4.2 Case Study 2 (CS2 Slovakia)

Concept focus	Development of inquiry skills Understanding photosynthesis – relationship between light and carbon dioxide
Inquiry skills	Planning investigations Forming coherent arguments
Scientific reasoning and literacy	Scientific reasoning (making predictions, forming conclusions)
Assessment methods	Classroom dialogue Student devised materials (documentation of inquiry process) Presentations
Student group	**Grade:** lower second level **Age:** 15 years **Group composition:** co-ed, groups of 3-4 (mixed ability and gender) **Prior experience with inquiry:** Yes

The skill focus in this implementation was on *forming coherent arguments* and associated *scientific reasoning* capabilities. Students engaged in peer-discussion, worked in groups and made key decisions in the planning process. The teacher used a four-level rubric when assessing students' artefacts – experimental plans or posters – and evaluated their ability to formulate conclusions. The teacher expected that students would relate carbon dioxide content and colour changes in the indicator in their conclusions.

(i) How was the learning sequence adapted?

The unit was implemented with a class of 17 students in a 180 min lesson. At the beginning of the lesson students were able to say that the photosynthesis is a plant process, in which inorganic substances (water and carbon dioxide) are converted to sugar, in the presence of light and oxygen is released. By conversion of sugar in cells other organic substances are formed.

At the beginning students should explain the meaning of the term "indicator" in their own words (some of them knew it). They should explicitly assume that the intensity of the light will be reflected over time by a change in the colour of the of carbon dioxide indicator solution.

In deciding upon the distribution of samples at different distances from the light source, students should consider how light intensity decreases with distance. If they distribute the sample at sufficiently large distances, at the end of the experiment a clear difference in colour of the indicator solution should be observed.

We used the following procedure to prepare an indicator of carbon dioxide (obtained from the saps.org.uk website):

<u>**Carbon dioxide indicator - recipe**</u>
Dissolve 0.2 g of thymol blue* and 0.1 g creosol red in 20 cm^3 ethanol. Weigh out 0.84 g of sodium hydrogen carbonate and dissolve this in about 900 cm^3 of distilled water.

Add the dye solution to the aqueous salt solution in a 1 litre graduated flask and makeup to the 1 litre mark with distilled water. Take care to exclude all traces of dust and dirt as these have a marked effect on the final colours the indicator will produce.

<u>Working solution:</u> Pipette 25 cm^3 of the stock solution into a 250 cm^3 graduated flask and make up to 250 cm^3 with distilled water.

<u>Equilibration with atmospheric air:</u> Before the reagent can be used, it must be allowed to reach equilibrium with the CO_2 in the atmosphere. Bubble air through the solution using a fish-tank bubbler. The air must come from outside the laboratory, as the solution is very sensitive to small changes in CO_2. The indicator should appear deep red in the bottle and orange red when viewed in 16 mm test tubes.

** Instead of thymol blue, bromothymol blue was used for this lesson. The base colour of the indicator was green, upon loss of CO_2 by photosynthesis near the light source the colour changed to dark blue, and in the absence of light intensity, due to increased respiration and CO_2 concentration, a yellow-green or yellow colour was observed.*

In the distribution of samples at different distances from the light source, students should consider how light intensity decreases with distance. If they distribute the sample at sufficiently large distances, the end of the experiment should show a difference in colour of the indicator solutions. Since this is a relatively time-consuming procedure (need to wait for 1-2 hours), we decided not measure the colour of the indicator using a colorimeter. Students simply poured the solution into the white plastic cup and the difference was compared visually. The result had to be recorded immediately, while concentrations in solution had not equalised with the surroundings.

(ii) Which skills were to be assessed?

<u>**Forming coherent arguments (reasoning, developing predictions and forming conclusions)**</u>

When students compared their samples with the samples of other groups, they found that those who predicted that a greater distance between the first and the third sample would be more apparent on the colour indicator were correct. When students carefully planned their investigations, significant results could be observed. Students who recognised the direct relationship between light intensity and photosynthesis deployed individual samples sufficiently far from each other and the light source. Furthermore, the teacher expected that students would use their knowledge of photosynthesis (discussed in initial dialogue) to realise that there is an inverse relationship between CO_2 concentration and light intensity. She also expected that students would relate CO_2 content and colour changes in the indicator in their conclusions. Individual student's reasoning was evaluated on the basis of the conclusions formulated in the outputs (experimental plan, PowerPoint presentation or poster) using an assessment tool as shown in Table 1.

Table 1: Assessment of forming coherent arguments based on scientific evidence

Inquiry skills and processes		Emerging	Developing	Consolidating	Extending
Scientific literacy	Thinking about photosynthesis based on enrolment and formulation of conclusions	Understanding the procedure (Example: When we do it this way, we see the colour change of indicator)	Arguments show understanding of the procedure (Example: The colour change of indicator occurs as the result of different distances from light)	Arguments show understanding of the process (Example: The colour change of indicator occurs as the result of photosynthesis)	Arguments point understanding of the purpose of experiment and the principle of action. (Example: We achieved higher concentration of carbon dioxide because lack of photosynthesis by decreasing light intensity)

(iii) Criteria for judging assessment data

Individual assessment of students on the basis of documentation of the experiment

Students divided the tasks, one of them was a writer and the output of other students was often based on the writers' notes. Individual students have made own photo documentation by cell phone. They complete output in the form of PowerPoint presentation protocol, poster or video.

The teacher expected that the students, on the basis of discussion in the introduction, would enter the weight of the material used in the sample, the amount of added indicator and the time of its action, when writing constants and variables. She expected that students would create a simple table, into which they would enter the distance from the light (in cm) and colour of the indicator in each of their three samples. She expected that the conclusion would indicate that the colour of the indicator changed, because in the sample closer to the light, is that where the algae consumed more carbon dioxide from the solution

(iv) Evidence collected

Teacher opinion

The teacher expected that students would mention that the colour of the indicator is changed and that in the sample closest to the light the algae would consume more carbon dioxide from the solution. However, students remained at the level of statement that the colour change is influenced by light and they haven't explained the essence of this change in their outcomes. It would be useful if students should have an aid in the form of an empty chart template (Figure 1), where would complete the direct and indirect relation of CO_2 concentration and light intensity. This will help them to realise the relationship of the observable demonstration, on which they focused their attention, to the hidden process of photosynthesis.

Draw the relationship into the graph, how the amount of carbon dioxide in the sample located at different distances from light changes (rises or falls).

How does the colour of the indicator relate to the amount of carbon dioxide?

In which of the samples there was the most intense photosynthesis?

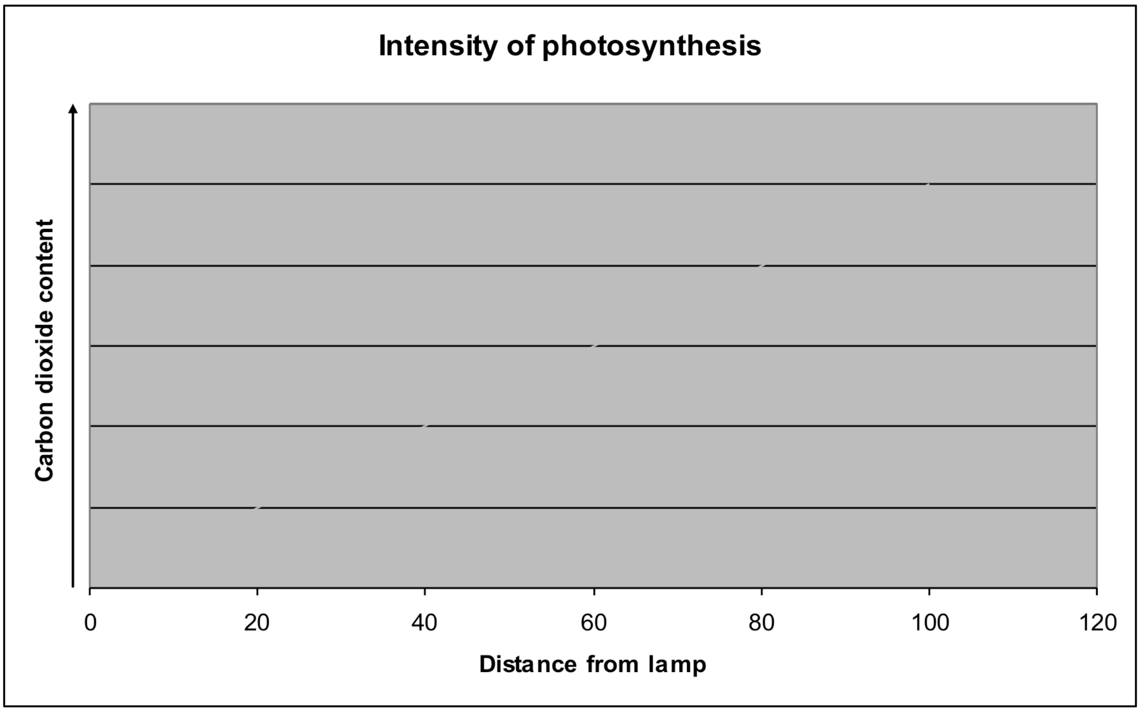

Figure 1: Chart template for recording of data

The teacher had expected that students would try to organise the data in some tables or graphs, but nobody chose this method to present their results. Assessment of this step of inquiry should be realised by use of checklist or worksheet, with a sample table provided as a guide.

When students planned their experiments, the teacher had to follow the discussion between group members, and asked questions of the group:

- Why did you choose this method of separation of the algal balls?
- Which distribution method would you choose you personally? Why?
- What do you think, in which sample is more carbon dioxide in solution at the end of the experiment? Make a prediction and justify it.

Also it is important that students work in small groups (maximum four students) because of distribution of tasks within the group.

Observer notes

The influence of CO_2 content on the colour change in the indicator can be demonstrated easily. Pour a little carbonated (sparkling) water from the store into a portion of the indicator and observe the change in colour. CO_2 content is usually marked on the label of carbonated water.

If the colorimeter was used the students would acquire numerical data of colour, which could be noted on the y-axis in the graph. However younger students could be distracted by the explanation of colorimeter principle and measurement procedures and divert their attention from the essence of the phenomenon. Measurement is more suitable for older students. Ideally they should learn to use the colorimeter before doing this activity. Alternatively, students could practice taking measurements by colorimetry while waiting to observe the effect of light on the samples (1-2 hours).

Sample student artefacts

The conclusion of a poster, where 15-year-old students reported the relationship between the indicator changes colour from green to dark blue, and decrease of carbon dioxide as a result of photosynthesis:

We found that the lightest colour of the indicator was in the sample that was in the dark. There was carried out intensive respiration in algae so CO_2 concentration increased.
Intensive photosynthesis takes place in the sample closest to the light, algae consume carbon dioxide. Therefore the solution indicator is dark.

The teacher asked some questions of the students for this case:

- What happens if we leave the sample container open (in the dark)?
- What happens in a closed container?

In another conclusion, student concluded with a general phrase only. He could not refer to specific results or knowledge.

Based on our observations we found various properties of algae Scenedesmus quadricauda.
We found out under which conditions the respiration and photosynthesis of plants start up.

Figure 2 shows an example of a student poster, in which they conclude that carbon dioxide concentration decreases as a result of consumption by the plant. This student has attempted to show the results on a graph.

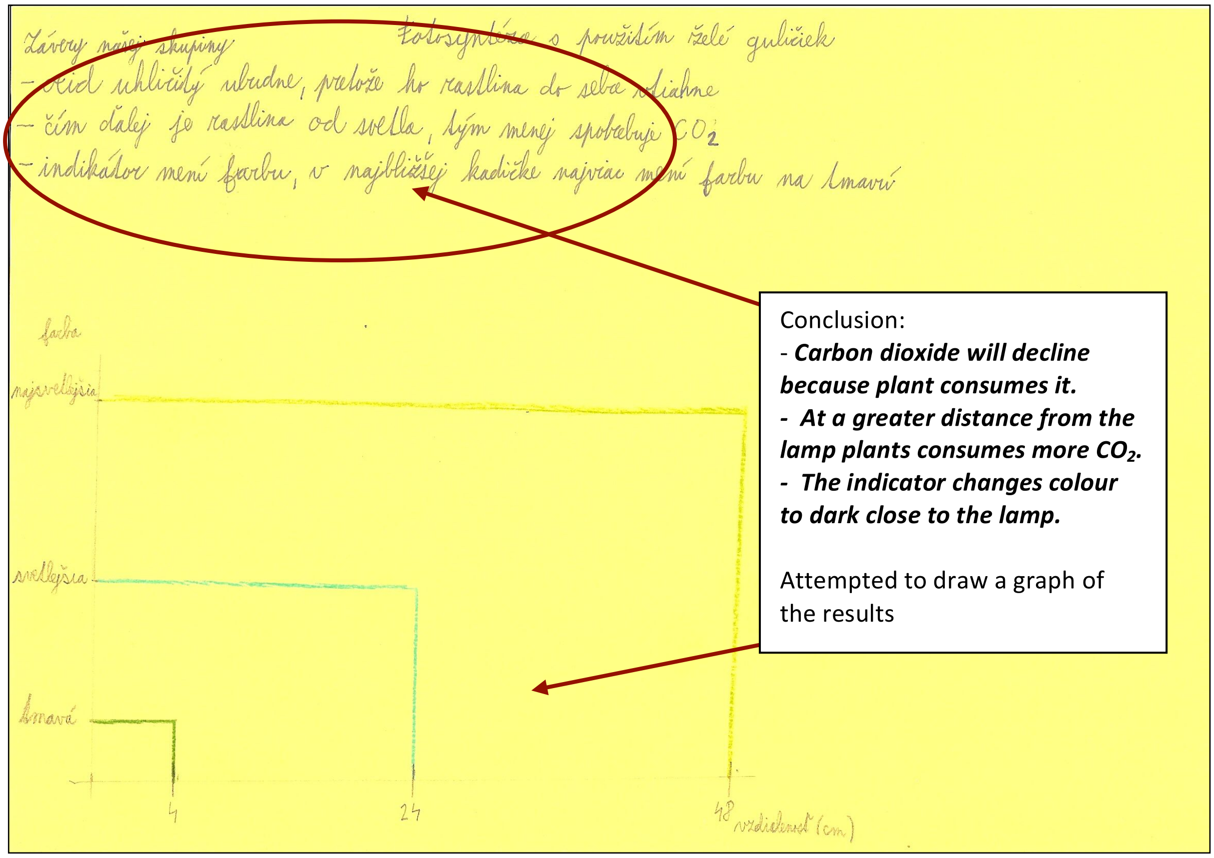

Figure 2: Example of student poster

(v) Use of assessment data

In the next inquiry activity, the teacher will observe whether individual students are making progress. She will record a shift in skill into next level, according to the criteria of the table. For example, if a student argued in favour of speed in the process earlier, now he/she gives priority to accuracy of chosen method. If data were recorded randomly before, then he/she can arrange data in a table. If a student entered the data into the table, now can suggest chart.

(vi) Advice for teachers implementing this unit

Younger students with poor experiences with data enrolment need help in a form of blank template of table or graph.