# Plant nutrition

Photosynthesis – how do plants grow?

# SAILS inquiry and assessment unit overview

|  |  |
| --- | --- |
| **Name** | Plant nutrition |
| **Key content/concepts** | * Photosynthesis * Plants and chlorophyll (leaves, algae) * Oxygen, light and organic substances * Carbon dioxide absorption * Importance of forest and water ecosystems |
| **Level** | * Lower second level * Upper second level |
| **Inquiry skills assessed** | * Planning investigations * Developing hypotheses * Forming coherent arguments * Working collaboratively |
| **Assessment of scientific reasoning and scientific literacy** | * Scientific reasoning (making predictions; forming conclusions; defining variables; argumentation) * Scientific literacy (evaluating and designing scientific inquiry; explaining phenomena scientifically) |
| **Assessment methods** | * Classroom dialogue * Teacher observation * Self-assessment * Worksheets * Student devised materials (documentation of inquiry process, experimental plans) * Presentations |

Table 1: Rubric used to evaluate planning investigations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **Distribution of materials** | Indicates chosen method | Indicates chosen method and argues its speed | Indicates chosen method and argues its accuracy | Indicates and compare speed and accuracy of chosen method |
| **Layout of samples** | Procedure precise, but small distances between samples (10 cm) | The layout is less accurate, time is marked | 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 |
| **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 source in self-proposed table |

Table 2: Rubric used to evaluate scientific reasoning

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **Argument in support of chosen method** | Indicates chosen method | Indicates chosen method and argues its speed | Indicates chosen method and argues its accuracy | Indicates and compares speed and accuracy of chosen method |
| **Drawing conclusions based on evidence** | Understanding the procedure | Arguments show understanding of the procedure | Arguments show understanding of the process | Arguments points to the understanding of the purpose of experiment and the principle of action. |

Table 3: Assessment criteria for sample layout in additive mode

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Inquiry skills and processes** | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **Planning investigations:**  **Layout of samples** | Procedure precise... | ... and  the layout is accurate (different light intensity), time is marked... | ...and  student is able to explain the layout design in practical terms... | and...  student is able to reason the procedure, builds on the fundamental of photosynthesis |

# 3. Synthesis of case studies

This unit was trialled in four countries, producing six case studies of its implementation – **CS1 Slovakia**, **CS2 Slovakia**, **CS3 Portugal**, **CS4 Hungary**, **CS5 Hungary** and **CS6 Sweden**. All the case studies were implemented by teachers who had some experience of teaching through inquiry, but the students involved had not been taught through inquiry in **CS1** or **CS2** (both **Slovakia**) and in **CS3 Portugal**. In **CS6 Sweden** and **CS4** and **CS5** (both **Hungary**) the students had some prior experience of inquiry. The students involved in the case studies were aged 12-16 years and of mixed ability and gender.

The activity was implemented as a 180-minute block in **Slovakia.** It was divided into two lessons in **CS3 Portugal**: one 150-minute lesson and another 100-minute lesson. The activity with Elodea (pondweed) instead of algal balls took two 45-minute lessons (**CS4** and **CS5 Hungary** and **CS6 Sweden)**. In **CS3 Portugal and CS6 Sweden**, the materials required for the activity were not available, and so the unit was implemented as a theoretical planning investigation.

The key skills identified for assessment were *planning investigations* and *forming coherent arguments*, as well as associated *scientific reasoning* capabilities. However, in **CS3 Portugal** the teacher chose to assess skills in *developing hypotheses* and *working collaboratively*. The assessment methods used include classroom dialogue, teacher observation and evaluation of worksheets, presentations or other student artefacts.

## 3.1 Teaching approach

**Inquiry approach used**

The inquiry approach used in all the case studies was that of *guided inquiry*, i.e. it was guided in the sense that the teacher posed the initial question but there were open inquiry opportunities in that students had freedom in formulation of predictions and *planning investigations*.

**Implementation**

During implementation of the activities in this unit, the optimal number of students per class is 15-18. It is possible to work with classes of about 30 students, but the assessment is more difficult for the teacher. With a large number of students an interactive demonstration is recommended, with the inclusion of discussion sequences. The assessment focuses on student proposals relating to the preparation and arrangement of samples, formulation of assumptions and hypotheses.

All teachers organised their students into smaller groups, consisting of 2-4 members. There are examples of single gender groups in **CS3 Portugal**, and also of mixed-sex groups in all case studies. In **CS3 Portugal**, the teacher tried to verify if the predominance of one gender could affect the dynamics in class, but due to small number of groups in which it was possible to watch the gender effect it is not possible to formulate clear conclusions. The students in all of the case studies worked in groups throughout the lessons, but there was variation in both how the groups were chosen and the group size, as shown in Table 4.

Table 4: Summary of case studies

|  |  |  |
| --- | --- | --- |
| Case Study | Duration | Group composition |
| **CS1 Slovakia** | One lesson (180 min) | * Groups of 3 students * Teacher assigned |
| **CS2 Slovakia** | One lesson (180 min) | * Groups of 3-4 students * Self-selected |
| **CS3 Portugal** | Two lessons  (1x150 min, 1x100 min) | * Groups of 3 students * Teacher assigned |
| **CS4 Hungary** | Two lessons (45 min each) | * Groups of 3-4 students |
| **CS5 Hungary** | Two lessons (45 min each) | * Groups of 3-4 students |
| **CS6 Sweden** | Two lessons (45 min each) | * Groups of 2-3 students |

**Adaptations of the unit**

The **Plant nutrition** SAILS inquiry and assessment unit explores the effects of light on the intensity of photosynthesis. A full experimental setup is provided, including the method for controlling the independent and the dependent variables. When implemented by the teachers in the case studies, several types of bicarbonate indicator were used and pH measurement using a meter was described (**CS4**, **CS5 Hungary**).

Some teachers could not implement the algal ball method described in the unit, because they did not have access to suitable algae colonies and could not make the jelly with alginate (**CS4 Hungary** and **CS5 Hungary**). Instead they used some algae from a water tank (Elodea). In **CS3 Portugal** and **CS6 Sweden**, the unit was implemented as a theoretical planning investigation, as the materials required for the activity were not available. In **CS3 Portugal**, students developed a hypothesis after researching the inquiry question, viewing a video of the implementation of the investigation and analysing a set of experimental data.

In all case studies, it was necessary to review students’ prior knowledge before introducing the inquiry activities. The teachers ensured that students already knew the principle of photosynthesis; this was achieved through a moderated conversation before the teacher introduced the activity. Students formed self-selected groups (**CS1 Slovakia**) or the teacher randomly organised students (**CS2 Slovakia**, **CS3 Portugal**). Groups were able to choose the format for recording their documentation and for the final presentation their work (PowerPoint presentation, poster, video documentation). Students in **CS3 Portugal** were told they would have to produce a written document using a word processor (e.g. Microsoft Word), where they would write the group’s answers to the activity questions. During the lesson, an introductory work document was provided to each student, with the objectives and the theoretical framework (**CS3 Portugal**). The students had computers with Internet access (one per group), so that they can search about terms/concepts and new information either on the algae or the selected reagents. Students in **CS4** and **CS5** (both **Hungary**) completed worksheets and in **CS6 Sweden** groups prepared a written plan of their experiment.

The student groups attempted to define the problem and the objectives of experiment. They discussed and designed some steps of the procedure, identified which variables are involved, and made predictions about the expected results. The experiment was followed by analysis and interpretation of results, and a group discussion was used to answer to the given questions (**CS1 Slovakia**), or at the end, the students completed a questionnaire (individually) on how the work in their groups went (**CS3 Portugal**). The self-assessment template also focused on how well the student thought their peers understood them during the peer discussion.

## 3.2 Assessment strategies

Within the six case studies, the inquiry skills of *planning investigations*, *developing hypotheses, working collaboratively*, *scientific reasoning* (arguing for a chosen method, drawing conclusions based on evidence) and *scientific literacy* were assessed (Table 5). Formative assessment was useful, in particular for the assessment of *working collaboratively*. Some assessment methods used include:

* Providing feedback through discussion with peers
* Individual assessment of students on the basis of documentation of the experiment
* Teacher questioning and feedback to students
* Students’ self-assessment

Table 5: Inquiry skills identified by teachers in the case studies

|  |  |
| --- | --- |
| **CS1 Slovakia** | * Planning investigations * Forming coherent arguments * Scientific reasoning (forming conclusions) |
| **CS2 Slovakia** | * Forming coherent arguments * Scientific reasoning (making predictions, forming conclusions) |
| **CS3 Portugal** | * Developing hypotheses * Working collaboratively |
| **CS4 Hungary** | * Planning investigations * Forming coherent arguments * Scientific reasoning (defining variables, argumentation, forming conclusions) |
| **CS5 Hungary** | * Planning investigations * Forming coherent arguments * Scientific reasoning (argumentation, forming conclusions) * Scientific literacy (evaluate and design scientific inquiry, explain phenomena scientifically) |
| **CS6 Sweden** | * Planning investigations |

In all case studies, except **CS6 Sweden**, the teachers used rubrics to help them to identify the performance level of students or groups for selected inquiry skills. These rubrics describe assessment criteria for four levels of performance – emerging/developing/consolidating/extending. Each student is able to achieve a basic level of skills (emerging), which then develops. Consolidating skill arises from repeatedly practicing. The most skilled students are able to extend this skill. It is not possible to observe and assess all skills at the same time. Simply, the teacher focuses on one or two selected skills at a time.

When students work in groups it is easier to provide formative assessment of the group as a whole. The teacher can note the group’s result in a table more easily than evaluating the reasoning of 3 or 4 individual students. The teacher can therefore see more discussion and outcome of groups. Only with practice can he/she be able to observe the work of many individual students during activities. However, a teacher can make a good judgement about of the reasoning skills of individual students, when group work is followed by a phase where each student writes their own conclusions or answers to the teacher’s questions.

The teacher in **CS1 Slovakia** used the rubric for *planning investigations* provided in the assessment of activities for teaching & learning section of this unit (Table 1), but altered the criteria for evaluation of students’ skill in data entry (Table 6). Table 7 shows the rubrics used by teachers in **CS1** and **CS2 (**both **Slovakia**), which provided expanded descriptions of each of the assessment criteria for evaluation of *scientific reasoning* and *scientific literacy* provided in the sample rubric in Table 2.

Table 6: Assessment tool for planning investigations (data entry), used in CS1 Slovakia

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Inquiry skills and processes** | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **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 |

Table : Rubrics for assessment of scientific reasoning (in CS1 Slovakia) and scientific literacy (in CS2 Slovakia)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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. |
| **Scientific literacy** | **2. 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. |

The teacher in **CS3 Portugal** also used 4-level rubrics for the assessment of students’ inquiry skills (Table 8), focusing in particular on *developing hypotheses* and *working collaboratively*. The teachers in both **CS4** and **CS5 Hungary** examined students’ written work in order to assess their skills in *planning investigations* and *forming coherent arguments*, and defined their assessment criteria as shown in Table 9.

Table 8: Assessment criteria for working collaboratively and developing hypotheses, as used in CS3 Portugal

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Inquiry skills and processes** | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **Working collaboratively**  **Interpersonal relationships and group functioning (emotional literacy)** | Observes and accepts the colleagues’ proposals in the organisation of the group work, but gives no suggestions; merely accepts what the colleagues are doing (due to difficulties in interpersonal relationships). | Participates in the organisation of the group work, but only makes one or two suggestions that add little value to what was already done (due to difficulties in interpersonal relationships). | Participates in the organisation of the group work and gives positive suggestions contributing to a productive group dynamic. | Participates in the organisation of the group work and significantly contributes to a productive group dynamic, creating positive personal interactions (allowing the improvement of others and raising the work level). |
| **Developing hypotheses** | Formulates hypotheses that are not consistent with the planning or that are not eligible for investigation. | Formulates hypotheses that are consistent with the planning of the experiment. | Formulates hypotheses that are consistent with the planned experiment and are based on the research questions. | Formulates hypotheses that are consistent with the planned experiment. Those hypotheses are based on the research questions and identified variables. |

Table 9: Assessment tool for planning investigations and forming coherent arguments in CS4 and CS5 Hungary

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Skills** | **Emerging** | **Developing** | **Consolidating** | **Extending** |
| **Planning investigations** | Has some ideas about manipulating the independent variable but the ideas of practical implementation are incorrect.  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.  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  Plans a viable method of manipulating the given independent variable.  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.  Plans a viable method of manipulating the given independent variable and considers possible errors.  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.  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.  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  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.  Analyses the data critically, uses a statistical approach, control for measurement errors and supports his or her decisions with scientific arguments. |

The assessment criteria outlined in the provided rubrics are merely guidelines; as shown, teachers can adapt these criteria to the needs of their own class or develop their own criteria. The students can also use these criteria for self-assessment. Additionally, the criteria can be adapted to the age of the students. For example, in **CS1 Slovakia**, the conclusions formulated by younger students revealed that they focused their attention on planning investigations. They did not perceive that this experiment provided proof of photosynthesis. In their conclusions they reported that the indicator changed colour as a variable dependent on the distance of the sample from the light source, but they did not relate the colour change to the change in CO2 concentration. They also do not have enough experience to design a table for recording of data.

In general, the teachers did not have difficulties in assessing their students. The greatest difficulty seems to be related to the use of teamwork observation grids in **CS3 Portugal**, in which the teacher noted the contribution of each team member (Table 9). This required a lot of the teacher’s time, although just two groups were chosen for assessment during this case study. As demonstrated in **CS3 Portugal**, rubrics have also proven useful for the assessment of *working collaboratively* (Table 8). However, watching and recording the rate of activity in a grid was difficult for teachers. They found that they were not able to watch all groups simultaneously. Therefore, it is very helpful to assess *working collaboratively* at the group level, rather than individually (**CS3 Portugal**, **CS4** and **CS5 Hungary**).

Table 9: Registration grid for observation of working collaboratively (teamwork) in CS3 Portugal

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Behaviour** | **Student name** | **Student name** | **Student name** | **Student name** |
| Does not interrupt when others speak |  |  |  |  |
| Questions the colleague regarding what he is saying |  |  |  |  |
| Defends his points of view |  |  |  |  |
| Talks with kindness |  |  |  |  |
| Challenges a more quiet colleague to speak |  |  |  |  |
| Congratulates the colleagues when they present a positive idea |  |  |  |  |
| Assumes an active role in order to solve conflicts between colleagues |  |  |  |  |
| Defines/clarifies the work’s objectives |  |  |  |  |
| Defines/distributes/negotiates tasks among colleagues |  |  |  |  |
| Draws attention to time |  |  |  |  |
| Faced with distractions draws the group’s attention to the work |  |  |  |  |

*Planning investigations* and practical implementation of the experiment is time-consuming. For this reason, the assessment is focused only on a few skills. The independent variable was given but the students had to devise ways of manipulating it. Older and more experienced students were free to plan different methods of creating the plant samples and setting levels of light intensity (**CS4** and **CS5 Hungary**). When they discussed their ideas they had an opportunity for critical thinking.

The students’ *scientific literacy* improved as a result of their deeper understanding of photosynthesis and the discussion of the practical aspects of the investigation (**CS4** and **CS5 Hungary**). 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

Generally the teachers observed communication between the students while they were working in groups. The groups needed some support and reinforcement. Later the teachers used written work for formative assessment. At the end of the activity some teachers performed summative assessment (**CS4** and **CS5 Hungary**), where the assessment criteria were discussed with the students.