INQUIRY AND ASSESSMENT UNIT

HOUSEHOLD VERSUS NATURAL ENVIRONMENT

The consequences of daily decisions

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HOUSEHOLD VERSUS NATURAL ENVIRONMENT

THE CONSEQUENCES OF DAILY DECISIONS

Overview

KEY CONTENT/CONCEPTS

- Properties of cleaning and washing agents
- Ecotoxicity

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 (considering the influence of various factors)
- Scientific literacy (drawing conclusions using reasoned arguments and evidence, presenting scientific results, searching for information)

ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Worksheets
- Student devised materials ("natural" soaps and detergents, documentation of inquiry, final report)
- Presentations
- Other assessment items (true/false test)

Classroom materials for this Inquiry and Assessment Unit are available at WWW.SAILS-PROJECT.EU

1. INQUIRY AND ASSESSMENT UNIT OUTLINE – HOUSEHOLD VERSUS NATURAL ENVIRONMENT

The **Household versus natural environment** SAILS inquiry and assessment unit focuses on the environmental implications of the use of cleaning agents. Students investigate the growth of cress in various conditions, allowing them to determine the impact of commonly used household chemicals on the environment. Students assess the consequences of daily decisions taken in their homes and thus develop a sense of responsibility for the actions they take. This unit is recommended for implementation at both lower and upper second level, as a *guided* or *open inquiry* conducted over two lesson periods.

This unit can be used for development of many inquiry skills, in particular *planning investigations, developing hypotheses* and *working collaboratively*. In addition, students can develop their *scientific reasoning* skills through collecting data and drawing conclusions, and enrich their *scientific literacy* by critically evaluating their investigations. Some assessment methods described include teacher observation, use of student artefacts and self-assessment.

This unit was trialled by teachers in Ireland, Greece, Portugal and Poland – producing six case studies of implementation (lower and upper second level students; mixed ability and gender). Key skills assessed were *planning investigations*, *working collaboratively* and *forming coherent arguments*. This activity was shown to enrich students' *scientific literacy*, in particular the ability to present scientific data and to understand the environmental impact of household chemicals. The assessment was based on teacher observation and the evaluation of students' presentations.

2. IMPLEMENTING THE INQUIRY AND ASSESSMENT UNIT

2.1 Activities for inquiry teaching & learning and their rationale

The teaching and learning activities described in the **Household versus natural environment** SAILS inquiry and assessment unit were based on the "Sustainable washing for a clean environment" project,[1] which was further developed by the FP7 ESTABLISH project unit Chemical care.[2] The activity was adapted for the SAILS project by the team at Jagiellonian University.

Concept focus	Properties of household cleaning and washing agents Ecotoxicity
Inquiry skill focus	Developing hypotheses Planning investigations Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (considering the influence of various factors) Scientific literacy (drawing conclusions using reasoned arguments and evidence, presenting scientific results)
Assessment methods	Classroom dialogue Teacher observation Worksheets or student devised materials Presentations

Rationale

The problem under consideration in this unit is the ecological consequences of the use of cleaning agents at home (e.g. detergents used to clean textiles). The investigation outlined allows students to assess the consequences of everyday decisions in a scientific way. The aim is to give 14 to 18-year-old students an insight into the potential environmental effects of the incorrect use of household chemicals, such as detergents. Various household detergents may be the subject of investigation, which will allow the teacher to match the activities to the students' interests. In addition, the proposed activity may be implemented as a *guided* or *open inquiry*, as appropriate for the student group.

This unit also offers an opportunity to address some common misconceptions, such as "all chemicals are toxic" or the idea that the toxicity does not depend on the concentration – it is important that students learn that some chemicals are not harmful or dangerous at low concentrations. Students are also encouraged to discuss the topic and develop tips on the safe use of cleaning agents and detergents in households, as well as to find information about other ecological tests that are used in industry.

Skills which can be developed include *planning investigations* (designing and conducting an experiment), *developing hypotheses* (identifying scientific questions and putting forward hypothesis), carrying out experiments, *forming coherent arguments* (drawing conclusions using reasoned arguments and evidence), *scientific reasoning* (consideration of the influence of variables) and *working collaboratively* (collaboration and cooperation), all of which enrich students' *scientific literacy*.

Suggested learning sequence

The implementation of the **Household versus natural environment** SAILS inquiry and assessment unit is recommended to cover two separate lesson periods. In the first lesson, students are introduced to the topic and inquiry, after which they design an experiment to investigate the impact of a household cleaning agent on the environment. They are then given a homework task, which should take one week – "conduct your experiment." In the second lesson, students present their findings to the class and engage in whole-class or group discussions to form recommendations for the everyday use of cleaning and washing agents in the home. A final homework task is assigned, in which the students search for information on professional ecological tests.

Lesson 1

1. Introduction

The teacher asks students to list cleaning and washing agents that they and their families use at home. Based on students' prior knowledge (gained from primary school, or other subjects e.g. biology or earth sciences classes) the teacher proposes a discussion on the possible consequences of the use of cleaning agents on the environment. For example, "Wastewater from households is thoroughly cleaned in sewage treatment plants, so that it can be discharged into the surface water system. What would happen if we discharged our wastewater into the environment without subjecting it to any sort of treatment beforehand?" Once the students have had an opportunity to discuss this or similar topics and have engaged with the concepts, the teacher can introduce the next phase of the lesson.

2. Planning an experiment

Students should work together in small groups to plan an experiment to investigate the influence of a cleaning agent on the growth of plants. The unit can be organised either as an *open inquiry* (various cleaning agents, various species – aquatic, terrestrial plants) or *guided inquiry* (influence of laundry detergent on the growth of garden cress), depending on the students' IBSE experiences and competencies. For a *guided inquiry*, the teacher can provide a student worksheet with a short procedure (Figure 1), but this should only be provided after some open discussion.

[1] "Sustainable washing for a clean environment. Chemistry for advanced classes (14 to 18 year-olds)" project between the University of Oldenburg, the University of Rostock and Henkel AG & Co. KGaA, Düsseldorf (2007/08)

[2] Establish Chemical care, http://www.establish-fp7.eu/resources/units/chemical-care [accessed October 2015]

- Discuss with peers what you would like to investigate – ask scientific questions, identify and define variables e.g. different concentrations of the laundry detergent
- Put forward/formulate your hypothesis of the impact of your suggested factors
- Plan/design the experiment to check your hypothesis. Decide what you will observe or measure and how you will make these measurements. Write down your plan.

3. Homework

At the end of the first lesson, the students are given a homework exercise: "Perform/conduct/carry out the experiment to find out the impact of your chosen cleaning agent on the environment." They are asked to record their observations, for example "How did the plant change under the influence of the cleaning agent?" and to analyse their data to look for trends and relationships. Again, this assignment can be entirely open or a *guided approach*, where the teacher provides a sample table for collection of data, can be used.

Lesson 2

4. Presentation of results

The students present the results of their group work, which should be in the form of tables and graphs, to the whole class. They should draw appropriate conclusions based on the evidence they present. Students are encouraged to compare their results with those obtained by other groups, if possible. They should try to identify any possible sources of inconsistency.

5. Peer discussion and evaluation

After the presentations, the students' ability to transfer the knowledge gained in their investigation to another context is probed. The students are asked to discuss with their peers and note any recommendations they have formed regarding the everyday use of cleaning and washing agents in the home. Some prompt questions can be useful here, such as, "What is the situation? What should it be? Why isn't it as it should be? What can be done?" Students should form their recommendations in the group discussion and present them to the class as a poster.

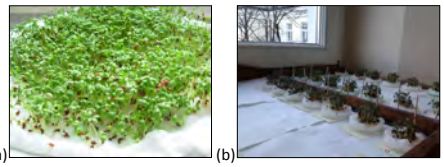
6. Homework

As a final task in this unit, the students are set a homework exercise to search for information on ecological tests using the internet or other sources. For example, students could be asked to investigate the following statement: "Cress is often not suitable for use in ecological tests, because it reacts relatively insensitively to many chemicals. Instead, organisms such as bacteria, algae, water fleas or small fish are used." They can be asked to find out about professional ecological tests and to describe two examples: What do they test? How do they test it? Students should quote their sources.

Investigating the influence of laundry detergent on the growth of garden cress

In this experiment, the detergent solution represents wastewater, and cress plants represent the environment

Typical apparatus and materials [per pair of students]: 7 dishes (e.g. crystallising dishes), 1 knife, 50 mL beaker, 100 mL graduated cylinder, 2 500 mL beakers, stirring rod, 20 mL graduated pipette, pipette filler, felt-tip pen, liquid detergent for coloured fabrics, 4 trays of garden cress (Figure 1a)



(a) (b)

Figure 1. Cultivation of cress

Procedure: Take the cress out of each tray, together with the mat in which it is growing. Use the knife to cut each mat in two. Place each half in its own dish. One half is left aside. Place the seven dishes in a row and mark them with the numbers 1 to 7. Prepare the solutions.* Leave the cress in the dishes for a period of 5 to 7 days in normal light (Figure 1b). Add tap water as necessary to replace any water that evaporates, so that the volume of solution in each dish remains at its original level.

Proposed concentration of liquid detergent in the series of dishes:* ***1.* *Blank sample,* ***2.*** *0.01 mL/L,* ***3.*** *0.1 mL/L,* ***4.*** *1 mL/L,* ***5.*** *10 mL/L,* ***6.*** *100 mL/L,* ***7.*** *1000 mL/L*

Disposal: Pour the detergent solution down the sink. Put the cress dishes in the waste bin.

Figure 1: Example of a student worksheet for guided inquiry

2.2 Assessment of activities for inquiry teaching & learning

In this section we present some tools for formative assessment of the following competencies: students' prior knowledge, involvement in the discussion, inquiry plans, data presentation, ability to search for information and group work. Several key opportunities have been identified for the assessment of inquiry skills during this activity, and tools for the assessment include observation sheets, rubrics and self-assessment cards. It is recommended that the teacher pre-select some students for evaluation through in-class observation, while all students can be assessed through collection of student artefacts, such as group worksheets.

Working collaboratively

During the introductory lesson, the teacher can observe pre-selected students and assess their skill in *working collaboratively* (engagement) and prior knowledge. An observation chart is recommended for this assessment (Table 1), in which the teacher records the responses given and the level of correctness (full/partial/incomplete/wrong).

Table 1: Observation card for the assessment of engagement

Student name	Engagement (names of cleaning and washing agents)	Engagement (possible consequences of use of the chosen cleaning agent in the environment)	Prior knowledge (correctness of answer)

After implementation of the unit, students can complete a self-assessment questionnaire (Table 2). This is based on a resource developed by the Assessing Group Practice project.[3] The adapted assessment instrument enables students to self-assess their contribution to the group and their ability to cooperate. They can also be asked to identify which two of the described skills they consider to be their strengths, and which two skills they should work on. This facilitates reflection on their skills in *working collaboratively*.

Table 2: Student self-assessment

Assessment criteria	Seldom	Sometimes	Often
1. Effort: I contributed as much as I could to group discussions and to the work required			
2. Risk-taking: I took risks by exploring something new to me			
3. Cooperation: I worked cooperatively with other members of my group			
4. Respect: I listened to others' ideas, respected them, considered their points of view			
5. Collaboration: I was flexible and willing to follow others but also took initiative when needed			
My two most important strengths in group work (from the list above) are:			
Two skills in group work (from the list above) which I need to work on are:			

Planning investigations

During the planning phase of the first lesson, the teacher can use a rubric to assess the group, rather than individual students. The proposed 4-level rubric is cumulative, in which an excellent student should be able to achieve the criteria identified for each performance level (Table 3). The rubric will depend on the teaching approach, and can be revised to reflect an *open* or *guided inquiry*. Evaluation of individual contributions to the group work can be based on students' self-assessment (Table 2). This rubric can be used for on-the-fly evaluation or for analysis of submitted experimental plans.

Table 3: Assessment of planning investigations

Poor	Acceptable	Good	Excellent
The group... propose a cleaning agent and a plant, enumerate 1-2 steps of an investigation plan,	and... propose a factor/variable which they would like to investigate, enumerate basic steps of an experimental plan,	and... formulate a hypothesis, enumerate almost all steps of an experimental plan, consider standardisation of a procedure	and... propose a consistent and complete procedure.

[3] R80 Student Self Evaluation Form for Group Work,

http://www.lancaster.ac.uk/palatine/AGP/resources/r80.doc [accessed October 2015]. A similar Group Work Self-Assessment Rubric is available from http://schools.sd68.bc.ca/cila/ireland/govt/evaluation_group.htm [accessed October 2015]

Assessment of scientific literacy – presentation of scientific data

The second lesson commences with a presentation of results by each of the groups. A rubric is proposed for the assessment of a groups' work (Table 4). Evaluation of individual contributions to the group work can be based on students' self-assessment (Table 2).

Table 4: Assessment of scientific literacy – presentation of scientific data

Poor	Acceptable	Good	Excellent
The group presents results only in descriptive way. The group presents conclusions but neither completely nor correctly and without supportive evidence.	The group presents results in the form of a table or graph. The group draws conclusions, but they are not completely correct.	The group presents results in the form of table and graph. The group draws appropriate conclusions but they are not fully supported by arguments and evidence.	The group presents results in the form of table and graph. The group draws appropriate conclusions that are supported using reasoned arguments and evidence and identifies possible sources of inconsistency.

Assessment of scientific literacy – searching for information

A homework exercise is assigned at the end of the second lesson, where students are asked to search for information about ecological tests. They should be able to find out information and quote their sources. A rubric can be used to assess students' skill in searching for information (Table 5).

Table 5: Assessment of scientific literacy – searching for information

Poor	Acceptable	Good	Excellent
The student finds out information from one internet-based source, does not quote the source. The student describes ecological tests improperly (in an incorrect or incomplete way).	The student finds consistent information from 1-2 sources, but does not pay attention to the independence of the sources and does not quote the source. The student copies a description of ecological tests directly from the source.	The student finds consistent information from at least two substantially different sources and quotes all or almost all sources of information. The student describes ecological tests correctly using his/her own words.	The student finds consistent information from at least two substantially different sources and quotes all sources of information. The student describes ecological tests correctly using his/her own words.

3. SYNTHESIS OF CASE STUDIES

This unit was trialled in four countries, producing six case studies of its implementation – **CS1 Ireland**, **CS2 Greece**, **CS3 Portugal** and **CS4-CS6 Poland**. In all case studies, the students involved had little or limited experience of inquiry learning and only in **CS1 Ireland** had the teacher significant experience in IBSE. The teachers used a *guided inquiry* teaching approach, which included the provision of student worksheets and specific guiding questions.

The unit is recommended for students aged 14-18 years, and was implemented with lower second level classes in **CS1 Ireland**, **CS2 Greece** and **CS3 Portugal** and at upper second level in the Polish case studies (**CS4-6**) and one class in **CS1 Ireland**. The students worked in smaller groups, usually of 3-5 students. The groups were mostly formed independently by the students, but in **CS4 Poland** student groups were assigned by the teacher. Students in most classes were of mixed gender and ability, although in **CS1 Ireland** the class was all female.

The case studies identify the versatility of the unit in that it allowed the teachers to focus on different concepts and inquiry skills to be developed and assessed. It can be used at different levels, as shown in the case studies where it was used with lower and upper second level students. Finally, the case studies demonstrate a range of strategies and assessment data that can be collected to assess student inquiry development.

3.1 Teaching approach

Inquiry approach used

Since most students had not conducted studies using an IBSE strategy before, the teachers chose to use a *guided inquiry* teaching approach. Several of the teachers developed worksheets, which were provided to the students to guide their work (**CS1 Ireland**, **CS2 Greece**, **CS3 Portugal** and **CS6 Poland**).

There was some variation in the level of openness of the guided approaches used at various stages in the activities. In all case studies, examples of students being led by multiple teacher questions are evident.

Implementation

There were variations in how the unit was delivered in the different countries. In all case studies, whole-class discussions were used, but the majority of the activity was carried out in smaller groups. Information on group size and composition, as well as duration of implementation are summarised in Table 6. The group sizes ranged from pairs to groups of five. In general, groups were of mixed gender, although **CS1 Ireland** details implementation in a single sex school (all-girls) and **CS3 Portugal** observes that one single-sex grouping was formed in addition to a mixed gender group.

CS3 Portugal describes an optional implementation, in which students with free time were welcome to come to the lab and carry out the activity. The students in **CS4-6** (all **Poland**) participated as part of extracurricular classes.

The unit was, in most cases, carried out in the form of two lessons separated by independent work done at home or in a laboratory. Where the effect of detergents on the development of cress was examined, students studied the effect of various substances or of different concentrations of one substance. The teachers noticed that students were excited to be working in a laboratory (**CS3 Portugal**); they enjoyed their work and asked for more such lessons (**CS2 Greece**); they got involved in learning (**CS1 Ireland**). It was noted that working with a computer, including searching for information online, was enjoyed by the students.

The unit was implemented in full in all case studies, with little modification from the activities for inquiry teaching and learning

Table 6: Summary of case studies

Case Study	Duration	Group composition
CS1 Ireland	Two lessons (45 min each)	• Students worked in pairs or groups of 3 • Student selected; mixed ability; all-girl school (2 classes)
CS2 Greece	Two lessons (60 min each)	• Groups of 3-4 students (21 students total) • Student selected; mixed ability and gender
CS3 Portugal	Three lessons (50 min each)	• Groups of 3 or 4 students (7 students in total) • Student-selected; one single sex, one mixed gender group • Voluntary participation
CS4 Poland	Two lessons (60 min each)	• Groups of 3-4 students (16 students in total) • Mixed ability and gender; extracurricular class
CS5 Poland	Two lessons (90 min each)	• Two groups of 5 students (10 students in total) • Mixed ability and gender; extracurricular class
CS6 Poland	One lesson (60 min)	• Groups of 2-4 students (12 students in total) • Mixed ability and gender; extracurricular class

described in the unit, with the exception of **CS3 Portugal** in which the investigation looked at the preparation and use of natural, biodegradable detergents as alternatives to commercial cleaners. In **CS1 Ireland**, the lower level students only engaged in theoretical planning and did not carry out their investigations. In addition to investigating the effect of detergents on plants in **CS4 Poland**, the research was expanded to include the impact of salt (used in winter to remove snow from roads). The teacher felt that this connected well with the issues raised in the unit, and will expand the unit to assess effect of vinegar also (as a simulation of acid rain).

Adaptations of the unit

Most groups carried out a study on the impact of cleaning agents on the growth of cress. However, the younger students from **CS1 Ireland** finished their work doing the theoretical part only. Several of the case studies commenced with a discussion on cleaning agents used in households and their potential impact on the environment (**CS1 Ireland**, **CS4 Poland**, **CS6 Poland**). In **CS2 Greece**, however, the teacher presented two short videos (one video concerned how the cleaning agents are made, while the other presented an advertisement of an environment-friendly detergent) as a starting point for the investigation.

The most significant adaptation was reported in **CS3 Portugal**. Using a worksheet as a guide, the students were invited to answer the question "How can we contribute to raising awareness within the educational community on the issue of the environmental impact of human activity?" Students then engaged in a whole-class or group discussion to identify the key ideas emerging from this problem and searched online for information regarding how growth of human populations is affecting rivers and oceans around the world. The second phase (*planning investigations*) focused on identification of chemicals with a high impact on the environment, and proposing alternatives for these. Students were led to consider cleaners and detergents. They then prepared "natural" detergents and investigated their biodegradability using online resources.

In **CS5 Poland**, the students had discussed the impact of chemicals on the environment earlier during their studies, and they had also attended hands-on laboratory classes during which they synthesised detergent and soap. Therefore, they did not engage in a discussion to start the lesson and instead commenced the activity with planning an experiment.

In **CS6 Poland**, the students attended one lesson in which they engaged in planning investigations. They then agreed experimental parameters and a date for submission of presentations, which were sent to the teacher in electronic form. They did not attend a second lesson on this topic.

3.2 Assessment strategies

Within the six case studies, the teachers used a variety of formative and summative assessment strategies; these included teacher observation, teacher questioning, student self-assessment and analysis of student work. The following competences were evaluated: students' prior knowledge, involvement in the discussion, *planning investigations*, data presentation, skill in searching for information and group work.

The inquiry skills and competencies that were assessed are summarised in Table 7. Teacher and student rubrics were used in many of the case studies to help the teachers to make judgements on student work and for the students to assess their own development. Whilst students gained experience of many inquiry skills not all of these were assessed. *Developing hypotheses, forming coherent arguments* and *planning investigations* were each assessed in three of the six case studies, while several case studies describe evaluation of *scientific reasoning* capabilities and scientific literacy (**CS1 Ireland**, **CS4-6 Poland**).

Table 7: Inquiry skills identified by teachers in the case studies

CS1 Ireland	• Developing hypotheses • Scientific reasoning (identifying variables)
CS2 Greece	• Planning investigations • Forming coherent arguments
CS3 Portugal	• Developing hypotheses • Working collaboratively
CS4 Poland	• Developing hypotheses • Working collaboratively • Scientific literacy (searching for information, presentation of scientific results)
CS5 Poland	• Planning investigations • Forming coherent arguments • Scientific literacy (searching for information, presentation of scientific results)
CS6 Poland	• Planning investigations • Forming coherent arguments • Scientific reasoning (data entry and observations skills) • Scientific literacy (presentation of scientific data)

Some project partners and/or teachers developed their own assessment tools, e.g. worksheets (**CS1 Ireland**, **CS2 Greece** and **CS3 Portugal**), a true/false test (**CS6 Poland**) or their own rubrics, which were usually more detailed or more holistic than those provided in the assessment of inquiry teaching & learning section of this unit. For example, in **CS4 Poland**, the teacher prepared an expanded 3-level rubric for the assessment of presenting scientific data. The following criteria were also introduced: clarity, use of all features of the software, ability to present with ingenuity and to arouse listeners' interest, content, language correctness and drawing of conclusions supported by literature (Table 8).

Table 8: Assessment of scientific literacy – presentation of scientific data – in CS4 Poland

Inquiry skills	Standard (2 points)	Whole (4 points)	Extended (6 points)
Data presentation	Content layout is not clear. Features of the presentation software used to a small extent. Presentation not very interesting. Lack of self-confidence in the person who made the presentation. The information/content presented is not interesting, with spelling and punctuation mistakes. Chosen information is of little interest. The results are presented only descriptively. The conclusions are not drawn properly and are without additional support.	Content arranged properly. Features of the presentation software used to a large extent. Presentation interesting but students not well prepared. Information/content is connected with the topic, not many spelling and punctuation mistakes. The results are presented in tables and diagrams (proper descriptions, axes). The conclusions are drawn properly but not completely supported by additional literature.	Content arranged properly and with clarity. Features of the presentation software fully used. Presentation presented in a very interesting way. Accompanied by ingenuity and originality in presentation manner, arousing listeners' interest. The topic is elaborated in a very interesting way. All information is included without mistakes. The conclusions are drawn properly and fully supported by literature.

In **CS6 Poland**, the teacher prepared expanded 4-level rubrics for the assessment of *planning investigations*, observation skills, presentation of scientific data and *forming coherent arguments*. For each skill, there were 2-3 competencies and associated criteria for evaluation of performance identified.

In some cases, the teachers indicated that they had presented the evaluation criteria to the students (e.g. **CS1 Ireland** gave the evaluation criteria to the older students during the first lesson, and to lower second level students in their second lesson), and in other cases they had not. For example, in **CS3 Portugal** the teacher did not disclose the evaluation criteria in advance, but recommends that other teachers implementing this unit should analyse the assessment criteria in advance and should give clear instructions to the students to ensure they have full knowledge of what is to be assessed. In **CS2 Greece**, the teacher found that the rubric used by the students during the peer-assessment was not clearly understood by them, but the teacher believed it was not a problem of the rubric itself but rather a problem of the maturity of the students. In general, the assessment instruments provided in the unit were positively regarded by the teachers (**CS1 Ireland** and **CS2 Greece**).

Developing hypotheses

This skill was chosen for assessment in **CS1 Ireland**, **CS3 Portugal** and **CS4 Poland**. In Ireland, the teacher used the rubrics provided in the unit, without modification. In **CS3 Portugal**, the teacher expected that students would develop a hypothesis, which provides a link to the research question and includes a justification for that hypothesis. In **CS4 Poland**, the teacher used the 0-1 system to evaluate a good/bad hypothesis. In **CS6 Poland**, *developing hypotheses* was evaluated as a component of *planning investigations*, using a 4-level rubric.

Forming coherent arguments

Students' skill in *forming coherent arguments* was explicitly assessed in **CS2 Greece**. This skill was evaluated based on the students' ability to present their data, i.e. they had to evaluate their results, come to appropriate conclusions and present their data scientifically. The teacher used a 4-level rubric to evaluate this skill (Table 9).

Table 9: Assessment of forming coherent arguments in CS2 Greece – presentation of scientific data

Poor	Acceptable	Good	Excellent
The student presents results only in descriptive way. Presents conclusions but neither completely nor correctly and not showing supportive evidence.	The student presents results in the form of a table or graph. Draws conclusions, but they are not completely correct.	The student is able to present results in the form of tables and graphs. Draws appropriate conclusions but they are not fully supported by arguments and evidence.	The student presents results in the form of tables and graphs. Draws appropriate conclusions. Supports conclusions using reasoned arguments and evidence. Identifies possible sources of inconsistency.

In **CS5** and **CS6 Poland**, the teachers evaluated students' skill in *forming coherent arguments* by evaluating their ability to form conclusions based on scientific evidence. 4-level rubrics were used to determine performance level, such as the rubric from **CS5 Poland** that is shown in Table 10.

Table 10: Assessment of forming coherent arguments (drawing conclusions) in CS5 Poland

Low	Acceptable	Good	Excellent
The group draws nearly correct conclusions, but the reasoning is incorrect, e.g. students mix up cause and effect.	The group draws nearly correct conclusions; the reasoning is correct, but not detailed.	The group draws conclusions based on obtained results and identifies factors influencing the observed effects. They explain the conclusions using logical argumentation. They do not analyse potential sources of errors.	The group draws conclusions based on obtained results and identifies factors influencing the observed effects. They justify the conclusions using logical argumentation and present logical verification of the hypothesis. They analyse potential sources of errors.

In **CS6 Poland**, the teacher used a true/false test to evaluate students' skill in drawing conclusions (Table 11), and combined the results of this test with use of a rubric for the assessment of students' overall skill in *forming coherent arguments*.

Table 11: True/false test for assessment of drawing conclusions used in CS6 Poland

Point out all properly formulated conclusions as a result of the experiment carried out. 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**

Scientific reasoning (identifying variables; data entry and observation skills)

Scientific reasoning, in this situation, refers to the many contributions that when combined enrich *scientific literacy*, and can include the ability to identify variables, collect scientific data in an appropriate manner and to note and explain observations. In **CS1 Ireland**, students' skill in identifying variables was assessed. The teacher collected worksheets during the lesson, reviewed students' work and returned the worksheets for completion. In this way, the teacher was able to see if students could identify a single variable for investigation ("identify and define variables").

In **CS6 Poland**, students' skill in recording data and observation skills were assessed using a 4-level rubric, as shown in Table 12.

Table 12: Rubric for the assessment of observation skills in CS6 Poland

Inquiry skill	Unsatisfactorily 1 point	Properly 2 points	Good 3 points	Perfectly 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 measurement; 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 the experiment results with suitable accuracy and appropriate units, prepares a 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 includes 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

In **CS2 Greece** and **CS4-5 Poland**, the 3-level rubrics proposed in the unit were applied for evaluation of presentation of scientific data. In **CS6 Poland**, the students did not present an oral presentation; instead the teacher evaluated visual presentations that were submitted electronically. The teacher devised and used a 4-level rubric to assess student performance under three criteria: "Does the student present the data collected? Does the student prepare a table/diagram? Does the student use technological tools for the data presentation?"

In the case of teachers from **CS4-5 Poland**, the skill of searching for information was evaluated on the basis of PowerPoint presentations prepared by the students. The teachers used the rubrics proposed in the unit (or modified versions of the rubrics).

Working collaboratively (teamwork)

Students' ability to cooperate during group work was evaluated in **CS3 Portugal** and **CS4 Poland**. In both case studies, the teachers used rubrics to evaluate performance levels (Table 13 and Table 14). The teacher from **CS3 Portugal** implemented a teamwork observation sheet for the group in the laboratory (Table 15); the teacher took notes and observed student groups for evidence of empathic listening, assertiveness (exhibits and keeps his point of view), interpersonal support and conflict-management. In addition, in this case study the students completed a self-assessment flow chart, in which they reflected on their contribution to group work and how well they felt they had listened and been listened to.

Table 13: Assessment criteria for working collaboratively in CS3 Portugal

Inquiry skills	Emerging	Developing	Consolidating	Extending
Teamwork **Interpersonal relationships and group functioning (emotional literacy)**	Observes and accepts the colleagues' proposals in the structuring of the group work, but gives no suggestions; merely accepts what the colleagues are doing (due to difficulties in interpersonal relationships).	Participates in the structuring 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 structuring of the group work and gives positive suggestions contributing to a productive group dynamic.	Participates in the structuring 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).

Table 14: Teacher rubric for assessment of working collaboratively in CS4 Poland

Inquiry skills	Standard (2 points)	Whole (4 points)	Extended (6 points)
Working collaboratively (teamwork)	Not all members of the group were involved in the work.	All members of the group were involved in the work. Some small disagreements/ conflicts.	Very good cooperation and involvement of all members of the group.

Table 15: Registration grid for observation of working collaboratively (teamwork)

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 quieter colleague to speak				
Congratulates 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				

In **CS4 Poland**, the teacher used both a teacher rubric (Table 14) and the group self-assessment tool proposed in the assessment of inquiry teaching & learning section of this unit (Table 2). The self-assessment proved useful for the teacher, when the students conducted an experiment themselves at home, stating, "owing to that questionnaire, it is easy to deduce which person is a leader." However, the teacher from **CS1 Ireland** negatively evaluated the proposed self-assessment tool, claiming, "The rubrics given were helpful in guiding assessment, except the self-assessment one, which did not provide any real useful feedback." It should be noted that *working collaboratively* was not assessed in this case study.

Problems encountered

The teacher in **CS2 Greece** was worried that "the students didn't have any previous experience in inquiry lessons and their answers were a bit unformed. All the groups managed to propose a cleaning agent, a plant and a basic set of inquiry steps. The teacher reported that no-one reached the excellent scale." The lack of achievement at the higher end of the scale should not be surprising. At least some assessment tools in the unit were intended for those who already know the basics of scientific research methodology, e.g. they know what is required from a well-formed hypothesis, or what dependent and controlled variables are. Other elements, such as e.g. group work self-assessment, do not require training in the area of IBSE, but the principles of appropriate self-assessment should be discussed with the students.

In another case, a teacher found it difficult to separate the group and individual evaluation (**CS5 Poland**), for example "I have evaluated the work of whole groups, because the students shared their work equally". Another issue was to hand over the evaluation function, typical for the teacher's role, to the students – "I decided to evaluate each skill with the same table designed by myself. That is because the students carried out the experiment at home, so it was difficult to carry out student's self-assessment to evaluate the group and cooperation in it" (**CS6 Poland**) and "The students should be heard regarding self-assessment, and difficulties should be identified" (**CS3 Portugal**).

The teachers pointed out that the proposed evaluation methods were laborious, especially the evaluation of students' homework: "I didn't expect the homework assessment to have been so time-consuming" (**CS6 Poland**).

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