4.1 Case study 1 (CS1 Slovakia)

Concept focus	Development of inquiry skills Understand the principles of photosynthesis
Inquiry skills	Planning investigations Forming coherent arguments
Scientific reasoning and literacy	Scientific reasoning (forming conclusions)
Assessment methods	Classroom dialogue Teacher observation Self-assessment Student devised materials (documentation of inquiry process) Presentations
Student group	**Grade:** lower second level **Age:** 12 years **Group composition:** co-ed, groups of 3 (mixed ability and gender) **Prior experience with inquiry:** Yes

In this implementation, the teacher used a *guided inquiry* approach and adapted the method of recording changes in carbon dioxide concentration to simple observation of colour change. The teacher used rubrics to identify students' performance levels in *planning investigations* and *forming coherent arguments*. Teacher observation and classroom dialogue allowed for assessment of *planning investigations*, while students' presentations were evaluated for assessment of *forming coherent arguments*.

(i) How was the learning sequence adapted?

The unit was implemented with a class of 15 students in a 180-minute lesson. Students already knew the concept of photosynthesis. They revised this in the form of a moderated conversation at the beginning of the activity: "photosynthesis is a process in the plant body when inorganic substances (water and carbon dioxide) using light arise sugar and release oxygen. The other organic substances are produced in cells by transformation of sugars."

Since this is a relatively time-consuming activity (have to wait 1-2 hours for the effect to be observed), the teacher 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. Each result had to be recorded immediately, to ensure concentrations in solution did not equilibrate with the surroundings.

After the teacher introduced the task, the teacher allocated students into groups. It was a mixed group of students, and the teacher arranged groups without considering gender. Groups chose a form for documentation and final presentation of their work and the results of their experiment (PowerPoint presentation, poster, video documentation).

(ii) Which skills were to be assessed?

Planning investigation

Considering the age and lack of experience of laboratory work, students did not plan the whole experiment alone. They made three key decisions, and other actions were carried out according to instructions. Students worked in groups of three. They prepared a certain amount of algal balls in two steps. First algal cells were mixed into the alginate solution. Then students made the balls by pouring the green mixture into a solution of calcium chloride. This first practical role that students enthusiastically mastered was followed by the first independent decision:

1. ***How to divide prepared balls equally into three experimental containers?*** First, students generated the ideas. They agreed that there are three possible ways: placed in each vessel the same number of balls, placed in each vessel the same amount of jelly balls weighed 3 times the same weight. Each group chose a way that seemed to be the best. They had noted the argument why they decided on a method. For example, one of the groups thought that weighing is the fastest way. Others suggested that counting would be the most precise. Another group said that putting three teaspoons of algal balls in each dish is the most practical. Others indicated that it would be more precise to measure volume using a measuring cup. They should continue the experiment using their chosen procedure.
2. Another opportunity for planning represented ***location (layout) of three samples*** supplemented by standard volume indicator at different distances from the light source. Specific distances in cm were not given in the instructions. Students groups should consult, and agree on an appropriate location.
3. The ***method for recording of constants and variables*** was also determined by the students. After a discussion, the student groups agreed what data to record (amount of algae, volume of indicator, the distance of samples from the lamp, the time until change of the indicator was observed) and how they would record the data (e.g. what can be put into a table and whether some data can be expressed as a graph).

A rubric was developed for assessment of the inquiry skill of *planning investigations* (Table 1). It was easy to fit the work of groups in to the categories, but assessment of individual students was more difficult. The teacher had to follow the discussion between group members, when students planned the experiment. Therefore, it is appropriate to add a self-assessment of students, which could be submitted verbally or through a short test. Another possibility is the distribution of roles in the group each member is responsible from something other, for example one student responsible for enrolment of data, another for sample layout, etc.

Table 1: Assessment of planning investigations for CS1

Inquiry skills and processes		Emerging	Developing	Consolidating	Extending
Planning investigations	1. Distribution of material (algal balls)	Indicates chosen method	Indicates chosen method and argues its speed	Indicates chosen method and argues its accuracy	Compares speed and accuracy (effectiveness) of different methods
	2. Layout of samples	Procedure precise, but small distances between samples (for example 10 cm)	The layout of the samples accurate in relation to light	Able to reason the procedure in practical terms (for example to use the full length of the table)	Able to reason the procedure, builds on the fundamental of photosynthesis. One sample is placed in total darkness
	3. Data entry	Data entered into a continuous text of process	Distinct process and results	Distinct process and results, accurate data entry	Enrolment of data about colour samples and their distance from the light student in itself proposed table

Example of questions for self-assessment of *planning investigations*:

- Did you actively participate in today's work?
- Do you think your considerations contributed to achieving the goal?

Forming coherent arguments; scientific reasoning (forming a conclusion)

Students compared their samples with the samples of other groups and discussed the colour changes. They realised the direct relation of light intensity and the intensity of photosynthesis on the basis of colour change of indicator. However, only a few of them realised the relationship between CO_2 concentration and light intensity based on knowledge about photosynthesis. Individual students were evaluated on the basis of the conclusions formulated in the outputs (protocol, PowerPoint presentation or poster) using the assessment tool shown in Table 2.

Table 2: Assessment of scientific reasoning (forming coherent arguments)

Inquiry skills and processes		Emerging	Developing	Consolidating	Extending
Scientific reasoning	1. Arguments for the benefit of the chosen method	Indicates chosen method (Example: We do it this way)	Indicates chosen method and argues its speed or simplicity (Example: We do it this way, because it is easier than finding the colour change in the samples)	Indicates chosen method and argues its sense (Example: We achieved changing the concentration of carbon dioxide by choosing different light intensity)	Indicates and compares methods (Example: It is the best way to achieve different rate of carbon dioxide concentration that indicates changing rate of photosynthesis)

(iii) Criteria for judging assessment data

Providing of feedback through discussion with peers

The teacher watched groups debate and, if necessary, asked prompt questions, for example "How would you realise it?" or "Why do you think this is the most suitable way?" She evaluated skills in planning how to distribute the material into equal parts during implementation (discussion groups) and immediately after the implementation of that step in a discussion with the whole class. The team that chose weighing concluded that it is not true that weighing is the fastest way of dividing. They needed to re-weigh, add and remove material. They agreed, however, that weighing is probably the most accurate of the proposed methods. Those who divided balls using a spoon were quickly done, but they admitted that this might not be the best way. There were visible differences between the amounts of material in the samples. It was better to measure the volume by a measuring cup. All agreed that counting jelly balls could be a quite reliable method. However, no groups chose this method, as the procedure seemed to be the most time consuming.

Layout of samples was evaluated in a discussion after a defined time. At the end of the experiment, the students sorted all their samples into a row, in order of how far from the lights they were placed. Students saw that those of them who thought that the greater distance between the first and the third sample is more apparent on the colour indicator, they were right. Planning the layout of samples related to the way of thinking and foresight students. They must realise the role of light in photosynthesis. Thus, there must be a sufficient difference in light intensity, which treats on the individual samples.

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

Students could choose the form of data collection themselves. Most groups divided the tasks and one of them was a writer, who was more an observer, while others realised the experiment. Their output was often based on the writer notes. Students took photographs of their experimental set-up, using their cell phones. They completed their reports at home in the form of PowerPoint presentations.

Teacher expected that students, on the basis of discussion in the introduction, should 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 supposed that students write a simple table into which enter three samples distance in cm from the light and colour of the indicator in each sample. She expected that the conclusion they indicate is that the colour of the indicator changed, because in the sample closer to the light, is that where algae consumed more carbon dioxide from the solution

(iv) Evidence collected

Teacher opinion

Most of groups set the distance of the samples and the lamp quite appropriately. Only in one of the groups did students chose too small of a distance between the samples (10 cm). These students were allowed to continue their investigation using this setup and they compared their results (colour difference between samples) with the results of other groups. Thus, they learned that not only the accuracy of distance is essential, but also the intensity of light reaching the algae.

The teacher expected that students would try to organise the data entry using tables or graphs, but nobody chose this method of presentation. Assessment of this step of inquiry should be realised by use of checklist or worksheet, with a sample table provided.

This was the first time that students worked with an indicator. They knew how indicators work theoretically, so using indicator in an experiment was a new experience. As a result, it was quite difficult for some of them to deduce that colour change of indicator is related to the intensity of photosynthesis. They did not know to explain the relationship between the intensity of photosynthesis and the colour change of indicator. It was not clear to some students which colour change shows the intensity of photosynthesis.

Observer notes

Some students indicated their chosen procedure in their output and also mentioned disadvantages and recommendations on how to change it. Others indicated the procedure and lack thereof. Others indicated only the chosen procedure. Although at the beginning the teacher talked with the students about the fact that a table could be used for recording data, no one used this possibility. Their attention was focused on the activities; recording the results was secondary for them. Variables were incorporated in continuous text. It seems that younger students need to see the proposed table in a worksheet, to become aware of the importance and significance of data tables for clarity of recording.

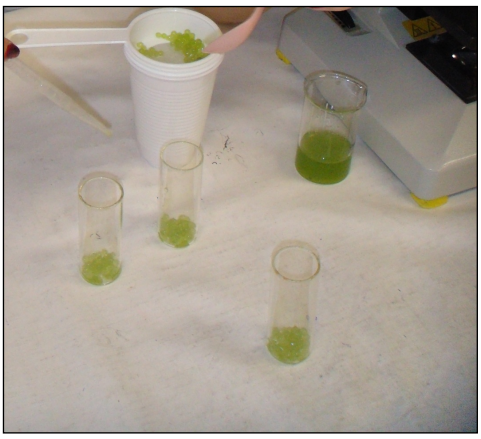
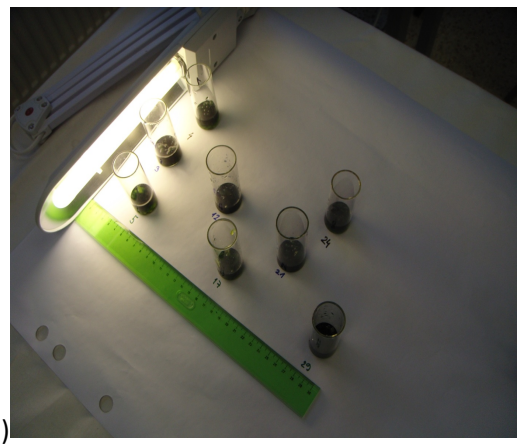
(a)  (b) 

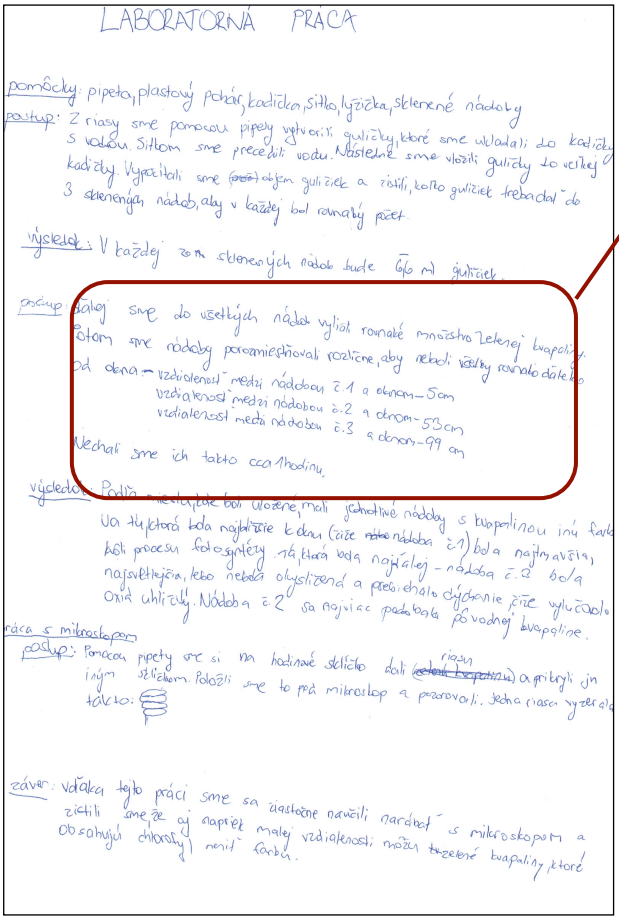
Figure 1: Student photo documentation

Sample student artefacts

Students used photos from cell phones in their output (PowerPoint presentation, poster). They tried to register the steps of the process (Figure 1).

When students decided on layout of samples, some of them chose distances that were too close (to each other and to the light source). The photo shows the protocol of the group, which tried to layout all samples along the 30cm long ruler they used (Figure 1b).

Students in groups of three spontaneously divided the tasks among themselves. One did most of the manual tasks, second assisted him and cared for digital video recording of each step, while the third recorded the results (Figure 2). At the initiative of teachers, all members of the group changed roles, to ensure all students participated in manual tasks.



Writer of the group (12 year old boy) did not create a table for data entry.

A similar method of recording was also used by students from different groups in their presentation, which they did at home.

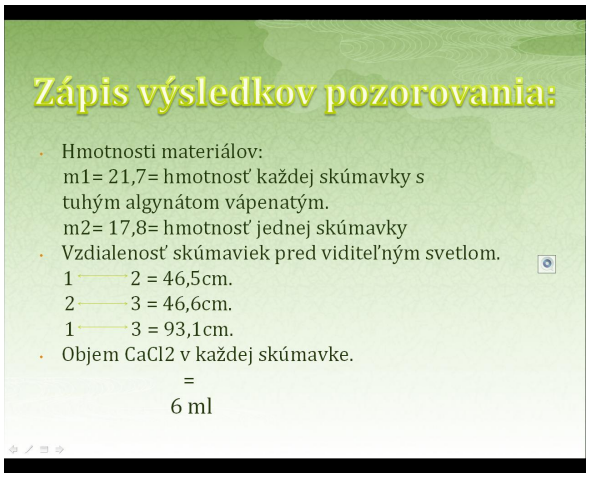
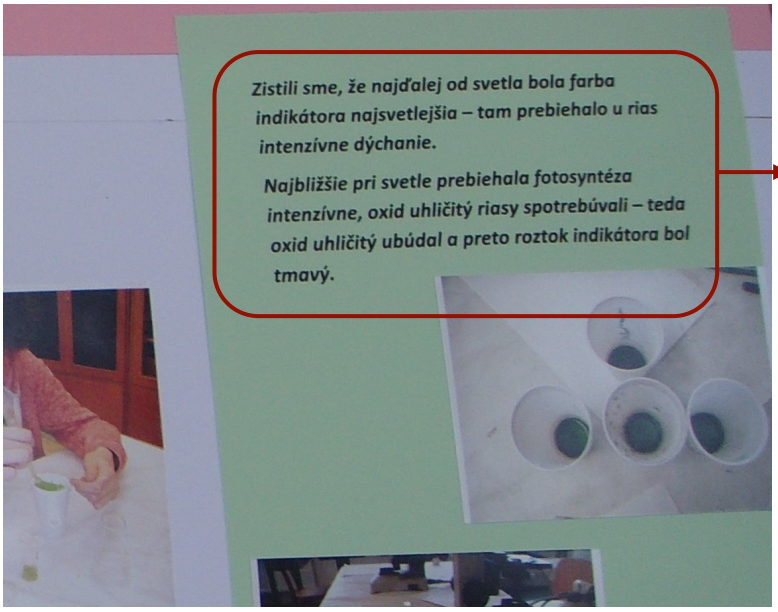


Figure 2: Example of outputs, without tabulated data

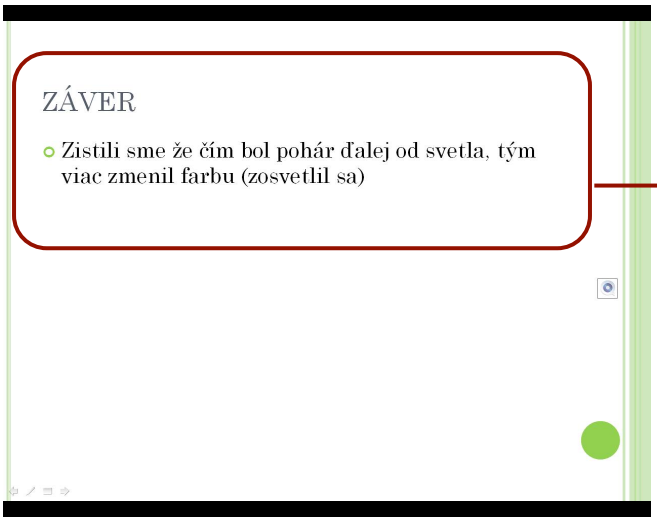
Figure 3 shows the conclusion of a poster, where students reported the relationship between the indicator changes colour from green to dark blue, and decrease of carbon dioxide as a result of photosynthesis.



The lightest colour of the indicator was in the sample which was a furthest from the light – there was carried out intensive respiration in algae.
Intensive photosynthesis takes place in the sample closest to the light, algae consume carbon dioxide. So therefore the solution indicator is dark.

Figure 3: Example of student poster

As shown in Figure 4, some of the younger students did not understand the role of indicator for experiment. Conclusion shown is from the presentation of a 13-year-old student.



Conclusion:
We found that the farther the glass was from the light, the more the colour changed/lightened.

Figure 4: Example of conclusion in student presentation

(v) Use of assessment data

Next the teacher will observe whether individual students are making progress. She will record the shift of a skill into the next level, according to the criteria of the rubrics. For example, if a student's arguments were in favour of speed in the process earlier, now he/she gives priority to accuracy of chosen method. Similarly, if results and data were recorded randomly before, than he/she arranges data in a table or if a student entered the data into a table, the teacher can now suggest using a chart.

(vi) Advice for teachers implementing this unit

Younger students need help with data recording in a form of blank template of table.