making predictions, forming conclusions)
Assessment methods	Classroom dialogue Teacher observation Self-assessment Worksheets
Student group	**Grade:** 10th grade (upper second level) **Age:** 15 years **Group composition:** co-ed, groups of 3 (co-ed and single gender), ability: inexperienced but the majority of the students succeed very well at school, with results above the average. **Prior experience with inquiry:** No

In this case study, the necessary materials were not available and so the students did not undertake the experimental part of the activity. Instead, the teacher provided a worksheet with a table of results, which they analysed. Assessment focused on skills in *developing hypotheses* and *working collaboratively*, which were assessed through teacher observation, classroom dialogue and self-assessment. The teacher used a four-level rubric to identify performance levels.

(i) How was the learning sequence adapted?

The unit was implemented over two lessons; one 150 minutes and one 100 minute lesson. The necessary materials were not available, therefore students did not undertake the experimental part of the activity. At the start of the lesson, the teacher explained the activity that would be developed and organised the working groups (10 groups, with 3 students each). Except two groups that were only girls, the rest were mixed-sex groups. Students were told they would have to produce a written document in Word processor, where they would write the group's answers to the activity questions.

The following lesson sequence was followed:

1. Each student in each group was given an introductory work document (Figure 1), with the objectives and the theoretical framework. The students had computers with Internet access (one per group), so that they can search about terms/concepts and new information either on the algae or the selected reagents. The main concepts discussion was made in class.
2. Next, the students discussed in their groups the provided experimental procedure, and then to facilitate the students understanding, they watched its implementation through the video available at www.saps.org.uk.
3. The students group attempted to define the problem and the objectives behind the procedure, which variables were involved, and made a sustained prediction about the expected results (Figure 1, Part 1).
4. The students analysed a table of results. From the analysis and group discussion they sought to answer to the given questions. (Figure 1, Part 2).
5. The students group organised the written work (student artefact).
6. Finally, the students completed individual self-assessment questionnaires on how they felt they had worked as a group.

Photosynthesis... using algae wrapped in jelly balls

Algae can be considered one-celled plants; they usually live in water. You are going to use algae to look at the rate of photosynthesis. Due to its tiny size, it is difficult to work with the algae directly in the water, so the first part of the practical work involves "immobilizing" the algae. This process effectively traps large numbers of algal cells in 'jelly like' balls so that you do not lose them. When these algae are 'wrapped up' in the jelly balls they are excellent to use in experiments on photosynthesis.

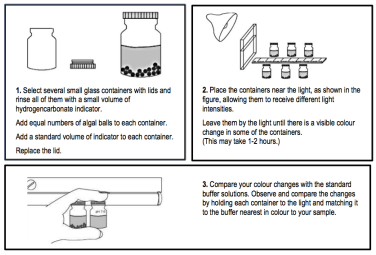
Hydrogen carbonate indicator is very sensitive to changes in carbon dioxide levels. The indicator has an orange/red colour when it is equilibrated with the atmospheric air. It changes to yellow when more carbon dioxide is added and changes to a deep purple colour when carbon dioxide is removed.

The following table shows these colours:

Yellow		Orange		Red		Magenta		Purple
pH 7.6	pH 7.8	pH 8.0	pH 8.2	pH 8.4	pH 8.6	pH 8.8	pH 9.0	pH 9.2

Doing investigations with algal balls

Below there is an outline of how you could investigate the effect of light intensity on the rate of photosynthesis. You will need to decide on details regarding quantities and how to vary the light intensity.



This activity was adapted from 'Algal balls' - Photosynthesis using algae wrapped in jelly balls:
http://www.sops.org.uk/secondary/teaching-resources/235-student-sheet-23-photosynthesis-using-algae-wrapped-in-jelly-balls

Part 1: Consider the shown procedure and answer the following questions:

1. What is intended to be studied with this procedure?
2. What are the variables involved in this procedure? Dependent variable, independent variable, controlled variables.
3. What do you think will happen? (NOTE to the teacher: for this question to make sense, the table with the results should only be presented after the students answer the question).

Part 2: Using the shown procedure, the following results were obtained:

Container with algae balls	Distance from light (cm)	Relative light intensity ($1/D^2$) ($x10^{-5}$)	pH value
1	**250**	**1.60**	**8.8**
2	**350**	**0.81**	**8.6**
3	**500**	**0.40**	**8.4**
4	**780**	**0.16**	**8.2**
5	**1250**	**0.006**	**8.0**

Based on the interpretation of the obtained results table, answer the following questions:

4. Which of the algae ball container received more light? And which container received less light?

The indicator used in this experience becomes purple when the carbon dioxide is absent from the solution.

5. What is the process in plants that uses carbon dioxide?
6. In which of the containers is that process happening with the greatest intensity? Justify your answer.

The indicator becomes yellow when the carbon dioxide is present in the solution.

7. What is the process in living beings (including plants) that produces carbon dioxide?
8. In which of the containers is that process happening with the greatest intensity?
9. What do the results show?
10. Based on the obtained results, what will be the answer to the initial question?
11. In what way could this procedure be altered in order to control this experience?

Figure 1: Student worksheet from CS3

(ii) Which skills were to be assessed?

The skills assessed were *developing hypotheses, scientific reasoning* and *working collaboratively*. The teacher gave constant feedback to students during the development of the activity and assessed the final products (student artefacts) after the lesson was completed (Table 1).

Developing hypotheses

Students develop a hypothesis, which includes a justification for that hypothesis and also provides a link to the research question. The skill of *developing hypotheses* was assessed based on students written productions.

Working collaboratively (teamwork)

Students are able to work with diverse teams. They can produce ideas based on views from team members. They can take into account and deal with disagreements. They can manage time and workload and agree procedures. The teamwork skill has been assessed during the activity implementation in the classroom. The teacher used an observation grid (Table 2), organised by descriptors, where it was registered the frequency of each behaviour and used student self-assessment (Figure 2) for evaluation of *working collaboratively*.

How were gender issues addressed?

To assess the skill of *working collaboratively*, two mixed-sex groups were deliberately chosen, both with students with good academic results, but one composed by two girls and one boy, and the other by two boys and one girl. The objective was to verify if the predominance of one gender in a group would affect in the group dynamic. At the same time, the whole class was observed for detection of any kind of possible discriminatory behaviour. At the end of the activity the teamwork

filled in, individually, an opinion questionnaire proposed by Brian Mathews (2006, pp. 104) for secondary schools (Figure 2).

Table 1: Assessment criteria for working collaboratively and developing hypotheses

Inquiry skills	Emerging	Developing	Consolidating	Extending
Teamwork **Interpersonal relationships and group functioning (emotional literacy)**	Observes and accepts the colleagues' proposals in the structuring of the group work, but gives no suggestions; merely accepts what the colleagues are doing (due to difficulties in interpersonal relationships).	Participates in the structuring of the group work, but only makes one or two suggestions that add little value to what was already done (due to difficulties in interpersonal relationships).	Participates in the structuring of the group work and gives positive suggestions contributing to a productive group dynamic.	Participates in the structuring of the group work and significantly contributes to a productive group dynamic, creating positive personal interactions (allowing the improvement of others and raising the work level).
Developing hypotheses	Formulates hypotheses that are not consistent with the planning or that are not eligible for investigation.	Formulates hypotheses that are consistent with the planning of the experiment.	Formulates hypotheses that are consistent with the planned experiment and are based on the research questions.	Formulates hypotheses that are consistent with the planned experiment. Those hypotheses are based on the research questions and identified variables.

Table 2: Registration grid for observation of working collaboratively (teamwork)

Behaviour	Student name	Student name	Student name	Student name
Does not interrupt when others speak				
Questions the colleague regarding what he is saying				
Defends his points of view				
Talks with kindness				
Challenges a quieter colleague to speak				
Congratulates the colleagues when they present a positive idea				
Assumes an active role in order to solve conflicts between colleagues				
Defines/clarifies the work's objectives				
Defines/distributes/negotiates tasks among colleagues				
Draws attention to time				
Faced with distractions draws the group's attention to the work				

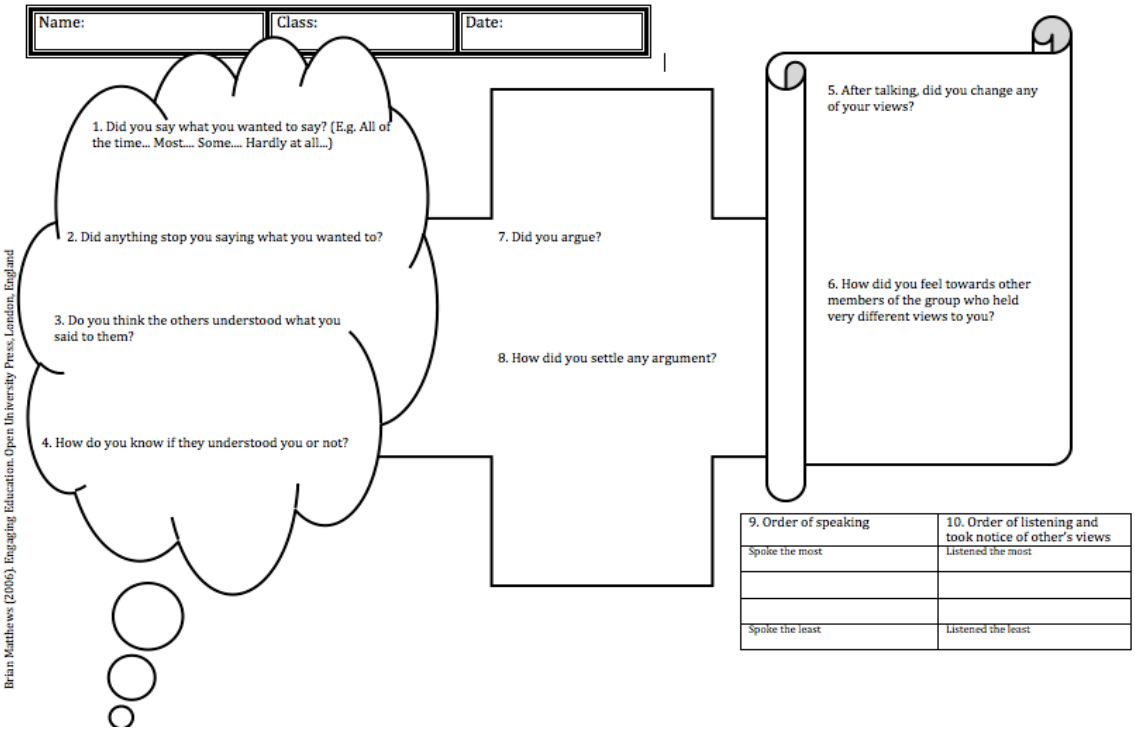


Figure 2: Self-assessment for working collaboratively

Analysis of the self-assessment questionnaires for the mixed gender groups revealed that gender did not have a significant impact on the group dynamic, as shown below:

<u>Group 1 – one boy with two girls</u>

The boy almost always got to say what he thought, although he sometimes was afraid that he might say something wrong. Students understood each other well; they repeated in other words the same reasoning that colleagues did; he defended his ideas and points of view. The group argued based on students' book, personal notes and reasoning. Facing different opinions, he first tried to understand and then articulate them with his own words. At an impasse they went to vote; all students spoke for similar time; and all were respected and listened by each other. He thinks that they worked well, would like to work with the same group again, but would also like to work with different groups.

The first girl in the group sometimes said what she intended to, but not always; in some situations she was hesitant and chose not to speak. She thinks that her colleagues sometimes understand what she said; she knew that she was understood through dialogue; she always defended her ideas; she organized her arguments based on the work sheet analysis and drew her own conclusions, although sometimes she changed her point of view after discussion and reflection. She felt that they were all different and think differently from each other and she tried to understand the differences. She thinks the boy was the one who spoke more and thinks it was herself who listened more. She believes that it was a good group to work with, because they divided the tasks and were able to help each other.

The second girl in the group always said everything she wanted to, and when she disagreed with the others points of view she gave her opinion. She thinks that her colleagues understood what she said because they heard and presented their points of view. She knows that she was heard because they had regard to her contributions. She defended her ideas, explaining them so that colleagues understand her and organized her arguments giving examples. There were times when her reasoning was incorrect. After hearing colleagues' explanations, she heard the different views and

tried to understand them. She did not think that any colleague spoke more than the others, but the boy was the one who most listened.

Group 2 – two boys and one girl

The first boy in the group always said what he thought and felt that all were free to do so; nothing inhibited him. Although sometimes he was not understood initially, after explaining again the idea he was understood. He knew when they understood by the explanations given back from colleagues. Sometimes he made colleagues understand some ideas and vice versa. He always defended his ideas; organized his arguments based on students' book content and logical reasoning. Sometimes he changed his point of view, after hearing his colleagues. He felt interested in confronting diverse opinions to achieve learning at the end of the work. No one spoke more than others and the girls was the one who listened most. He enjoyed working with the group and would like to work with them again.

The girl always said what she thought and when she disagreed; nothing inhibited her and she felt comfortable with the group. She knows that she was understood through the existing dialogue with each one giving his opinion. She defended her ideas and organised her arguments, trying to explain what she thought in the best way possible and whenever it was not understood she explained again. She sometimes changed her point of view. She returned well to different points of view but also tried to defend her point of view. She always listened to others opinion. She thinks that collaboration was quite balanced, with all spoken and heard at the same level. She really likes to work with her colleagues.

The second boy in the group always said what he intended to and never felt inhibited. He thinks that colleagues always understood him. He knows it because after he presented his ideas, his colleagues were able to explain those ideas. He always defended his ideas and only when he had evidence of his mistakes did he change his point of view. He organised his arguments with informal language so that they were understandable, but he also used formal language to defend his ideas. He sometimes changed his point of view, when it was shown that he was wrong. When the colleagues' points of view were different from his own he tried to get them to accept his point of view, or tried to understand them, asking them for coherent and logical arguments. He thinks the group was very well composed and balanced since all had the opportunity to discuss, defend ideas and listen to others.

(iii) Criteria for judging assessment data

Initial expectations were high because the students have good school results and show much interest in biology. They like challenges and discussion activities. The assessment was formative, and developed in class by following the groups as they worked, clarifying doubts and questioning. Assessment was also summative, regarding analysis of students' written work.

(iv) Evidence collected

Teacher opinion

Students' response was enthusiastic. Showed great interest and enthusiasm carrying out the work; were very curious and questioned a lot. Some groups' debates were quite "heated" and sometimes the teacher had to moderate the discussions.

Students showed a very high performance level, according to their usual performance, and sometimes exceeded the teacher expectations. Students regretted not having had the opportunity to conduct the experimental work. The activity was very interesting and had other operating potential contemplated on the site, but it was not possible to implement it so far.

The main difficulties were related to the large number of classroom working groups (10), taking into account the students' profile, they were very participatory and questioning and often asked for teacher's support. Oral feedback and the use of questioning were beneficial. Summative evaluation of written work and the presentation of hypotheses went very well according to the used scale. The greatest difficulty was related to the teamwork observation grid (Table 2). Given the high number of dimensions and the fact that the teacher has to register the frequencies of behaviours revealed, this assessment tool a lot of the teacher's time. As a result, the teacher chose just two working groups for assessment and had to remain with the same groups for a long time. Consequently the support provided to other groups was compromised; those students also wanted the teachers' help and would also be subject to summative assessment. The observation grid was not practical to apply given the large number of students in class and those students' characteristics.

Sample student artefacts:

Some selected examples of students' work are shown, with teacher annotations in red (**(c)** correct | **(i)** incorrect).

Examples of excellent work based on question 3. What do you expect to happen?

Group A:

What we expect to happen is that each solutions container, being at different distances from the light source (c), will change colour (c). As the hydrogen carbonate, that is the carbon dioxide indicator present in all containers is very sensitive to variations in the level of CO_2 (c), showing an orange/red colour when the atmospheric air is balanced, a yellow colour when it is added CO_2 (c) and a dark purple colour when removed the CO_2 (c), we can conclude that the larger distance from the light source is (where there is less light intensity (c)), the photosynthetic rate is reduced (c) which increases the solution carbon dioxide concentration (c), as there is a bigger respiration rate (c) (due to the dark environment), the concentration of CO_2 will increase (c). Consequently, a higher concentration of CO_2 leads to a more acidic solution (c), and a lower pH and then hydrogen carbonate indicator changes colour to yellow (c). On the other hand, when a container is at a shorter distance from the light source (i.e., there is more light intensity on the algae (c)), increases the photosynthetic rate (c), which means that there is a lower concentration of carbon in solution (c), therefore the solution turns to be more basic (higher pH), and with a purple colour (c) (due to hydrogen index). At a distance more or less equidistant from these two containers above, it will find the compensation point (c) in which the O_2 concentration is equal to CO_2, which makes the indicator turns into red colour (c).

Group B

Based on the data supplied in the worksheet, we can predict that the greater the distance of the containers to the lamp, the lower is the pH value; the smaller the distance of the containers to the lamp, the higher is the pH value.
Such prediction can be explained by the fact that the greater the distance from the lamp; the lower will be the luminous intensity the containers are subjected, leading to a reduced rate of photosynthesis and thus higher concentrations of CO_2, which causes the highest pH value.
The same can be applied to the reverse situation, that is, the shorter the distance from the lamp, the greater will be the light intensity at which the containers are subjected, leading to a higher rate of photosynthesis and the consequent reduction of CO_2, which causes the lowest pH value.

Examples of satisfactory/poor achievement based on question 3. What do you expect to happen?

Group C

Containers that receive a higher light intensity are expected to have higher rate of photosynthesis and, consequently, a decrease in the concentration of CO_2 in the solution. The solution becomes more pH basic than the normal concentration (container with red colour) getting a purplish colour.

Group D

There will be a photosynthesis rate fluctuation due to the light intensity (c), because the higher the light intensity, the higher will be the rate of photosynthesis (c), the carbon dioxide release will increase (i), which will cause the pH value to decrease (c) (becomes more acid) becoming yellow. (c)

(v) Use of assessment data

The teacher has since applied the same observation grid, with the same class, during another activity, and experienced the same problems. She will continue to implement inquiry tasks, but will change the methods for observation of *working collaboratively*; she will look for another way of recording the observations without using frequencies.

(vi) Advice for teachers implementing this unit

If it is not possible to perform the experimental activity, watching the video is particularly valuable. Apply the task to classes with less than 30 students. Do not form groups randomly, and keep in mind what is meant by working in groups for activities (take care with division of tasks within the groups). Reformulate the teamwork grid by using fewer items.