INQUIRY AND ASSESSMENT UNIT

BLACK TIDE – OIL IN THE WATER

Oil in our waters – cleaning up our mess!

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OIL IN OUR WATERS – CLEANING UP OUR MESS!

Overview

KEY CONTENT/CONCEPTS

- The effects of an oil spill on our coast
- Chemical mixtures (behaviour of oil in water)
- Equilibrium of ecosystems

LEVEL

- Lower second level

INQUIRY SKILLS ASSESSED

- Planning investigations
- Developing hypotheses
- Forming coherent arguments
- Working collaboratively

ASSESSMENT OF SCIENTIFIC REASONING AND SCIENTIFIC LITERACY

- Scientific reasoning (defining variables)

ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Worksheets
- Student devised materials (investigation plan, photographs of investigations)
- Presentations

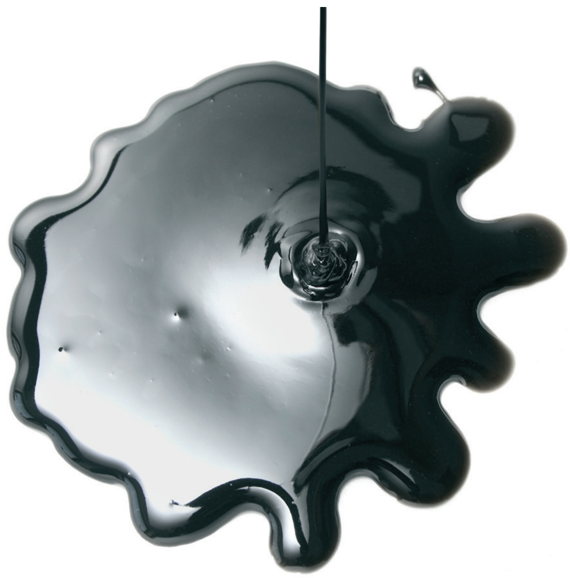
Classroom materials for this Inquiry and Assessment Unit are available at WWW.SAILS-PROJECT.EU

1. INQUIRY AND ASSESSMENT UNIT OUTLINE – BLACK TIDE – OIL IN THE WATER

The **Black tide – oil in the water** SAILS inquiry and assessment unit focuses on the study of the effects of an oil spill on our coast. Students investigate an oil spill using a model system to simulate the behaviour of oil in water and identify factors that influence the spread of oil. Students can consider the ecological impact of an oil spill, and the challenges that they pose to scientists and society. This unit is recommended for implementation at lower second level, as a *bounded* or *guided inquiry*.

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. Proposed assessment methods include teacher observation, student artefacts and peer- and self-assessment.

This unit was trialled in Portugal, Hungary, Germany and Greece – producing five case studies of its implementation. Four case studies describe the experiences of teachers with lower second level students, while one Hungarian implementation was with upper second level students. Students in the case studies were aged 12-16 years and of mixed ability and gender. *Planning investigations* was assessed in four of the case studies, while *developing hypotheses* and *working collaboratively* were also assessed in some cases.



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 **Black tide – oil in the water** SAILS inquiry and assessment unit were adapted from the iLit project [1], developed by Cláudia Faria at the Instituto de Educação da Universidade de Lisboa (IEUL) and adapted for the SAILS project.

Concept focus	The effects of an oil spill on our coast Chemical mixtures (behaviour of oil in water) Equilibrium of ecosystems
Inquiry skill focus	Developing hypotheses Planning investigations Forming coherent arguments Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (identification of variables) Scientific literacy (identifying the consequences of oil spills on ecosystems)
Assessment methods	Teacher observation Worksheets Student devised materials (experimental plans)

Rationale

Since the 1970s, oil spills in the ocean have been frequently in the news. The Amoco Cadiz accident, which occurred in the French administrative region of Brittany in March 1978, is one of the most well-known. This disaster spilled 1.635 million barrels of oil, equivalent to about 220 tons. The Exxon Valdez accident, discussed in this unit, spilled 260 thousand barrels, or about 35 tons. The consequences of such spills for living species (including human beings) and ecosystems are dramatic. This activity aims to explore some of these consequences, allowing students to increase their *scientific literacy* while developing their inquiry skills. This activity aims to contribute to:

- Development of an ecological consciousness,
- Understanding the ecological impact of oil spills,
- Understanding of inquiry processes, in particular *planning investigations*
- Promotion of thinking skills, attitudes and values that enable students to take an active role in decision-making about socio and environmental concerns.

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

Suggested learning sequence

The **Black tide – oil in the water** SAILS inquiry and assessment unit is recommended to be implemented as a *bounded or guided inquiry*, and suggested student worksheets are detailed. The task should be investigated by groups of 3-4 students, with mixed abilities and genders where possible. In this way, the groups can benefit from multiple perspectives and each student should be able to carry out a comprehensive reflection on their skill of *working collaboratively*. The teacher should take care to guide students through questioning, providing suggestions to guide their progress, but not to give definitive answers during the period in which the students are working in groups. Whole-class discussions can be useful, where the teacher can assist with any problems that arise. In this situation, it is preferable to first give students the opportunity to speak, thus each group can present its contribution to the general discussion.

This unit develops over four phases; first, the students engage in discussion about the topic of the lesson – how does oil behave when spilled in the ocean? Next, the students plan an experimental activity to investigate this question, which they implement once the teacher has approved the method. This allows for formative assessment of the work plan, and an opportunity to identify any problems or misconceptions that may arise. For the third phase, students can relate their experimental simulations to a real-world context, i.e. the factors that affected the spread of oil following the Exxon Valdez oil spill. The final phase seeks to further students' knowledge of the impact of an oil spill on the environment, and the associated social and economic effects.

There are several underlying objectives to the set of questions outlined on the student worksheets, such as discussion of topics related to the immiscibility of two liquids, but also the promotion of students' familiarity with scientific procedures:

1. To begin the inquiry, students are introduced to the topic by reading an introductory text (Figure 1). The students can engage in a brief discussion about the topic, prompted by the question, "What happens to the oil spill in the ocean?" This gives them an opportunity to engage with the topic and review their prior knowledge. They can begin to develop research questions.

2. Next, the students are asked to plan an experiment to investigate the research question. They can be given a worksheet, which provides guidance through a list of materials and some suggested parameters for investigation (Figure 2).

[1] Between tide marks: Integrating Literacy's (iLIT), funded by the Portuguese Foundation for Science and Technology (FCT), https://www.fct.pt/apoios/projectos/consulta/vglobal_projecto.phtml.en?idProjecto=117923&idElemConcurso=4231 [accessed October 2015]

Black Tide – Oil in the Water

Student's document

Introduction: Since the mid-nineteenth century, when we learned to distil oil and separate it into various components such as gasoline, diesel, kerosene (fuel used in airplanes) and oil tar, demand for oil worldwide has been increasing. Since it is a natural resource that is not evenly distributed across the planet, it is necessary to transport it from the countries of production to where it is consumed. One of the main ways to transport oil is by sea. For this, large ships equipped with big reservoirs, known as tankers, are used, which can reach over 400 m in length with a capacity exceeding 500 000 tons of oil.

The oil is a viscous black liquid and when a tanker has an accident, the oil may be spilled at sea and its removal is very difficult. Recently, scientists have been working to find ways to remove spilled oil from water, but have not had much success. What happens to the oil spill in the ocean?

How does oil behave when spilled into the ocean? To answer to this question, you have to plan and carry out experiment(s) to investigate the behaviour of oil when poured into a mass of water.

1. Think, with your colleagues, of possible answers to the previous question.

Figure 1: Student worksheet, page 1 – introductory text

2. Now **plan**, **in groups**, **an experiment** that helps you to find an answer to the previous question. On the laboratory bench, you will find some materials and equipment, listed below, that can be used in your planning. You must take into account the different natural factors that interfere with the ocean's activity – currents, waves, winds – and consider them in your planning.

Materials: *Glass or plastic bowls, spoon, water, oil (such as vegetable oil or "simulated oil," prepared by mixing 12 tablespoons of vegetable oil and 8 tablespoons of cocoa powder).*

If you need other materials that are not in the list above, please request these from your teacher.

When planning the experiment don't forget to identify the different variables:

- the independent variable (what you change during the investigation),
- the dependent variable (what you will measure or observe), and
- the controlled variables (what you are you going to keep constant).

2.1. **Discuss** your group's experimental plan with the teacher, before you carry out the experiment.

2.2. **Write down what you predict will happen** as a result of the experiment that you have planned. **Present a justification** for this prediction.

2.3. In your group, **carry out the experiment**.

2.4. **Record** the results.

2.5. **Compare** the prediction presented in question 2.2 with the obtained results. Do you need to re-evaluate your initial prediction?

2.6. **Explain** the results registered in question 2.4. If needed, you may consult literature or websites that help you build an explanation.

2.7. **Answer** the initial question: ***How does oil behave when spilled into the ocean?***

Figure 2: Student worksheet, page 2, Question 2

Question 2 consists of seven sub-questions, which guide the students through the planning and implementation process. The teacher should ensure that students understand the role of the materials used in the simulation, and allow them to identify some limitations of the model. Students should be aware of the key aspects involved in an experimental activity, in particular careful recording of data throughout the process, isolation of variables that are being tested (presence/absence of oil) and use of a control system. For example, as a control when investigating the effect of currents, waves or wind, students should repeat the entire procedure with undisturbed oil in the water.

3. Question 2.1 allows the teacher to analyse the students' plans and assess the feasibility and adequacy of the experimental protocol (Figure 2). Two distinct types of problems may arise: (1) the experimental plan does not answer the research question, or (2) the plan contains procedures that are difficult or impossible to implement. In both situations, the teacher should ask questions and give clues to help/allow the students to be able to solve the question.

4. Question 2.2 asks the students to make predictions and to justify their predictions (Figure 2). This is an opportunity for the teacher to assess students' skills in *developing hypotheses* and *forming coherent arguments*. The hypothesis (prediction) should be related to the experimental plan, and the investigation carried out (Question 2.3) and the results obtained (Question 2.4) should be used to test the hypothesis (Question 2.5).

5. It is recommended that students can approach their experimental work as a way of testing the falseness of a hypothesis, instead of focusing only on verifying that a hypothesis is true. While students often focus on getting the "right answer," it is equally valid to disprove an incorrect hypothesis and this is an opportunity to introduce this concept to the students.

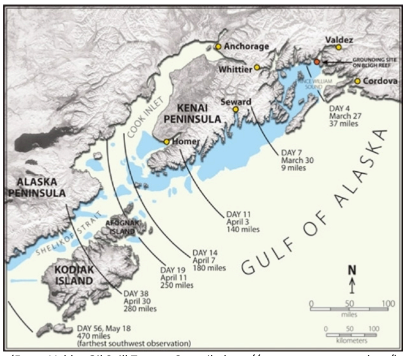
6. In Question 2.6, students are asked to explain their results, which can be supported using references to literature or websites (Figure 2). This activity offers an opportunity for the assessment of students' skill in *forming coherent arguments*, and can also allow for evaluating students' ability to search for information.

7. In the final part of Question 2, the students draw conclusions (Figure 2). They should use their results to support their conclusions and relate the conclusions to the original prediction from Question 2.2.

8. Once the experimental process is complete, students should consider Question 3 (Figure 3) and Question 4 (Figure 4). These questions allow the students to go further in exploring the problems related to oil spills in the ocean. This time, however, the teacher can choose to emphasise other procedural aspects of science, in particular the interpretation and use of third party data, the use of technological tools to search and the establishment of relations between science, technology and society

9. Using the *Exxon Valdez* case as a real-life example of an oil spill, in Question 3 students are shown a map of the area affected by the oil spill (Figure 3). The map units are presented in the imperial system, so the teacher can ask the students to convert these units to metric. There

3. In the following figure you can observe the area affected by the oil spill released from the *Exxon Valdez* tanker during an accident that occurred on March 24, 1989 near Valdez town, Alaska. The sea regions demarcated in blue (or light grey) denote the area affected over the 56 days following the accident.



(Exxon Valdez Oil Spill Trustee Council - http://www.evostc.state.ak.us/)

This map shows the distances in imperial units (miles). For a better understanding of the scale of this disaster it is useful to convert these values to kilometres, since you're more familiar with this length unit. Knowing that 1 mile = 1.61 km, convert and register the values in the map. Convert the value of the affected area indicated in the map legend to km^2. Confirm the results with your teacher.

3.1. Based on the conclusions you made from your investigations, explain the expansion of the oil spill from the Exxon Valdez.

3.2. Find a justification for the statement from the text: "In recent years, scientists have been working to find ways to remove the spilled oil from the water, but have not had much success."

3.3 To get a better idea of the extent of the spill, use Google Maps to find the location of the spill and make an image similar to that shown in the figure.

Figure 3: Student worksheet, page 3, Question 3

4. As you can imagine, the *Exxon Valdez* oil spill had not only an environmental impact, but also economic and social effects. Search for information on the implications of this accident on marine life and human populations in the affected coastal areas. Write a story for a newspaper telling what happened, the adverse consequences of the accident and the effect it had on the establishment of new rules for the transport of oil at sea.

Image of the Exxon Valdez (Wikimedia Commons)

Figure 4: Student worksheet, page 4, Question 4

are two possibilities for this conversion: (1) calculate the extension using the scale and (2) ask the students to find the conversion ratio and use it in calculations. The teacher's decision should take into account the contexts where the task will be applied and the time that will be devoted to it. Question 3 consists of three sub-questions. Question 3.1 seeks to allow students to transfer the knowledge gained in their experimental tasks to a real-world context. In addition, they can learn more about the challenges faced by scientists during the clean-up activities where the oil spill occurred, and gain a greater understanding of the far-reaching effects of such an accident.

10. Finally, in Question 4 (Figure 4), students are encouraged to consider the economic and social impact of an oil spill. This can increase their understanding of the role of science in society, and offers an opportunity for students to develop coherent arguments and to search for further information.

2.2 Assessment of activities for inquiry teaching & learning

As detailed in the suggested lesson sequence, this unit offers opportunities for the assessment of all SAILS inquiry skills (*planning investigations, developing hypotheses, forming coherent arguments, working collaboratively*) and key competencies (*scientific reasoning, scientific literacy*). The teacher may carry out the assessment in class through observation and classroom dialogue, or utilise the student worksheets for evaluation. The assessment should be based on aspects such as understanding the terms and concepts involved, full development of the experiment (planning and implementing), correct handling of materials and equipment, accuracy in recording data and adequacy of the proposed experimental protocol (variables tested experimentally and answers to questions).

In addition to developing students' inquiry skills, students can gain substantive and procedural knowledge. After carrying out the tasks in this unit, students should be able to explain the behaviour of oil in water, plan experiments and record data appropriately. Through development of their reasoning capabilities, students should be able to interpret data and make inferences. In addition, they should be able to communicate scientifically, using appropriate language and presenting data and ideas in different ways. This inquiry should encourage students to be curious and creative and to pursue their investigations with rigour and perseverance.

Even though this activity presents many assessment opportunities, a teacher's guide was devised that focused on assessment of two inquiry skills – *planning investigations* and carrying out an investigation. This assessment tool was built with teachers' cooperation, using the following guidelines:

Purpose: During this activity, it is intended that students will learn the scientific content associated with the behaviour of oil in water and the effect of oil spills on ecosystems, as outlined in the unit. This unit allows students to develop several inquiry skills; however, for the data collection about the assessment process it will be focused on *planning investigations* (and carrying out an investigation).

Teacher actions

1. Before class
   a. Build an assessment instrument for the inquiry skill(s) to be assessed. For example, Table 1 details a rubric for use where the main focus is the assessment of students' skills in *planning investigations* and carrying out an investigation.
   b. Adapt the task for your students and for the context.

Table 1: Assessment tool for planning investigations

Actions	1	2	3
Define goals	Does not define coherent goals according to the proposed problem.	Defines some coherent goals according to the proposed problem.	Defines coherent goals according to the proposed problem.
	Does not operationally define the variables.	Defines, with some difficulty, the variables of study.	Operationally defines the variables of study.
Define strategies and procedures	Does not define the necessary strategies and procedures to achieve the goal.	Defines, with some difficulty, the necessary strategies and procedures to achieve the goals.	Defines the necessary strategies and procedures to achieve the goals.
	Unclear planning requiring reformulation.	Planning well presented but requiring reformulation.	Clear, concise and complete planning.
Choice and use of resources	Does not select adequate resources according to the goals and strategies.	Selects some resources that are adequate for the goals and strategies.	Selects the resources that are adequate for the goals and strategies.

2. In class
   a. At the beginning of the process, clarify the assessment criteria (in particular those relating to the chosen inquiry skills).
   b. At the end of the process, apply a semantic differential to students for identification of their perceptions related to the assessment process.
3. After class
   a. Assess students' artefacts (worksheets, experimental plans), having regard to the assessment tool developed and produce written formative feedback,
   b. Reflect on the assessment process.

Note: Evidence collected can include student artefacts, classroom video recording (optional) or other evidence.

3. SYNTHESIS OF CASE STUDIES

This unit was trialled in four countries, producing five case studies of its implementation – **CS1 Portugal**, **CS2 Hungary**, **CS3 Hungary**, **CS4 Germany** and **CS5 Greece**. All the case studies were implemented by teachers who had some experience of teaching through inquiry and most of the students had prior experience of inquiry activities. However, in **CS1 Portugal** and **CS5 Greece**, the students had no prior experience with inquiry.

The case studies detail implementation at lower second level, except in **CS3 Hungary**, which features a 9th grade class (upper second level). The students involved in the case studies were 12-16 years old and of mixed ability and mixed gender. In **CS1 Portugal**, the student group represented a very good performance level in school achievement.

CS2 Hungary and **CS4 Germany** describe two lesson periods of 45 minutes each. **CS3 Hungary** describes one lesson of 45 minutes, plus a double lesson period of 90 minutes. **CS1 Portugal** describes four 90-minute lesson periods, while **CS3 Greece** was implemented over three 45-minute lessons.

The key skill assessed was *planning investigations*, but the teachers in the case studies also selected additional skills to develop. The assessment methods described include classroom dialogue, teacher observation, evaluation of student artefacts and peer-assessment.

3.1 Teaching approach

Inquiry approach used

The inquiry approach used in all the case studies was that of *bounded 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 addressing the question. For example, the unit activities start with the introduction of an environmental problem, and the students are asked to plan an experiment related to this problem. This can be totally open (students propose a full experimental plan and implement their plans) or can *be guided* (students propose and discuss an experiment, but follow a given protocol for implementation).

Implementation

This activity aims to contribute to the understanding of inquiry processes, such as experimentation and argumentation, and to the promotion of thinking skills, attitudes and values required for students to take an active role in decision-making about socio and environmental concerns. The activities of this unit can be used to integrate different curricular subjects (physics, chemistry, biology, geography, mathematics, environmental education).

The students in all the case studies worked in groups throughout the lessons, although group composition varied (Table 2). In **CS3 Hungary**, the students were from an upper second level grade, however for the other cases the students were all lower second level, as recommended in the unit. Most classes and groups were reported to be of mixed ability and gender. In particular in **CS3 Hungary** the teacher describes the support required for some students with emotional and behavioural difficulties and with special educational needs. In **CS3 Hungary**, the unit was implemented in the context of the formation and use of sedimentary rocks, their mining and the environmental effects of transportation in geography.

Most case studies implemented the unit without significant alterations. In all case studies, except in **CS4 Germany**, a worksheet was provided to the students. This was quite unstructured, similar to the one provided in the activities for inquiry teaching & learning section of this unit. Implementation in **CS4 Germany** was part of a special science course – "Science Experiments" – which is taught in parallel to regular science classes. In this case study, the teacher mentions using the "marketplace method" for group discussions, where the groups showcase their ideas and plans for experiments, and students can go from group to group to look at the plans.

Adaptations of the unit

In some case studies the teachers made some adaptations to the unit, so that the tasks were more suited to their student groups or curricula. For example, while the teaching and learning activities described in the unit focus on observation skills during the experimental phase, in **CS2 Hungary** the students also

Table 2: Summary of case studies

Case Study	Duration	Group composition
CS1 Portugal	Four lessons (90 min each)	• Groups of 3-4 students (20 students) • Student selected; mixed ability
CS2 Hungary	Two lessons (45 min each)	• Groups of 3-4 students (23 students)Student selected; mixed ability and gender
CS3 Hungary	Two lessons (1x45 min, 1x90 min)	• Groups of 4 students (20 students in total) • Student-selected; mixed ability and gender, some single-sex groups (all-girls)
CS4 Germany	Two lessons (45 min each)	• Student worked in pairs (10 students in total) • Mixed ability and gender (5 boys, 5 girls) • Student-selected course "science experiments"
CS5 Greece	Three lessons (45 min each)	• Groups of 3-4 students (17 students in total) • Teacher assigned groups; mixed ability and gender

collected data through physical measurements of surface area and volume of the simulated oil spill.

The unit as outlined focuses primarily on the behaviour of oil in water. However, this unit may also be used to discuss environmental considerations, as shown in **CS3 Hungary** and **CS5 Greece**. In **CS3 Hungary**, students studied the consequences of an oil spill on life in the sea and the human settlements along the affected coastline. In **CS5 Greece**, the students dipped a feather in the oil water, and tried to find a good cleaning agent to remove oil from the bird feathers. In **CS5 Greece**, the students watched some introductory videos at the start of the lesson, after which the topic for investigation was introduced.

CS4 Germany describes the most significant adaptation to the unit, whereby the teacher focused the problem on oil pollution and potential methods for clean up. The students did not use a worksheet, and the implementation was very open. As a result, the students investigated a range of factors related to oil spills, and in particular to methods for removal of oil from water. One group investigated the topic of removal of oil, while another group looked at the effect of oil on feathers, wool and sand. A third group "invented" a technique for the removal of oil from water and a further group tried to burn the oil on the water surface.

3.2 Assessment strategies

The **Black tide – oil in the water** SAILS inquiry and assessment unit was recommended to teachers for the assessment of *planning investigations and scientific reasoning*, however implementation has shown that this activity is appropriate for the assessment of the four SAILS inquiry skills – *planning investigations, developing hypotheses, forming coherent arguments, working collaboratively* – and *scientific reasoning*, as outlined in Table 3. Although the skills developed during these activities are valuable contributors to a students' overall *scientific literacy*, no teacher chose to assess this dimension in the case studies. However, within the case studies, the students' increase in understanding of both the properties of oil in water, and how the experiment provides a model of a real-world oil spill is observed.

Table 3: Inquiry skills identified by teachers in the case studies

CS1 Portugal	• Planning investigations
CS2 Hungary	• Planning investigations • Working collaboratively • Scientific reasoning (defining variables)
CS3 Hungary	• Developing hypotheses • Planning investigations • Working collaboratively
CS4 Germany	• Planning investigations
CS5 Greece	• Planning investigations • Forming coherent arguments • Working collaboratively

The assessment was conducted through the analysis of students' artefacts in almost all case studies, which included worksheets (all case studies, except **CS4 Germany**) and presentations (**CS5 Greece**). The teacher also assessed students' skills through direct observation of students working in groups, for example in **CS2 Hungary**. Some teachers used rubrics for in-class evaluation of performance (**CS3 Hungary**), although they may also be used for evaluation of student artefacts after the lesson. Peer-assessment was used in **CS4 Germany** and **CS5 Greece**; in both case studies students provided oral comments on the ideas of other students. In **CS5 Greece**, the teacher provided assessment tools for use for peer-review, which helped students understand the assessment criteria. In all case studies, the teacher provided formative assessment through oral feedback, in particular during collaborative work. In some cases, the teacher provided written feedback at the end of the activity.

In **CS1 Portugal**, the teacher used the rubric shown in Table 1 to assess three dimensions of *planning investigations* – defining goals, defining strategies and procedures, and identifying and selecting appropriate resources. The instrument contains three performance levels, where level one corresponds to the lowest level and level three to the highest level. The teacher prepared this tool in advance of the implementation, but did not use it for the first lesson. Instead, she evaluated students' work and provided written comments after the first lesson. In the next lesson, the teacher returned the students' work with written feedback, and they had the opportunity to read the feedback and to ask questions. The teacher then used the assessment tool to follow the development of the students' skill, through questioning students and answering their queries.

In **CS2 Hungary**, the teacher provided formative assessment during the lesson and each group was given oral feedback. Teacher observation was used to assess skills exhibited during group work. The teacher posed three questions at the end of the second lesson: "What variables did you notice during the experiment? Which variable or variables did you think were fixed? To what extent does your experiment support the idea of the group?" and used the responses to these questions for the assessment of students' *scientific reasoning* (ability to identify variables). The assessment criterion was for students to be able to identify the fixed variable in the research problem. However, the teacher observed that they struggled with this concept. The students' work was submitted to the teacher at the end of the second lesson; the teacher evaluated the worksheets while engaging the class in discussion about the activity.

In **CS3 Hungary**, the teacher used both formative and summative assessment. During the lesson, the teacher guided the students with facilitating questions and observed the students' work during the task. The teacher used a 4-level rubric for the assessment of performance in the inquiry skills (Table 4). The groups were given grades based on the collected worksheets and the photographs they took during the activity.

Table 4: Assessment of inquiry skills in CS3 Hungary

Skill assessed	Extending	Consolidating	Developing	Emerging
Working collaboratively (participation)	Always participates in the work and works on the task throughout the class.	Mostly participates in the work and usually works on the task.	Participates in the work but does not make good use of time or spends little time on the task.	Does not participate in the work, does not make efficient use of time or is occupied with something other than the task.
Working collaboratively (cooperation)	Treats others with respect and shares responsibilities.	Usually treats others with respect and shares responsibilities.	Sometimes lacks respect in interacting with others.	Often lacks respect in interacting with others.
Developing hypotheses (research question)	The research question is precise and detailed.	The research question is unambiguous.	The research question is somewhat incomplete.	The research question or its formulation is incomplete or incorrect.
Planning investigations (inquiry process)	The research design is appropriately constructed based on the hypothesis; the experiment gives a complete answer to the research question. The individual steps of the experiment are described accurately. The independent and dependent variables are correctly identified.	The research design is reasonably constructed based on the hypothesis; the experiment gives an answer to the research question. The steps of the experiment are described. Most independent and dependent variables are identified.	The research design is incorrectly constructed based on the hypothesis; there are mistakes in the hypothesis. Some steps of the experiment are described but some crucial details are omitted. Some independent and dependent variables are identified.	The research design is not related to the hypothesis or contains serious mistakes. There are fundamental problems with the experimental procedure. Dependent and independent variables are not identified.

In **CS4 Germany,** the teacher mainly used two different formative assessment strategies – peer-assessment and classroom dialogue. Peer-assessment was relatively informal, where students commented on the ideas of other students when they discussed their ideas for investigations. In addition, the teacher watched, listened and gave advice throughout the unit implementation. Formative assessment was provided on the spot, and focused on specific feedback regarding students' experimental approaches. The teacher did not use rubrics or record criteria in a written format before the unit, although she had a clear idea about her expectations.

In **CS5 Greece**, the teacher used a selection of assessment methods, with an emphasis on formative assessment. During the introductory discussion, the teacher provided formative feedback and posed questions to aid the students in developing their research questions. The teacher used a 3-level rubric to assess students' skill in *developing hypotheses* as poor/needs improvement/good. At the end of the experimental phase, the students used a self-assessment tool to re-evaluate their hypotheses. This was an opportunity to develop their skill in *forming coherent arguments*, and they used a simple form as a guide (Table 5).

Table 5: Re-evaluation of hypothesis (self-assessment tool) from CS5 Greece

The mistake was...			
The correct explanation is ...			
	I was right ❐	I edited it ❐	I rejected it ❐

Two peer-assessment opportunities were identified. First, groups exchanged their work plans and their peers assessed the plans using the peer-assessment tool, which details seven criteria for forming judgements on *planning investigations* (Table 6). The teacher reported that students had difficulty using the peer-assessment tool for *planning investigations*, but this was their first experience in inquiry and peer-assessment. In the second case, students used a similar assessment tool to critique their peers' skill in *forming coherent arguments* during their final presentations. In this instance, there were no difficulties reported.

Table 6: Peer-assessment of inquiry plans (planning investigations) in CS5 Greece

Assessment criteria	1 – poor	2 – acceptable	3 – good	Score
1. The description of the plan is clear	No	Needs improvement (some gaps exist)	Yes (no gaps)	
2. The plan includes independent variables	No	Needs improvement (some gaps exist)	Yes (no gaps)	
3. The plan includes dependent variables	No	Needs improvement (some gaps exist)	Yes (no gaps)	
4. The plan includes controlled variables	No	Needs improvement (some gaps exist)	Yes (no gaps)	
5. The plan takes into consideration natural factors (currents, waves, wind)	No	Needs improvement (some gaps exist)	Yes (no gaps)	
6. The plan takes into consideration living beings (such as seabirds)	No	Needs improvement (some gaps exist)	Yes (no gaps)	
7. The plan takes into consideration cleaning issues	No	Needs improvement (some gaps exist)	Yes (no gaps)	
			Total Score	

Students also engaged in self-assessment to evaluate their skill in *working collaboratively* (Table 7). This enabled them to reflect on their strengths and weaknesses when working as part of team.

Table 7: Self-assessment of working collaboratively in CS5 Greece

Assessment criteria	3 - always	2 - sometimes	3 - rarely
1. I actively participated in all discussions of the group			
2. In all discussions I took into consideration the views of all team members			
3. I helped in resolving disputes between team members			
4. I used convincing arguments to support my views			
5. I provided assistance in the team whenever needed			
6. I looked for information on the subject throughout the activity			
7. I completed without delay all the work undertaken to do in the team			