

## 4.6 Case study 6 (CS6 Poland)

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| <b>Concept focus</b>                     | Environmental impact of household chemicals  |
| <b>Inquiry skills</b>                    | Planning investigations<br>Developing hypotheses<br>Forming coherent arguments   |
| <b>Scientific reasoning and literacy</b> | Scientific reasoning (data entry and observation skills)<br>Scientific literacy (presentation of scientific data)  |
| <b>Assessment methods</b>                | Classroom dialogue<br>Teacher observation<br>Worksheets<br>Student devised materials (documentation of inquiry)<br>Presentations<br>Other assessment items (true/false test)   |
| <b>Student group</b>                     | <b>Grade:</b> upper second level, chemistry class<br><b>Age:</b> 17 years<br><b>Group composition:</b> mixed ability and gender; 12 students<br><b>Prior experience with inquiry:</b> No prior experience with inquiry |

This implementation describes an extracurricular class, in which students planned an experiment to carry out at home. The teacher assessed students' skill in *planning investigations* through observation and used a four-level rubric to identify performance levels for each student. The students submitted presentations electronically, which were evaluated using rubrics to assess skills in presentation of scientific data and *forming coherent arguments*. A true/false test was also completed to assess this skill.

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

The **Household versus natural environment** SAILS unit was implemented during extracurricular classes, when students carry out interesting experiments. Within the classes we talked about types of cleaning agents and consequences of their usage. I asked students how they could investigate this (brainstorming). A lot of interesting ideas were suggested. I identified the most active students. Then we decided together that the cuckoo flower would be the subject of our research. The research problem was established: "Investigate the influence of cleaning agents on natural environment." The students were divided into groups in which they were to think over how to check it (work in groups lasting 15 minutes). Then a representative of each group presented the groups' plan for how they would proceed with the investigation:

| <b>Group 1<br/>(4 students)</b>                              | <b>Group 2<br/>(2 students)</b>   | <b>Group 3<br/>(3 students)</b>   | <b>Group 4<br/>(3 students)</b>   |
|--|---|---|---|
| Influence of various detergents on cuckoo flower development | Influence of different concentrations of liquid for washing dishes on cuckoo flower development | Influence of different concentrations of fabric softener on cuckoo flower development | Influence of different concentrations of fabric softener on cuckoo flower development |

At the end, I gave a work sheet to each student. We jointly determined the experiment time limit. I gave the students an e-mail address, to which they could send questions in case of any problems.

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

The activity was used in order to assess students' skills in *planning investigations* (including *developing hypotheses*), *scientific reasoning* (observations, recording results), *scientific literacy* (presentation of scientific data) and *forming coherent arguments* (drawing conclusions).

### (iii) Criteria for judging assessment data

#### Planning investigations

The teacher used observation to evaluate students' skill in *planning investigations*, and gathered the results in table. Each member of a group was assessed individually, using a four-level rubric to determine performance level (Table 1).

**Table 1: Rubric for assessment of planning investigations**

| Inquiry skill           | Unsatisfactorily<br>1 point  | Properly<br>2 points   | Good<br>3 points  | Perfectly<br>4 points  |
|-------------------------|--|--|---|--|
| Developing hypotheses   | Student does not formulate hypothesis or formulates it incorrectly; determines the aim of the experiment inaccurately. | Student gives one hypothesis; properly formulates the aim of the experiment, with slight mistakes.   | Student gives two hypotheses; asks research question; formulates an experimental aim. | Student formulates more than two hypotheses; asks research question; formulates an experimental aim.   |
| Defining variables      | Student does not define variables.   | Student gives variables without dividing them into dependent, independent, controlled.   | Student gives variables and classifies them as dependent, independent or controlled.  | Student gives at least three variables and classifies them as dependent, independent or controlled.  |
| Planning investigations | Student does not present an experimental plan.   | Student presents an experimental plan, without giving details of how they will carry out the experiment, e.g. does not inform how successive concentrations are prepared or what quantities of detergent are added; formulates prediction about what will happen but does not explain cause. | Student presents an experimental plan, however insufficient detail is provided.       | Student presents an experimental plan that includes preparation of samples (method for sowing cuckoo flower), definition of the control sample, lists measured parameters and the method for measuring e.g. measuring the length of stalk by setsquare, plans time of experiment, calculates and prepares solutions of various concentrations. |

#### Scientific reasoning – observation skills

The teacher was particularly interested in how well developed students' observation skills were, and so evaluated each student individually using a four-level rubric (Table 2).

**Table 2: Rubric for assessment of observation skills**

| Inquiry skill                                | Unsatisfactorily<br>1 point  | Properly<br>2 points   | Good<br>3 points   | Perfectly<br>4 points  |
|--|--|--|--|--|
| Number of observed parameters                | Student does not define observed parameters.   | Student observes a change of only one parameter, e.g. the change of leaf colour.   | Student observes a change of two parameters, e.g. the change of leaf colour and length of stalk.   | Student describes properties of object at the beginning of the experiment and at the time of its duration; observes changes of some parameters, gives probable reason for the changes, uses more than one sense for description of the object. |
| Writing down results                         | Student writes down the results carelessly; does not give units; does not give measurement time. | Student writes down the results carelessly, without noting measurement time; omits relevant units; prepares tables, but they are not described or described incorrectly. | Student tries to reliably record the experiment results, gives measurement time; uses appropriate units; prepares a correctly described table. | Student records proper results with suitable accuracy and appropriate units, prepares correctly described and completed table; notes recorded when carrying out the experiment are made carefully.   |
| Documentation of carrying out the experiment | Student does not make any documentation.   | Student encloses photographs without descriptions  | Student provides documentation, however insufficient detail is provided.   | During the experiment student uses various technological resources; photographs are described, e.g. student notes which day is it, what amount of detergent is added, what kind of detergent is given to sample.                               |

### **Scientific literacy – presentation of scientific data**

To assess this skill, the teacher analysed groups' presentations and worksheets that were submitted by e-mail and used a four-level rubric to determine performance level (Table 3). Each student was assessed individually, and teacher also evaluated student engagement.

**Table 3: Rubric for assessment of presentation of scientific data**

| Inquiry skill   | Unsatisfactorily<br>1 point   | Properly<br>2 points   | Good<br>3 points   | Perfectly<br>4 points   |
|---|---|--|--|---|
| Does the student present gathered data?                             | Student does not present data.  | Student presents results but he does not compare them with other colleagues.             | Student compares obtained results with colleagues. Not all parameters from column on the right side are fulfilled. | Student compares obtained results with colleagues; thinks over reasonableness of his results; identifies possible sources of mistakes and uncertainty of measurements; suggests changes leading to improvement. |
| Does the student prepare a table, diagram?                          | Student does not prepare tables and diagrams.   | Prepared diagram is not named, is incorrectly described or axes are without description. | Not all parameters in the column on the right side are fulfilled.  | Prepared diagram is named; axes are described; tables are described; data in a table are given always with units.   |
| Does the student use technological tools for the data presentation? | Student does not take photographs; does not prepare presentation; work sheet fulfilled with mistakes. | Presentation is made carelessly; photographs without descriptions.                       | Not all parameters in the column on the right side are fulfilled.  | Student carefully prepares presentation in the format of MS PowerPoint; puts the whole documentation of experiment in it: tables, diagrams, photographs with full description.                                  |

### **Forming coherent arguments (drawing conclusions)**

The skill of *forming coherent arguments* was assessed through evaluation of students' ability to draw conclusions based on their experimental results. To determine performance levels in this skill, a true/false test was used (Table 4), as well as a rubric (Table 5). Assessment of student groups and individuals was carried out.

**Table 4: True/false test for assessment of drawing conclusions**

| Point out all properly formulated conclusions as a result of the carried out experiment.<br>Mark T if the sentence is true or F if it is false. |     |
|---|-----|
| 1. Negative influence of chemical agents on cuckooflower development increases linearly with the increase of concentration.                     | T/F |
| 2. When the influence effect reaches maximum, then in spite of much more doses it remains almost constant.                                      | T/F |
| 3. In this experiment, detergent solutions represent household wastewater and cuckooflower represents the natural environment.                  | T/F |
| 4. Ecotoxicology is a science dealing with the influence of toxic substances on the functioning of ecosystems.                                  | T/F |

**Table 5: Rubric for assessment of forming coherent arguments**

| Inquiry skill                                     | Unsatisfactorily<br>1 point  | Properly<br>2 points  | Good<br>3 points   | Perfectly<br>4 points   |
|---|--|---|--|---|
| Formulation of conclusions based on obtained data | Student draws conclusions based on obtained results incorrectly or does not give any conclusion. | Student draws conclusions but they are based on limited range of results; relates obtained results to hypothesis formed at the beginning of the experiment. | Student draws conclusions based on the results of his/her experiment; refers to hypothesis formed at the beginning of the experiment.<br>Not all parameters from the column on the right side are fulfilled. | Student draws conclusions based on the results of his/her experiment; refers to hypothesis formed at the beginning of the experiment; refers to information from various sources; uses specialised language.  |
| Comparison of results – analysis of faults        | Student does not compare results with other colleagues in a group.                               | Student compares results with other colleagues in a group; does not think over faults and differences in measurements.                                      | Student compares results with other colleagues in a group; thinks over faults and differences in measurements.<br>Not all parameters from the column on right side are fulfilled.                            | Student compares results with other colleagues in a group; rationally approaches interpretation of his results; thinks over faults and differences in measurements; specifies accurately factors causing differences in measurements and their potential cause. |

#### (iv) Evidence collected

##### Teacher's opinion

I decided to evaluate each skill with the rubric tables designed by myself. That is because the students carried out the experiment at home, so it was difficult to use student's self-assessment to evaluate a group and their cooperation. Therefore I preferred to evaluate each student individually. For the skill of *forming coherent arguments* (drawing conclusions), I evaluated groups and each person individually as well. Unfortunately not all the students who had declared their intention to participate in the experiment sent me their presentations on time; that is why there is a different number of students in each group. I wish once more to run the unit during a lesson, then I could use other methods of assessment. I did not expect the homework assessment to be so time-consuming.

The maximum grades available for this task were 46 points. The performance levels were defined as 46–44= excellent, 43–36= very good, 35–26= good, 25–20= satisfactory and 20–12= mediocre. There performance level of unsatisfactory was omitted, because the students performed the experiment and such a form of assessing had never been used earlier.

##### Sample student artefacts

A summary of the grades obtained by the students for each skill is shown in Table 6.

**Table 6: Results of assessment for all students**

| Assessed skill<br>Mark | Planning investigations | Observation skills | Presentation of scientific data | Forming coherent arguments (drawing conclusions) |
|------------------------|-------------------------|--------------------|---------------------------------|--|
| Perfectly              | 67%                     | 50%                | 34%                             | 0%   |
| Good                   | 8%                      | 8%                 | 8%                              | 8%   |
| Properly               | 8%                      | 17%                | 8%                              | 67%  |
| Unsatisfactory         | 17%                     | 25%                | 50%                             | 25%  |

Some examples of students' work, and the grades assigned are shown below:

**Planning investigations, example 1: student in Group 1**

The research problem: *whether detergents adversely affect the growth of cuckooflower?*

Hypothesis: *detergents adversely affect the growth of cuckooflower.*

Procedure: -

**Grade given:** 4 points – unsatisfactory

**Planning investigations, example 2: student in Group 2**

The research problem: *Effect of detergent on the growth of stem, leaf colour and stem.*

Hypothesis:

- *Detergent inhibits the growth and development of plants.*
- *Under the influence of detergent is changing colour of the leaves and stems.*
- *Under the influence of a high concentration of the detergent plant droops.*

Procedure: *For 5 days at 6.00 p.m. cress was watered water and then the growth was controlled.*

*I did this by using a toothpick. The plant height was marked on the toothpick and then transferred on ruler. After 5 days, on Saturday (12nd April) samples were watered with the use detergent (fabric softener) with different concentration:*

- *Water*
- *7 teaspoon detergent + 4 teaspoon water (7:4)*
- *7 teaspoon detergent + 2 teaspoon water (7:2)*
- *10 teaspoon detergent + 10 teaspoon water (10:10)*
- *100% detergent*

**Grade given:** 12 points – perfectly

For assessment of the skill of presentation of scientific data, the student presentations were evaluated. While most students used MS PowerPoint for this task, one student in Group 3 prepared a video presentation. This featured a video of the procedure for carrying out the investigations, evidence of how measurements were performed and photographs of the results (day by day). This student was assigned a grade of 12 points (perfectly), as all desired information was provided and very well presented.

Presentations that did not feature tabulated results, for example as shown in Figure 1, and detailed little of the experimental procedure were assigned 4 points (unsatisfactory). The teachers comments regarding this student were "The student prepared the multimedia presentation, formed hypothesis and wrote proper conclusions from the experiment; unfortunately she did not compare them with other students. She took photographs documenting the experiment proceedings but without description. She did not make any observations, tables and diagrams."



Figure 1: Sample slides from student's presentation

### Study of the effect of detergent on the growth and appearance of the plant

**The research problem:** The effect of the cleaning agent on the growth of stems, color of the leaves and stems.

**Hypotheses:**  
Detergent inhibits the growth and development of plants.  
Under the influence of the detergent leaves and stems change color .  
Under the influence of a high concentration of the detergent plant goes limp.

### Planning experience

| STAGE I  | STAGE II  |
|--|---|
| <b>Preparation of experiments</b> <ul style="list-style-type: none"> <li>- water-logged cotton</li> <li>- garden cress seeds (about 30 seeds for one container)</li> <li>- Small trays</li> <li>- designation of consecutive samples using toothpick with number</li> <li>- water for watering plants</li> </ul> | <b>For the preparation of formulations:</b><br>jars, sticky notes and tape to mark cups of the solution, water, dishwashing liquid<br><b>Composition jars:</b><br>I. Water<br>II. Dishwashing liquid + water 1:8<br>III. Dishwashing liquid + water 1:4<br>IV. Dishwashing liquid + water 1:2<br>V. Plyn Dishwashing liquid |

The plants are watered once a day (approx. H. 18.00)  
Recording room temperature  
1. Observation of the color change of leaves and stems  
2. The observation of plant growth (save the plant size [mm])

| Date       | tubes       | I     | II          | III         | IV          | V           |
|------------|-------------|-------|-------------|-------------|-------------|-------------|
| 12.04.2014 | size        | water | 1:8         | 1:4         | 1:2         | detergent   |
|            | size        | 80mm  | 45mm        | 90mm        | 50mm        | 80mm        |
|            | Leaf colour | green | green       | green       | green       | green       |
| 13.04.2014 | size        | 65mm  | 25mm        | 25mm        | 20mm        | 20mm        |
|            | size        | 65mm  | 25mm        | 25mm        | 20mm        | 20mm        |
|            | Leaf colour | green | green       | green       | green       | green       |
| 14.04.2014 | size        | 70mm  | 20mm        | 20mm        | 15mm        | 15mm        |
|            | size        | 70mm  | 20mm        | 20mm        | 15mm        | 15mm        |
|            | Leaf colour | green | green       | green       | green       | green       |
| 15.04.2014 | size        | 80mm  | 15mm        | 20mm        | 15mm        | 10mm        |
|            | size        | 80mm  | 15mm        | 20mm        | 15mm        | 10mm        |
|            | Leaf colour | green | green       | green       | green       | green       |
| 16.04.2014 | size        | 85mm  | 10mm        | 15mm        | 10mm        | 5mm         |
|            | size        | 85mm  | 10mm        | 15mm        | 10mm        | 5mm         |
|            | Leaf colour | green | dark green  | dark green  | dark green  | dark green  |
| 17.04.2014 | size        | 90mm  | 5mm         | 10mm        | 5mm         | 5mm         |
|            | size        | 90mm  | 5mm         | 10mm        | 5mm         | 5mm         |
|            | Leaf colour | green | dark green  | dark green  | dark green  | dark green  |
| 18.04.2014 | size        | 90mm  | 10mm        | 10mm        | 10mm        | 10mm        |
|            | size        | 90mm  | 10mm        | 10mm        | 10mm        | 10mm        |
|            | Leaf colour | green | light green | light green | light green | light green |

**Conclusion:** The higher the concentration of detergent, the faster the plant goes limp and lose the color of the leaves and stems.  
We should restrict the use of chemicals to protect the environment.

**Toxic dose** is lower than the detergent concentration of 1:8 because at this concentration and plant slowly dies.  
Ecotoxicity is a feature of certain substances and preparations causing or likely to cause immediate or delayed risks for one or more slices environment.  
(Substance that in this case is dishwashing liquid, and cress represents the environment)

**Invalid result of an experiment can cause:**  
 - the temperature in the room which was unaffected by the day  
 - radiator positioned under the sill  
 - ventilation  
 - no sufficient amount of sunlight  
 - too much / too little water  
 - plastic cups containing liquids for irrigation

**Results from people in the group:**  
The differences in the results are caused by the fact that one of her friends cress sown later and later he started watering are differences in the growth of plants with another friend arise from the fact that my watercress were grown at a higher temperature than it.

Figure 2: Sample slides from student's presentation

An example in which more detail was provided regarding the experimental plan and results were tabulated is shown in Figure 2. The photographic documentation for this case was similar to that shown in the previous example, and the teacher assigned this example a grade of 6 points (properly). Teacher comments regarding the total grade of this student (41/46) were "Three first

skills have been made perfectly by the student. The problem for her was drawing conclusions – she did not send the test.”

**Forming coherent arguments (drawing conclusions), example 1: student in Group 1**

Conclusions:

- ***A small amount of detergent inhibits the growth of cuckooflower***
- ***Watered with clean water cuckooflower grow properly.***

**Grade given:** 8 points – properly

**Forming coherent arguments (drawing conclusions), example 2: student in Group 2**

Conclusions:

- ***A small amount of detergent influence on retention the plant growth.***
- ***Increased quantity of detergent has negative effects on cress and then plants wither.***

**Grade given:** 6 points – properly