## 4.4 Case Study 4 (CS4 Hungary)

| | |
|---|---|
| **Concept focus** | Effect of light on the intensity of photosynthesis |
| **Inquiry skills** | Planning investigations<br>Forming coherent arguments |
| **Scientific reasoning and literacy** | Scientific reasoning (defining variables, argumentation, forming conclusions) |
| **Assessment methods** | Classroom dialogue<br>Teacher observation<br>Worksheets |
| **Student group** | **Grade:** 9th grade (upper second level)<br>**Age:** 15-16 years<br>**Group composition:** co-ed, groups of 3 (co-ed and single gender, mixed ability)<br>**School type:** Alternative secondary school (school with a unique pedagogical programme, accredited by the government. Has a curriculum with special subjects like integrated science, which doesn't exist in secondary state school, arts, social sciences and economy.)<br>**Prior experience with inquiry:** Yes, the student group began to participate in inquiry learning activities in the previous school year. The students regularly attend lab sessions but only a small share of these lab activities are unstructured. The students have had experience with different types of variables, hypotheses and falsification. |

Algae from a water tank (Elodea) were used instead of the algal ball method. In this case study, the most important skill for assessment was *planning investigations*, which was guided using a worksheet that was used later for formative assessment purposes. The teacher also assessed skills in *forming coherent arguments* and *scientific reasoning*, which were evaluated through teacher observation and reviewing of worksheets. 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 (45 minutes each). The necessary materials were not available; therefore the teacher adapted the activity, which keeping it as close as possible to the original unit outline. The original unit explored the effects of light on the intensity of photosynthesis. An experimental setup was given in full including the method of controlling the independent and the dependent variables. The teacher kept some of these recommendations, such as using the bicarbonate indicator as one type of indicator but also included pH measurement with an instrument (Figure 1). The students worked in groups to devise ways of manipulating the intensity of the light and then they selected the one that seemed to be most practical.

The algal ball method described in the original unit could not be implemented, as access to suitable algae colonies was not available, and students could not make the jelly with alginate. Instead, algae from a water tank (Elodea) were used. The students had to divide a given quantity into samples. As time to carry out the experiment was limited (2 x 45 minutes), not much time was available to set up the experiment and to analyse the results.

## (ii) Which skills were to be assessed?

In this trial the most important skill for assessment was *planning investigations*. The independent variable was given but the students had to devise ways of manipulating it. The students were also asked to define possible dependent variables and, following some introductory questions by the teacher, to analyse the process and provide arguments in favour of one or another dependent variable. Students were given greater freedom than was suggested in the original unit. They were free to plan different methods of creating the plant samples and setting levels of light intensity. The groups listened to each other's ideas, asked questions and discussed these ideas, which gave them an opportunity for critical thinking. The teacher also assessed *forming coherent arguments*, looking at the decision making process and how students defended their choices. The students' *scientific literacy* improved as a result of their deeper understanding of photosynthesis and the discussion of the practical aspects of the investigation. During the introductory phase, the teacher questions had brought the students' prior knowledge of the theoretical process of photosynthesis to the surface. They could think of examples for the role of light and mentioned, for instance, the variation in the amounts of light different plants required and the problem of caring for houseplants.

**Figure 1: The experiment being carried out**

## (iii) Criteria for judging assessment data

In order to provide a satisfactory solution to the problem, the students had to discuss their ideas and make decisions as a group about the details of implementing the investigation (Figure 2). The central question was the quality and quantity of the plant samples. This involved considering constant factors and the practicability of a fair test. The students had to find a way to have equal quantities of plants and to vary light intensity. A satisfactory solution could be any method where the plant photosynthesis was uninterrupted and sufficiently intensive throughout the measurement period, and where the differences in light intensity were large enough to be able to detect a change in the dependent variable (pH). The students had to formulate hypotheses with respect to changes in pH and had to justify these hypotheses by scientific arguments (plants use $CO_2$).

**Figure 2: Student group implementing their investigation**

The assessment criteria were discussed with the students. The teacher observed communication between the students while they were working in groups. The groups needed some support and reinforcement, especially during the initial phases. Their planning work was guided by a worksheet on which they could write their ideas and solutions. This written work was later used for formative assessment. The assessment tool followed a modified version of the rubric given in the original unit (Table 1).

## (iv) Evidence collected

**Teacher opinion**

The students showed substantial variation with respect to these inquiry skills. Only one group reached the highest level and one other group showed emerging performance. The rest of the class (16 students) performed at consolidating level.

While there was no observer present during the activity, teacher discussed the unit before and after the activity sessions with a colleague who also trialled it. He made good use of his colleague's experiences and found that his ideas and suggestions were of great help.

**Table 1: Assessment tool for planning investigations and forming coherent arguments**

| Skills | Emerging | Developing | Consolidating | Extending |
|---|---|---|---|---|
| Planning investigations | Has some ideas about manipulating the independent variable but the ideas of practical implementation are incorrect.<br>Only plans the measurement of the dependent variable using a pre-given method. | Has some ideas about manipulating the independent variable and identifies errors with the teacher's help.<br>Has ideas for dependent variables other than the pre-given one (e.g. measuring dissolved oxygen level) | Identifies the possibilities provided by the independent variables and has some ideas about how to test them<br>Plans a viable method of manipulating the given independent variable.<br>Has ideas for dependent variables other than the pre-given one and prepares a plan of implementation. | Thinks of a number of independent variables and prepares plans of implementation.<br>Plans a viable method of manipulating the given independent variable and considers possible errors.<br>Has ideas for dependent variables other than the pre-given one and prepares a plan of implementation. |
| Forming coherent arguments | Does not provide scientific arguments for or against the different experimental plans devised by the group.<br>Occasionally draws conclusions from the data but does not provide scientific arguments for these conclusions. | Provides scientific arguments for the original experimental plan and the various alternative plans devised by the group but the reasoning is not always correct.<br>Analyses the data and occasionally provides scientific arguments but has difficulty with measurement errors and statistical analysis. | Provides accurate scientific arguments for the various experimental plans devised by the group<br>Analyses the data, supports his or her conclusions with scientific arguments, and control for measurement errors. | Provides accurate scientific arguments for the various experimental plans devised by the group and a critique of other plans.<br>Analyses the data critically, uses a statistical approach, control for measurement errors and supports his or her decisions with scientific arguments. |

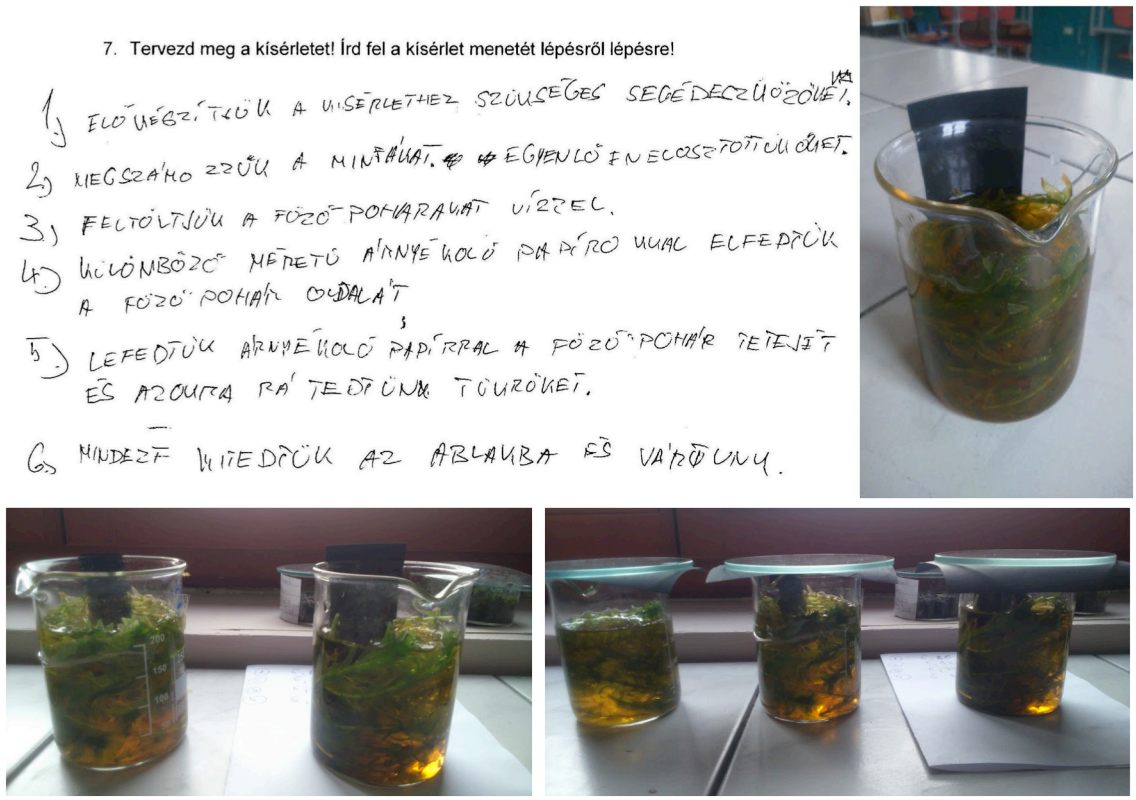
**Sample student artefacts:**

Student artefacts showing *planning investigations* are shown. These include examples of answers from a worksheet, as well as supporting images and sample results.

**Examples of excellent student work**

One of the groups planned the investigation step by step. They also used shading sheets, the plants were intact and the students measured the weight of the samples. This experiment was the most successful (Figure 3).

**7. Design your experiment! Write on the progress of the experiment step by step!**




***1. Preparing the tools needed for the experiment.***
***2. Numbering the samples, they were equally divided.***
***3. Filling the beaker with water***
***4. Obscuring the side of the beaker with different sizes of shading paper***
***5. Covering the top of the beaker with the shading paper and putting mirrors on it***
***6. We put them in the window and waited***

**Figure 3: Planning investigation step by step**

Table 2 shows the data obtained by the best group. They obtained pH measurements for four samples at six time points over a four-day period.

**Table 2: Results of the best group, pH measurements taken over a 4-day period**

| Sample number/ pH | Time (Month, day; hour, minute) | | | | | |
|---|---|---|---|---|---|---|
| | **03.26 11.10** | **03.27 10.55** | **03.27 14.10** | **03.30 9.00** | **03.30 17.15** | **03.31 11.40** |
| **1** | 6,86 | 7,65 | 8,00 | 8,90 | 9,31 | 9,23 |
| **2** | 6,92 | 7,55 | 8,46 | 8,80 | 9,23 | 9,10 |
| **3** | 6,97 | 7,40 | 8,27 | 8,77 | 8,97 | 8,94 |
| **4** | 6,95 | 7,30 | 7,60 | 8,63 | 8,91 | 8,98 |

**Examples of work at the consolidating level (**Figure 4**,** Figure 5 **and** Figure 6**):**

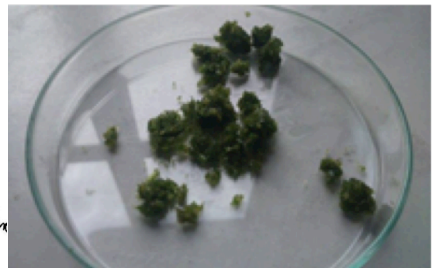
**5. How can we ensure the equal amount of the plants?**

5. Hogyan lehet biztosítani a növény mennyiségének azonosságát az egyes minták esetében? (Milyen mennyiségi adatra kell/lehet figyelni?)

– Lédarálás így megfelelő mérni a tömegét és nem fog különbözni a levelek mérete és elhelyezkedése ~~a zöld~~ amiken a zöldbuborékok vannak.

↓

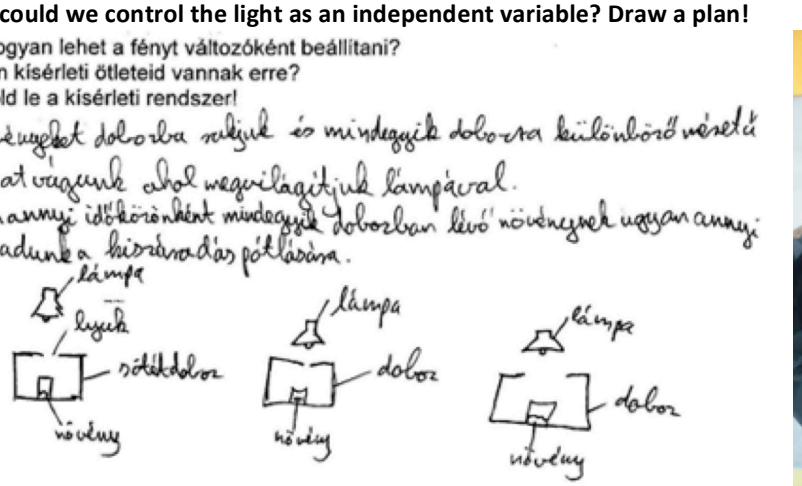
ugyanolyan mennyiségű ledarált növényt ~~az~~ asztunk szét egyszerre



***We have to grind the plant in order to measure the mass, because the size and the position of the leaves (in which the chlorophyll is) will not be different. We have to divide the same amount of grinded plants to units.***

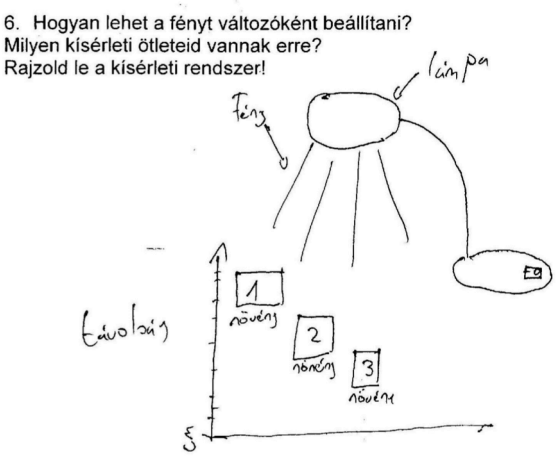
**Figure 4: Example of student plan to measure quantity of plant for investigation**

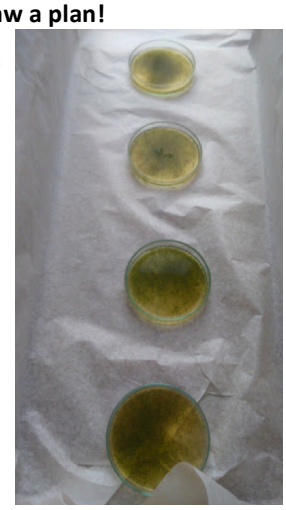
**6. How could we control the light as an independent variable? Draw a plan!**




***We put the plants into boxes, we cut hole on the top of the box and we light it with a lamp. We give the same amount of water for the plants in given time periods.***

**6. How could we control the light as an independent variable? Draw a plan!**



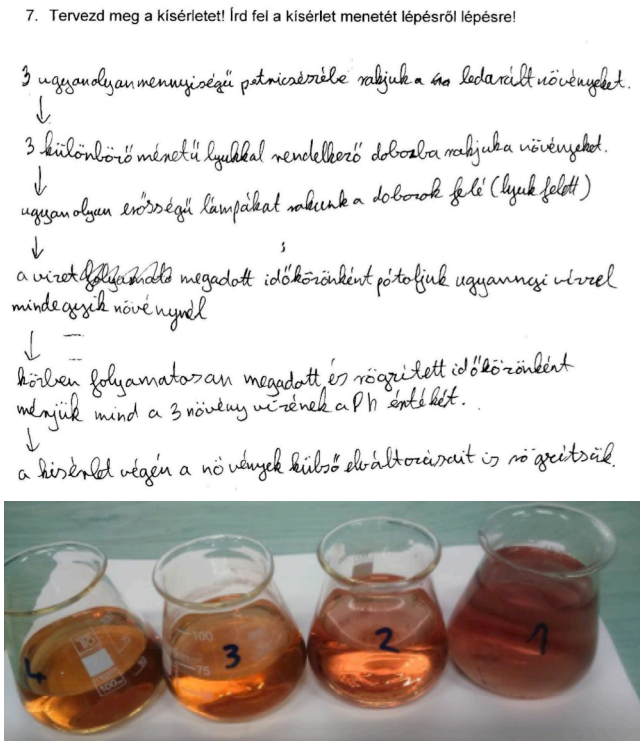
This group used a closed box (opened at one end), and they placed the Petri dishes with the plant suspension different distances from the opened end (from the light).

**6. How could we control the light as an independent variable? Draw a plan!**


Another experiment with shading sheets: the samples are placed in a shaded container, at different distances from the light source

**Figure 5: Examples of student plans to investigate light as an independent variable**

**7. Design your experiment! Write on the progress of the experiment step by step!**



7. Tervezd meg a kísérletet! Írd fel a kísérlet menetét lépésről lépésre!

3 ugyanolyan mennyiségű petricsészébe rakjuk a szétdarált növényeket.
↓
3 különböző méretű lyukkal rendelkező dobozba rakjuk a növényeket.
↓
ugyanolyan erősségű lámpákat rakunk a dobozok felé (lyuk felett)
↓
a vizet folyamatosan megadott időközönként pótoljuk ugyanannyi vízzel mindegyik növénynél
↓
közben folyamatosan megadott és rögzített időközönként mérjük mind a 3 növény vizének a pH értékét.
↓
a kísérlet végén a növények külső elváltozásait is rögzítsük.

In another experiment the students ensure to replacing the evaporated water. They controlled the light intensity with the same lamps and with different holes in cardboard sheets.

***We put the grinded plants to the same sized Petri dishes***
***We put the plants into boxes with different sized holes***
***We lighten the boxes with same light intensity lamps***
***We pour the same amount of water in given time periods***
***We measure the PH value of the water in given and fixed time periods***
***We document the external changes of the plants at the end of the experiment.***

**Figure 6: Example of student plans and their resultant sample solutions**

## (v) Use of assessment data

I assessed the completed worksheets for each group and gave oral feedback to the students. We discussed general issues as a whole class. Oral feedback was also given during group work. The levels of the rubric were discussed with the students and they used the rubric to evaluate themselves after doing the investigation. It was useful, however, for fostering inquiry skills and supporting the mastery of scientific investigations. In future inquiry activities related to other topics, the students will be more skilful at manipulating independent variables and planning experiments.

## (vi) Advice for teachers implementing this unit

The activity is suitable for inquiry learning, but not with novice students. The tools and procedures are fairly complex and some prior knowledge is needed from the students. They need to know the types of variables and must be able to link them to the process they are investigating. The substitution of seaweed and suspension for algal balls did not affect the success of the experiment. The bicarbonate indicator provided spectacular outcomes but its quantity had to be increased substantially. For technical reasons, we could not carry out measurements with a colorimeter but the manual measurement of pH proved to be adequate for obtaining accurate data.