## 4.5 Case study 5 (CS5 Hungary)

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|---|---|
| **Concept focus** | Effect of light on the intensity of photosynthesis |
| **Inquiry skills** | Planning investigations<br>Forming coherent arguments |
| **Scientific reasoning and literacy** | Scientific reasoning (argumentation, drawing conclusions)<br>Scientific literacy (evaluate and design scientific inquiry, explain phenomena scientifically) |
| **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>**Prior experience with inquiry:** Some prior experience |

In this implementation, students were free to plan different methods of creating the plant samples – using Elodea, rather than algal balls – and setting levels of light intensity. The teacher chose to assess *planning investigations* and *forming coherent arguments*. Oral formative feedback was provided throughout the lesson, while the teacher assessed the completed worksheets for each group and gave formative feedback on general issues to the class. Summative assessment was also provided, in line with school policy.

### (i) How was the learning sequence adapted?

When adapting the activity, the teacher's main concerns were to keep as close as possible to the original problem and to make use of the experiences of a colleague. 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. Some of these recommendations were retained, such as using the bicarbonate indicator as one type of indicator; pH measurement with an instrument was also introduced. 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.

It was not possible to implement the algal ball method described in the original unit, as there was no access to suitable algae colonies and the jelly with alginate could not be prepared. Instead, teacher used some algae from a water tank (Elodea). The students had to divide a given quantity into samples. The students used undamaged algae. Two versions of the experiment were investigated - three of the groups used a beaker while the fourth group put the plants in a test tube. The test tube method had the advantage of not letting the plants cover each other, which made it easier to vary light intensity.

As there was limited time available to carry out the activity (2 x 45 minutes), not much time was available to set up the experiment and to analyse the results. After setting up the experiment, the students had time to complete only one measurement before the one-week mid-term break. Therefore students set up the experiment in one week, and repeated the measurement after the break.

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

Planning and practical implementation were time-consuming, leaving little time to carry out the experiment. Therefore the teacher observed and evaluated only two skills – *planning investigations*

and *forming coherent arguments*. The most important phase was the planning of the investigation. 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. With the teacher's guidance and using their prior knowledge, the students finally decided on measuring the pH value as the dependent variable

In this implementation, 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. Towards the end of the activity the groups were encouraged to evaluate the activity and say whether they would make any changes to the worksheet or the description of the experiment.

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.

### (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. The central question was the quality and quantity of the plant samples. This involved considering constant factors and the practicability of a fair test (*planning investigations*). 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 *forming coherent arguments* (plants use $CO_2$).

The assessment criteria were discussed with the students (albeit only briefly because of time constraints). 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. The teacher later used this written work for formative assessment. The assessment followed a modified version of the rubric given in the original unit (Table 1). At the end of the activity, the teacher also performed summative assessment. The electronic grade book used by the school only allows summative assessment in the form of numerical grades.

**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. |

## (iv) Evidence collected

**Teacher opinion**

The students showed substantial variation with respect to these inquiry skills. Only one group reached the highest level and two groups showed emerging performance. The rest of the class (18 students) performed at consolidating level. One of the groups did worse than expected, which they attributed to the fact that it was the last class period before the mid-term break.

Although there was no observer present, the teacher discussed the unit before and after the activity sessions with a colleague who also trialled it. The teacher made good use of the colleague's experiences, his ideas and suggestions were of great help. The teacher adopted the assessment rubric used by the colleague.

**Sample student artefacts**

Two experimental procedures were investigated – one group placed the algae samples in test tubes, while the other groups used beakers (as shown in Figure 1). As there was a mid term break after the

first lesson, samples were analysed after one week and the change in carbon dioxide concentration observed by measurement of pH of the samples (compare Table 2 and Table 3).

**Figure 1: Comparison of test tubes and beakers (after one week)**

**Table 2: Results obtained for samples in test tubes**

| Sample/pH | Time (year, month, day, time) | |
|---|---|---|
| | 2015. 04.01 14.00 | 2015. 04.08 14.15 |
| 1 | 6.95 | 9.32 |
| 2 | 6.93 | 8.94 |
| 3 | 6.84 | 8.77 |
| 4 | 7.01 | 8.71 |
| 5 | 7.05 | 8.57 |
| 6 | 7.02 | 8.50 |

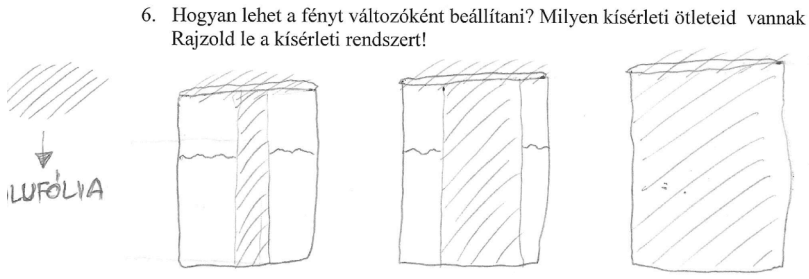
**Table 3: Results obtained for samples in beakers**

| Sample/pH | Time (year, month, day, time) | |
|---|---|---|
| | 2015. 04.01 14.00 | 2015. 04.08 14.15 |
| 1 slight overlap | 7.95 | 10.27 |
| 2 medium overlap | 8.18 | 9.53 |
| 3 large overlap | 7.86 | 9.17 |

**Sample answers to questions on the work sheet:**

**How would you measure the same quantity of sample into each sample?**
Every group included the answers: *"We need to weigh them."* and/or *"We select plants of the same length."* The students were given unintended help in that there were some digital scales on the back desk in the lab. They immediately incorporated the scales into the task.

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

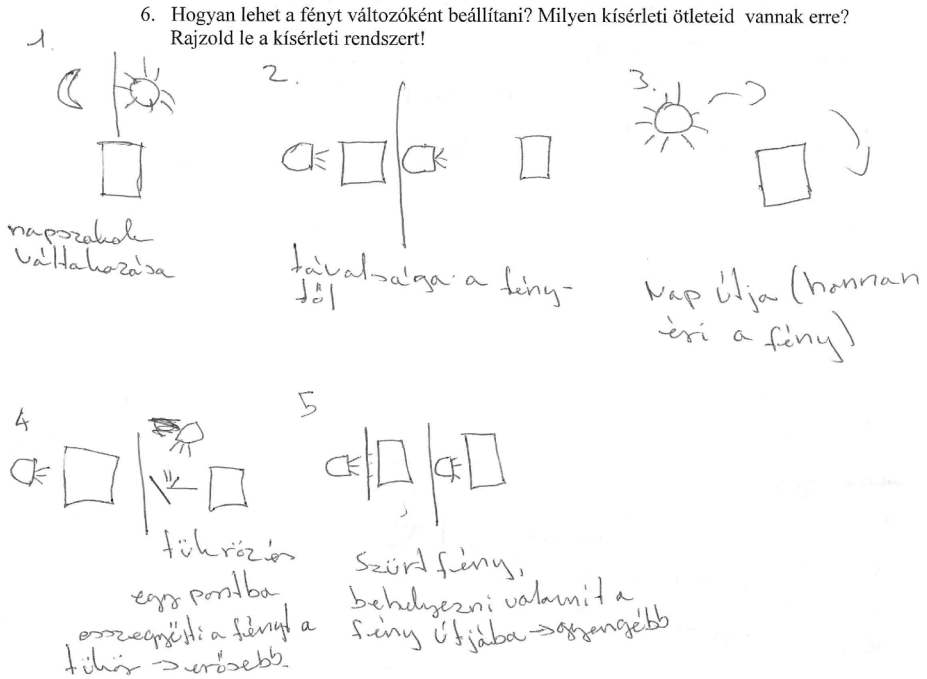



An experimental plan of light intensity manipulation

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

***"We place the test tube at different distances from the light. We cover half of it or a quarter of it or three quarters of it with aluminium foil."***

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




***"Day–night cycle. Distance from the light. Path of sun (where the light comes from) Reflect light onto a spot, the mirror collects the light – stronger light. Filtered light – we put something between the light source and the beaker – weaker light."***

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

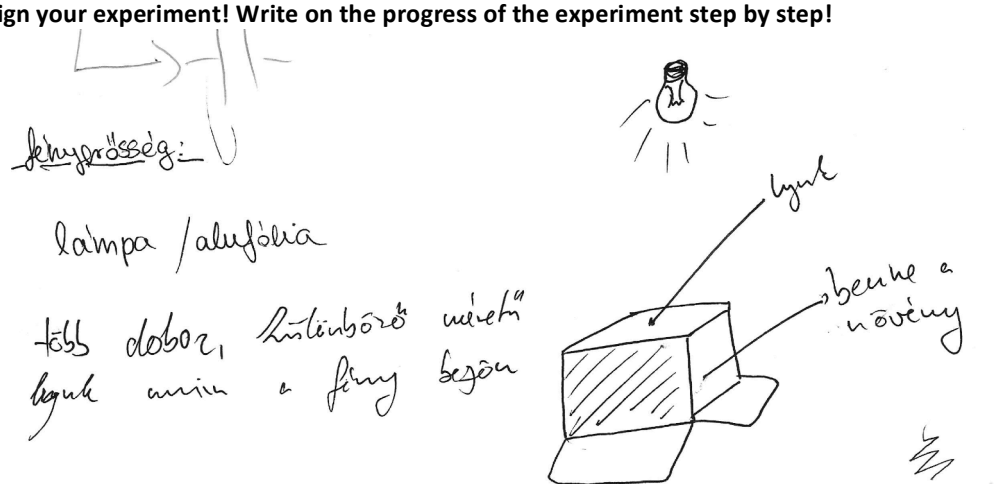
***Plan to investigate light intensity:***
The sealed test tubes were placed in a box in a diagonal. The box had one side open.

This experiment was implemented as planned and provided the most accurate series of data.


**6. How could we control the light as an independent variable? Draw a plan!**
This plan controls light intensity using foil. A given section of the beaker is covered. The plants were used whole. This set-up gave the largest measurement differences.

**7. Design your experiment! Write on the progress of the experiment step by step!**
***"We cut plants of equal weight. We put them in equal amounts of water. We wrapped a strip of the beakers with UNEQUAL pieces of foil. We also covered the top of each beaker. We added 5cm$^3$ of bicarbonate indicator.***
***-> "The larger piece of foil, the less light reached the plant and we should get a lower pH."***

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




***"We put the plant in a box with holes in it. Different sizes of holes – different amounts of light."***

## (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. The students were also given summative evaluation: two groups did a very good job and two groups had room for improvement.

This inquiry task did not match the topic of regular classes; it is closer to the subject matter of the next school year. 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. Our work was made easier by having student groups that were well accustomed to working together as they had collaborated in a number of activities before. It did not make a significant difference to the work process whether the group was all male or co-ed. Each group found advantages from their own point of view. 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 spectroscope but the manual measurement of pH proved to be adequate for obtaining accurate data.