INQUIRY AND ASSESSMENT UNIT

ELECTRICITY

Electric current – lighting up the darkness!

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ELECTRICITY

ELECTRIC CURRENT – LIGHTING UP THE DARKNESS!

Overview

KEY CONTENT/CONCEPTS

- Introduction to conductivity and electric circuits
- Simple electric circuit
- Conductivity of different materials

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 (identifying connections between concepts; choosing components for and electrical circuit)
- Scientific literacy (searching for information; using scientific terminology; explaining concepts scientifically)

ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Worksheets
- Student devised materials (mind maps, documentation of inquiry, drawings of electric circuits)
- Other assessment items (post-activity test)

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

1. INQUIRY AND ASSESSMENT UNIT OUTLINE – ELECTRICITY

The **Electricity** SAILS inquiry and assessment unit provides an introduction to electrical conductivity and electric circuits and is recommended to be implemented after students have studied electrostatics. This topic is usually included in the lower second level science curricula across Europe. Three activities are presented and use a guided inquiry-based approach. The classroom implementation of this unit is typically over two lessons (~ 90 minutes).

Activity A introduces the students to the topic through a whole class brainstorming activity, and students construct a mind map of the topic based on their prior knowledge. In Activity B, the students design and assemble a simple working electric circuit. Students then use their circuits for planning and carrying out an investigation on the conductivity of every-day objects and materials (Activity C). As a further challenge, students can propose an experiment to show lightning in the classroom without the use of any device plugged into the mains. This unit presents opportunities for assessment of several inquiry skills, in particular *planning investigations* and *working collaboratively*, as well as improving students' *scientific reasoning* capabilities and *scientific literacy*.

The assessment methods described in the unit include teacher observation, group brainstorming and use of student artefacts.

This unit was trialled in Slovakia, Ireland, Turkey and Poland (five case studies, 17 classes, 333 students). *Planning investigations* and *scientific reasoning* were the main skills assessed; although in Ireland *working collaboratively* (debating with peers) was assessed. One teacher in Turkey added an activity on *developing hypotheses* to the unit, and provided oral feedback to the students on this skill.

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 **Electricity** SAILS inquiry and assessment unit were developed by the FP7 Fibonacci project [1] and adapted for use in the SAILS project by the team in Jagiellonian University. The unit comprises three activities, which are recommended for use with lower second level students, aged 12-15 years. The topic is first introduced through a whole class brainstorming activity and individual/small group construction of a mind map based on their prior knowledge (Activity A). In the second activity, the students design and assemble a simple working electric circuit (Activity B). They then use this circuit for planning and executing an investigation on the conductivity of every-day objects and materials (Activity C). Students are facilitated to improve their skills in *developing hypotheses* through peer discussion on the conductivity properties of these materials. Everyday contexts are included and students are facilitated to develop skills in *scientific literacy* and searching for information, e.g. how lightning is formed during a thunderstorm and what is the conductivity of air?

Teachers should be aware that the materials listed below will be needed during the implementation of this unit, but should not be given to the students until after their planning has been completed.

- Torch bulb (one per group)
- Two separate wires (per group), not connected to the bulb, but prepared for an easy adjustment (plastic coating removed at both ends of each wire)
- Two crocodile clips (optional)
- Plasticine or insulating tape
- 4.5 V battery (one per group)
- Everyday objects made out of different materials (at least 2 objects of each): wood, different kinds of metal, plastic, rubber, textile, glass, paper (at least 16 objects per group); one piece of graphite

Students will require access to the internet or other resource materials (books, films, etc.) about meteorology, electricity, formation of lightning, etc.

Activity A: Introduction to electricity

Concept focus	Connecting the concept of electricity to everyday life
Inquiry skill focus	Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (making scientific connections) Scientific literacy (explain concepts scientifically)
Assessment methods	Classroom dialogue Worksheets Student devised materials

Rationale

In this activity, students are asked to draw a mind map starting with the word electricity in the centre of a page. This approach should encourage students to recall their prior knowledge of the topic. Students should then discuss the words used, identify scientific terms and distinguish them from everyday words. Through this task, students strengthen their *scientific literacy* and make scientific connections.

Suggested lesson sequence

1. At the start of the lesson, the teacher can encourage the students to brainstorm, by asking questions that relate to the use of electricity in their everyday life, for example:
   a. What do we need to be able to see?
   b. Are there any other ways that help us to see, e.g. moving around when one is not able to see? Do you know any respective adaptations of animals?
   c. We live in a world of day and night. When and where in the world does a human being lack sunlight?
   d. How did people in the past adapt to living in darkness?
   e. How do people do that today?
   f. What caused this change and when did this occur?
2. Once the students have identified electricity as an answer to the latter questions, they are provided with a worksheet (Figure 1).
3. Students individually construct a mind map on the first page of their worksheet.
4. The teacher can ask some prompt questions during this task, e.g.
   a. What is the possible origin of the word “electricity”?
   b. What are the other small elements of matter?
   c. What does “electric current” mean?
   d. What do you think happens when an electric current flows?
   e. What is a general term for materials that conduct an electric current?
   f. What is the general name used to denote materials that do not conduct an electric current?
5. After completing their mind maps, students distinguish between the scientific terms and everyday words.
6. Students form groups (up to 4 student per group) and debate the words on their mind maps.

[1] Fibonacci Electricity unit, http://www2.if.uj.edu.pl/fibonacci/class3.html [accessed October 2015]

ELECTRICITY
Introduction to conductivity and electric circuits

A. Introduction to electricity

1. Draw a mind map with the word "electricity" in the centre.

electricity

2. Mark separately the "scientific" words linked to electricity and distinguish them graphically from the other words taken from everyday language.

3. Discuss in a small groups (4 students) the meaning of each word in your mind map.

Page 1 of 7

B. Simple electric circuit

1. Think of what elements you would need to collect in order to light a small bulb. List them below.

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2. Discuss with a peer which elements might be omitted or replaced if one would like to create the simplest electric circuit for switching on a small bulb.

3. Draw the simplest working electric circuit for switching on a small bulb.

Page 2 of 7

Figure 1: Student worksheet, pages 1 and 2 – activities A and B

Activity B: Simple electric circuits

Concept focus	Building a simple electric circuit
Inquiry skill focus	Planning investigations Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (choosing components for electric circuit) Scientific literacy (critiquing a method; explaining electric current scientifically)
Assessment methods	Classroom dialogue Worksheets

Rationale

In this activity, students are asked to identify the components needed to construct a simple electric circuit. They engage in peer discussion and distinguish between items that are necessary and those that are not needed, before drawing a sketch of their proposed electric circuit. This activity allows the students to develop their skills in *planning investigations*, critiquing experimental design, and *working collaboratively*. Opportunities exist for strengthening *scientific literacy* and *scientific reasoning* capabilities.

Suggested lesson sequence

1. In this activity, students think of the elements (components) needed to form a simple electric circuit.
2. The students work in pairs or small groups and discuss the chosen components. Through this discussion, they decide which components are necessary for their simple circuit.
3. Students draw the simple electric circuit in their worksheet (Figure 1, page 2).

C. Conductivity of different objects.

1. Plan the experiment to check conductivity of different objects, using the electric circuit with a single electric bulb. Include the list of possible objects you could investigate in the classroom. Write down the plan below.

2. Draw the simplest working electric circuit enabling investigation of conducting properties of an object.

Page 3 of 7

3. Put forward the hypothesis of conducting properties of selected objects. In the table below, in column "hypothesis" next to each selected object, write down your hypothesis on how well the particular object conducts an electric current, using expressions: "well", "poorly", "not at all". Whenever you investigate a solution (e.g. salt in water), in the first column include the relevant information about the amount of substance used (concentration).

Conductivity table.

object/ material	hypothesis	experimental result			general type
		well	poorly	not at all	

4. Perform the experiment finding out conducting properties of the selected objects. You can add more objects in the course of experiment. Always put forward the hypothesis first and write it down in the table before conducting the experiment. After each part of experiment check the right box in section "experimental results" in the table above. Leave the column "general type" empty.

Page 4 of 7

5. In science, technology and engineering, people use schematics rather than pictorial drawings. E.g. an electric circuit can be represented by an electrical diagram (electronic schematic). To do so, one needs to know abstract, graphic symbols denoting particular objects. In an electrical diagram the following symbols are usually utilized:

a bulb/lamp | a battery | a piece of wire | an object connected to the circuit

Using the symbols listed above, draw in the boxes below two simple electrical diagrams representing the electric circuits used by you in section B.3 and C.2 of the worksheet.

6. Write down your opinion, answering the question:
Is conductivity an inherent property of an object, or a property of a material the object is made of? Explain your answer.

Page 5 of 7

7. After a brainstorming with your peers about the common names of conducting and non-conducting materials, complete the two sentences below.

   a. Solid materials, like …………………………, conducting an electric current are called …………………………

   b. Materials not conducting an electric current, like …………………………, are called …………………………

8. Fill out the last column of the conductivity table on page 4, ("general type"), indicating the common names of a relevant material/object in relation to its conducting/non-conducting properties.

9. Discuss with your peer if the air can or cannot conduct an electric current. Write down 1-2 sentences summing up your discussion.

10. Check with an appropriate experiment if the air in the classroom conducts an electric current. Describe experimental setup and your observation.

Page 6 of 7

Figure 2: Student worksheet, pages 3-6, for Activity C: Conductivity of different objects

Activity C: Conductivity of different materials

Concept focus	Conductivity – conductors, insulators
Inquiry skill focus	Planning investigations Developing hypotheses Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (making predictions) Scientific literacy (searching for information; explaining conductivity scientifically)
Assessment methods	Worksheets

Rationale

In this activity, students are asked to plan an investigation to check the conductivity of different materials, using an electrical circuit with a single bulb. They first develop a hypothesis about various materials, plan an investigation to investigate their research question, observe and record the results and draw conclusions. During this activity, students develop their *scientific literacy* through introduction to the symbols used for representation of an electric circuit, enrich their *scientific reasoning* and skills of *developing hypotheses*, drawing conclusions and *planning investigations*.

11. Search the Internet or other sources and find out how the lightning is formed during the thunderstorm. Write down 3-4 main steps, required to form a thunderstorm cloud and lightning. Quote the internet sources.

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12. Propose other topics or questions related to electricity or conducting, you would like to explore during the subsequent lessons or at home.

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Safety note: A human being conducts an electric current. Always make sure that your hands are dry before you handle any electrical equipment. Never put your fingers into an electrical contact.

Challenge
Propose an experiment showing in the classroom a small lightning without use of any device plugged into the mains.

Homework
Using argumentation, write a short essay based on question:
Is an electric current always dangerous to a human being?

Page 7 of 7

Figure 3: Student worksheet, page 7 – end of Activity C, challenge and homework

Suggested lesson sequence

1. In this activity, students complete the third section of the student worksheet (Activity C: Conductivity of different materials, Figure 2). They suggest materials with which they would investigate conductivity, and propose a circuit that can be used to test the materials.
2. The students develop their hypotheses for each of the materials, and record these hypotheses in the table provided in the worksheet.
3. Students carry out the investigation using the simple circuit and their chosen materials, and record the outcomes in their table.
4. Students are introduced to the electrical symbols used in drawing circuit diagrams. They investigate these through reproducing the diagrams that they had already drawn and using these scientific symbols.
5. The teacher facilitates a class/group brainstorming session, in which students discuss conductivity. Questions to support the session include:
   a. Is conductivity an inherent property of an object, or a property of a material the object is made of?
   b. What is a general name for materials that conduct electricity?
   c. What is a general name for materials that do not conduct electricity?
6. The brainstorming session should move to discussion of everyday experiences of electricity, in particular “Can air conduct an electric current?”
7. Students are encouraged to search for scientific information; using the internet or other sources to find out how lightning is formed. They should summarise their findings in their worksheet, and provide details of their sources (Figure 3, worksheet page 7).
8. At the end of the session, self-assessment and peer-assessment evaluations can be conducted.
9. A further challenge is provided to encourage further inquiry, “Propose an experiment to show lightning in the classroom without the use of any device plugged into the mains”, and a homework question, “Is the electric current always dangerous to a human being?” These can be used for the assessment of individual *scientific literacy* and *scientific reasoning* capabilities.

2.2 Assessment of activities for inquiry teaching & learning

There are opportunities identified throughout this unit for the development and assessment of inquiry skills. Evidence of skill development can be collected in the form of student artefacts (worksheets or student devised materials, such as mind maps), through teacher observation or peer- and self-assessment. While some assessment tools are described within this unit, there is also flexibility for the teacher to devise and implement their own assessment instruments. Suggested skills to be assessed during implementation of this unit include *developing hypotheses, planning investigations* and development of *scientific literacy*, in particular, explaining electrical current and electrical conductivity using scientific terminology.

Assessment of Activity A: Introduction to electricity

In this activity, the brainstorming task offers opportunities for the assessment of *scientific literacy, working collaboratively* and *scientific reasoning*:

- *Scientific literacy* (prior knowledge from everyday life and other sources)
- *Working collaboratively* (student engagement in brainstorming)
- *Scientific reasoning* ("creativity" during brainstorming, i.e. clearing explaining their choice of terms and words)

Prior to the activities the teacher chooses a group of students to assess during each brainstorming session throughout these lessons. It is suggested that this should not exceed six students. During each brainstorm the teacher checks an appropriate box in the table below to record the frequency and type of selected students' contributions (Table 1). It is also possible to indicate cases where disrespect is shown to the peers' opinions expressed during the brainstorming, e.g. by marking (R).

Table 1: Assessment of individual student's contributions during a brainstorming activity

Student name	Context – history, everyday life			Scientific words, meaning			Scientific symbols, circuits	
	Prior knowledge	Engagement	Creativity	Engagement	Prior knowledge	Creativity	Engagement	Prior knowledge
Name 1								
Name 2								
Name 3								

In addition, depending on the teacher's and students' experience in using a mind map as a teaching/learning tool, a rubric can be used to assess students' skills in drawing a mind map (Table 2). The teacher can use this 4-level rubric for the assessment all of the students' mind maps after the lesson is completed.

Table 2: Rubric for the assessment of the skill of drawing a mind map

Assessed skill	Emerging	Developing	Consolidating	Extending
Drawing a mind map	The student's mind map is empty or full of words unrelated to the concept of electricity	The student draws a mind map containing only a few words and/ or the words are listed with no relation to each other	The student draws a mind map with more than 10 words, both scientific and belonging to everyday language, but the visualisation of relationships and categories is poor	The student draws a mind map with more than 10 words, both scientific and belonging to a common language, with a good visualisation of the relationships and categories

Assessment of Activity B: Simple electric circuits

In this activity, teachers can assess *planning investigations*, *scientific literacy*, *working collaboratively* and *scientific reasoning* based on the students' responses on their worksheets. A suggested 4-level rubric for the assessment of *scientific literacy* (drawing an electrical circuit) is shown in Table 3.

Table 3: Rubric for the assessment of students' ability to draw an electric circuit

Assessed skill	Emerging	Developing	Consolidating	Extending
Drawing an electric circuit	The student... ... chooses a set of adequate objects: a bulb, two wires and a battery but does not draw any pictures	The student... ... chooses a set of four adequate elements and draws a schematic drawing that is not completely correct	The student... ... chooses a set of four adequate elements and draws a completely correct schematic drawing of a simple circuit, but does not draw a circuit with additional materials	The student... ... chooses a set of four adequate elements and draws two schematic drawings completely correctly

Assessment of Activity C: Conductivity of different materials

In this activity, inquiry skills *planning investigations*, *forming coherent arguments* and *working collaboratively* may be assessed, as well as *scientific literacy* and *scientific reasoning*. The student drawings on their worksheets can be evaluated for this assessment. The suggested rubric for the assessment of drawing an electrical circuit, shown in Table 3 and used in Activity B, can be used to assess students' *scientific literacy*.

In order to assess the inquiry skill *planning investigations*, a 4-level rubric can be utilised (Table 4). The rubric can be used to evaluate the work of a number of students, selected prior to the lesson, for this particular assessment. For each assessment intervention, the teacher can choose the same or different group of students.

Table 4: Rubric for the assessment of planning investigations

Assessed skill	Emerging	Developing	Consolidating	Extending
Planning investigation of conducting properties of different materials	The student... ... lists a limited number of objects made of 1-2 different kinds of materials but does not write the plan at all or the investigation plan is incomplete	The student... ... lists a limited number of objects made of 1-4 different kinds of materials and the investigation plan is almost correct	The student... ... lists a limited number of objects made of over 4 different kinds of materials and the investigation plan is almost correct	The student... ... lists a limited number of objects made of over 4 different kinds of materials and the investigation plan is complete

In order to assess the skill of searching for information, the following 4-level rubric can be used (Table 5). The rubric should be used to evaluate the work of a number of students, selected prior to the lesson for this particular assessment.

Table 5: Rubric for the assessment of searching for information

Assessed skill	Emerging	Developing	Consolidating	Extending
Searching for information	The student... ... finds information from 1-2 sources, but does not pay attention to the independence of the sources; summary is incorrect or incomplete and does not quote the source	The student... ... finds consistent information from 1-2 sources, but does not pay attention to the independence of the sources; summary is almost correct, but does not quote the source	The student... ... finds consistent information from at least two substantially different sources; summarises it in 3-4 almost correct sentences, quotes all or almost all sources of information	The student... ... finds consistent information from at least two substantially different sources; summarises it in 3-4 correct sentences, quotes all sources of information

In order to assess the development of the skill of *working collaboratively*, a self-assessment tool is proposed for use at the end of the unit. This allows the students to reflect on their involvement in group work during the lesson. Using the scale 0 (not at all) to 6 (very much), students score their own engagement, according to the statements listed in Table 6.

Table 6: Self-assessment tool for assessing the skill of working collaboratively

Self-assessment card	0 (not at all)	1	2	3	4	5	6 (very much)
1. I was involved in planning the experiment							
2. I carried out the given tasks							
3. I helped colleagues							
4. I was involved in collection of data							
5. I was active in performing the experiment							
6. I communicated properly with the others							

A similar peer-assessment tool is shown in Table 7. This allows the student to reflect on the involvement of their peers in group work during the lesson. Using the scale 0 (not at all) to 6 (very much), students score their peers' engagement, according to the statements listed.

Table 7: Peer-assessment card for the assessment of working collaboratively

Peer-assessment card	Peer 1	Peer 2	Peer 3
1. Did your colleague take part in planning the experiment?			
2. Did your colleague take part in carrying out the given tasks?			
3. Did your colleague help the group?			
4. Did your colleague engage in data collection?			
5. Did your colleague take part in performing the experiment?			
6. Did your colleague communicate properly in the group?			

3. SYNTHESIS OF CASE STUDIES

The **Electricity** SAILS inquiry and assessment unit was trialled in four countries, producing five case studies of its implementation – **CS1 Slovakia**, **CS2 Ireland**, **CS3 Turkey**, **CS4 Poland** and **CS5 Poland**. The case studies were conducted by 14 different science teachers in a total of 17 classes and with 333 students.

The activities have been carried out with lower second level students from mixed ability classes; **CS1 Slovakia** combines the classroom experiences of 10 teachers in 11 classes, **CS2 Ireland** reports on one teacher's implementation with two different class groups (all girls, aged 14 years) and **CS4 Poland** describes one teacher's implementation with one class of 14 year old students. **CS3 Turkey** and **CS5 Poland** present the experiences of teachers implementing this unit at upper second level, with students aged 15-16 years and one of the teachers in **CS1 Slovakia** also trialled this unit with this age group.

The key inquiry skill evaluated was *planning investigations*, while most case studies also reported on collecting evidence of *scientific reasoning* and *scientific literacy*. The identified assessment opportunities included students' contribution during brainstorming, students' construction of mind maps, students' abilities to draw electrical circuits and develop investigation plans. The assessment methods used include classroom dialogue, students' worksheets and other devised materials, such as mind maps, and peer-/self-assessment tools.

3.1 Teaching approach

Inquiry approach used

The inquiry approach used in all the case studies was that of *guided inquiry*, as outlined in the unit description. In two case studies – **CS2 Ireland** and **CS3 Turkey** – students did not have lessons on electricity prior to the implementation of this unit, while in all other classes the activities of this **Electricity** SAILS inquiry and assessment unit were used for revision purposes. The purpose of this unit was particularly important in student's construction of mind maps in Activity A: Introduction to electricity. If students had no prior knowledge of the topic electricity, the mind map was used to set the everyday context. If electricity was introduced beforehand, the mind map was utilised as a revision exercise. In one class (**CS2 Ireland**) the mind map was used for comparison at the beginning and at the end of the unit. The unit was usually adopted as outlined, however in some cases (**CS2 Ireland** and **CS5 Poland**) the final challenge was partially or entirely skipped during the implementation.

Implementation

Implementation of the unit took 45-90 minutes, depending on the country. This corresponds to only one lesson (45 min) in some classes (Slovakia) and two lessons (~90 min) in all other cases. Students worked in groups of 2-3 students of mixed abilities in **CS2 Ireland**; of 4 students in **CS4 Poland**; in pairs in **CS5 Poland**; of 4 students in each class in **CS1 Slovakia**; and as a whole class comprising of 16 students in **CS3 Turkey** (due to the shortage of appropriate equipment). Each student was given one worksheet and completed it individually, except in **CS5 Poland** where it was not possible for the teacher to provide photocopies for all students (34); so instead, the students took their notes on separate pieces of papers.

Table 8: Summary of case studies

Case Study	Activities implemented	Duration	Group composition
CS1 Slovakia	Activities A-C	Mainly two lessons (45 min each)	• Groups of 3-4 students (12 classes in total) • Mixed ability; some single gender groups
CS2 Ireland	Activities A-C	One or two lessons (80 min total)	• Groups of 2-3 students (2 classes in total) • Mixed ability; single gender (all-girl school)
CS3 Turkey	Activities A-C	Two lessons (40 min each)	• Participated individually (16 students in total) • Mixed ability and gender class
CS4 Poland	Activities A-C	Two lessons (45 min each)	• Groups of 4 students (20 students in total) • Mixed ability and gender
CS5 Poland	Activities A-C	One lesson (45 min)	• Groups of 2-3 students (34 students in total) • Mixed ability and gender

Adaptations of the unit

The teachers that implemented the unit shared the opinion that it was appropriate for two lessons. Slight modifications were proposed by some of the teachers, namely the assessment of generating research questions (**CS3 Turkey**), use of a mind map both at the beginning and at the end of a unit (**CS2 Ireland**, both class groups), construction of a model of an electric circuit (**CS2 Ireland**) and omissions or shortcuts in latter sections (**CS2 Ireland** and **CS5 Poland**).

3.2 Assessment strategies

In the **Electricity** SAILS inquiry and assessment unit, several assessment opportunities were identified. No one teacher that implemented this unit used all of the opportunities or tools for assessment that were provided, and instead they focused on particular skills for development and assessment, as detailed in Table 9.

Table 9: Inquiry skills identified by teachers in the case studies

CS1 Slovakia	• Planning investigations • Scientific literacy (searching for information; explaining lightning scientifically)
CS2 Ireland	• Planning investigations • Working collaboratively • Scientific literacy (searching for information; use of scientific language, explaining electrical conduction scientifically)
CS3 Turkey	• Developing hypotheses • Forming coherent arguments • Scientific literacy (explaining electrical conductivity scientifically)
CS4 Poland	• Planning investigations • Scientific reasoning (identifying connections) • Scientific literacy (explaining the principles of electricity scientifically)
CS5 Poland	• Planning investigations • Working collaboratively • Scientific reasoning (choosing components for an electrical circuit)•Scientific literacy (ability to explain electrical conductivity scientifically)

Three key skills identified in the activities for teaching and learning were highlighted for assessment during implementation in the classroom. *Scientific literacy* and *scientific reasoning* about electricity could be evaluated four times – during brainstorming in activities A and C, using mind maps in Activity A and using graphical and schematic representations of working electric circuits (activities B and C). The assessment of *planning investigations* was suggested in Activity C and could be used as part of a group work assessment. A task involving searching for information was proposed at the end of the unit and could be offered as a homework exercise.

In addition to these, three other assessment opportunities were realised by the teachers that implemented this unit in their classrooms and are included in their case studies, together with new assessment tools. The assessment of "constructing a model of an electric circuit" was added by a teacher in **CS2 Ireland** and a 4-level rubric was proposed for this purpose (Table 10). *Working collaboratively* (engagement in group work) was assessed by one of the Polish teachers (**CS5 Poland**) and *developing hypotheses* (generating a research question) was evaluated by a teacher in **CS3 Turkey**.

Table 10: Rubric for the assessment of circuit drawing/models proposed in CS2 Ireland

Assessed Skill	Level 1	Level 2	Level 3	Level 4
Scientific literacy: circuit model/ drawing	Circuit symbols drawn and connected correctly	...and includes reference to flow of electrons/direction of current	... and indicates that electrons already present throughout the wires, etc., begin to move as soon as switch goes on and some explanation as to why they begin to move (reference to battery/ potential difference, etc.)	...and an explanation of energy conversion, i.e. electrical energy – light energy in the bulb and/or reference to how kinetic energy of electrons does not change

Assessment tools

At different stages, the unit offers different assessment methods for assessing the skill of *working collaboratively*, namely a tool for assessing engagement in collaboration, a tool for the assessment of brainstorming and a tool for self- and peer-assessment. In the assessment of teaching and learning activities second of this unit, rubrics are proposed for the assessment of four activities – twice for the assessment of *scientific literacy* and *scientific reasoning* (drawing a mind map and use of graphical and schematic representations of working electric circuit), once for the assessment of *planning investigations* and once for *searching for information*. All rubrics are based on four levels of student development of the particular skill. These rubrics were implemented without changes, except in the case of **CS4 Poland**, where the teacher extended three of these rubrics from four to six levels (Table 11). A six-level scale is used for traditional grading in Poland and the teacher was used to this format in her teaching practice. Additionally a new rubric for the assessment of a student's ability to construct a model of an electric circuit was proposed by the teacher in **CS2 Ireland** (Table 10).

Brainstorming is utilised twice in the **Electricity** SAILS inquiry and assessment unit, as an assessment method for evaluation of *scientific reasoning* and *scientific literacy*, and at times when all students take part in whole class discussion. Self- and peer-assessment tools were not included in the resources provided to the teachers trialling this unit, but were added by one of the teachers in **CS4 Poland** for evaluation of *working collaboratively* (engagement in group work). These have been subsequently been incorporated into the final **Electricity** SAILS inquiry and assessment unit (Tables 6 and 7).

Table 11: Rubric for the assessment of inquiry skills in CS4 Poland

Task	1	2	3	4	5	6
Drawing a mind map	Student doesn't draw mind map or draws it putting words not connected to topic (can't explain the connection to the topic).	Student draws a mind map containing 5 words connected to the topic, but there is a lack of connections and relations between them.	Student draws a mind map containing more than 5 words connected to the topic and the majority of the words are from common language. There is a lack of connections and relations between words.	Student draws a mind map with more than 8 words connected to the topic (majority of words are from common language). Student draws the connections between some words.	Student draws a mind map with more than 10 words connected to the topic (most of words are from common language). Student draws connections between words but the structure is not expanded very much.	Student draws a mind map with more than 10 words connected to the topic and most of words are scientific. Student draws proper relations and connections between words.
Drawing circuits	Student chooses proper components of circuits to light a bulb (B.1) but doesn't draw the scheme or draws it incorrectly (B.3). S/he doesn't draw a proper circuit (C.2) or schemes of circuits (C.5)	Student chooses proper components of circuits to light a bulb (B.1) and draws this circuit (B.3). S/he doesn't draw a circuit or does it incorrectly (C.2). S/he doesn't draw schemes of circuits (C.5)	Student chooses proper components of circuits to light a bulb (B.1) and draws this circuit (B.3). Student draws a circuit (C.2) but doesn't correctly draw the schemes of circuits (C.5).	Student chooses proper components of circuits to light a bulb (B.1) and draws one of the circuits B.3 or C.2, but doesn't correctly draw the schemes of circuits (C.5).	Student chooses proper components of circuit to light a bulb (B.1) and draws circuits B.3 and C.2. Student makes mistakes in drawing one of the schemes of circuits (C.5).	Student chooses proper components of circuit to light a bulb (B.1) and draws circuits B.3 and C.2. Student draws schemes of both circuits (C.5).
Planning investigations	Student doesn't list things made of different materials for measurement and doesn't write down an experiment plan.	Student lists 2-3 things made of different materials for measurement but doesn't write down an experiment plan.	Student lists 4-5 things made of different materials for measurement and writes down an incorrect experiment plan.	Student lists 4-5 things made of different materials for measurement and writes down an almost correct experiment plan.	Student lists 6-7 things made of different materials for measurement and writes down an almost correct experiment plan.	Student lists more than 7 things made of different materials for measurement and writes down a correct experiment plan.

Implementation and evidence

Students working with the **Electricity** SAILS inquiry and assessment unit were assessed both as they worked during the lessons and afterwards, on the basis of student worksheets. Solely in **CS1 Slovakia** all teachers used only the latter strategy of assessment. In addition, most teachers posed questions and gave formative feedback orally during the lessons (**CS2-CS5**), but this was not documented. As can be observed from the case studies, individual teachers showed preferences for different assessment tools.

The assessment of the mind map activity using rubrics was utilised only in **CS4/CS5 Poland** and **CS2 Ireland**, although in the latter it was utilised twice – at the beginning and at the end of unit implementation – and in this case the rubrics for the assessment of a mind map were changed accordingly. Evaluation of *planning investigations* with use of rubrics was introduced in **CS4**, **CS5 Poland** and **CS1 Slovakia**. The searching for information activity was given as homework only in **CS1 Slovakia** and was assessed with rubrics. Group work engagement was evaluated by self- and peer-assessment tool only by one teacher in **CS5 Poland**, who added these tools to the unit (Table 6 and Table 7). Constructing a model of an electric circuit was assessed only in **CS2 Ireland**, since rubrics for this activity was an original contribution of an Irish teacher to the unit (Table 10). Evaluation of generating a research question was implemented by only one teacher in **CS3 Turkey**, who did not propose any specific assessment tool for this activity but gave feedback based on her own judgements.

Problems encountered

The teachers in **CS1 Slovakia** considered the assessment based on observing students during their brainstorming activity (assessing pre-knowledge, activity and creativity) and drawing a concept map rather problematic. Thus they utilised only the rubrics. At the same time the teacher in **CS3 Turkey** liked to use the brainstorming chart, but reported substantial problems with the use of rubrics during the lesson and would prefer to utilise this tool for evaluation of student worksheets, after the lesson. The teachers in **CS2 Ireland**, **CS4** and **CS5** (both Poland) did not mention any problems in implementation of the assessment strategies proposed for this unit.

Proposed adaptations

From the case studies, a number of adaptations were proposed in this unit, which seek to expand the opportunities to develop inquiry skills and to assess students' performance.

1. The rubric tools proposed in the unit are composed of four levels of skill development – emerging/developing/consolidating/extending. A teacher in **CS4 Poland** found that composition of six levels provided more clarity (Table 11). This can be taken into consideration by teachers who need a more fine-grained structure of rubrics and shows the flexibility in the adaption of the provided assessment tools for use in different curricula and context.
2. One teacher utilised a mind-map before and after the unit (**CS2 Ireland**). Students were assessed on what changes they made to the mind-map, which gave the teacher a clearer measure of the students' ideas of what it means for something to be a conductor of electricity).
3. In **CS5 Poland**, the tool for the assessment of drawing the mind map on electricity was extended by including an additional rubric for evaluation of engagement in peer-discussion in pairs (Table 12).
4. The teacher in **CS2 Ireland** suggests an extension to the task of drawing a simple electric unit, asking students to draw what they think is happening inside the wires (Table 10).
5. It was suggested by one of the teachers that for the conductivity table in the student worksheet, it would be better to get students to explain why they made the prediction. This would help the teacher assess argumentation and justification skills and means that students who just guess correctly are not assessed as being at the higher end of an assessment scale (**CS2 Ireland**).
6. Formulation of the inquiry research question has been added by a teacher from **CS3 Turkey** to the unit just after activity with a mind map, and a simple three-point scale for the assessment is proposed:
   - Point 1: Students cannot formulate a good hypothesis.
   - Point 2: Student formulates a hypothesis but with an inappropriate statement
   - Point 3: Student formulates an appropriate hypothesis and states it appropriately

Table 12: Rubric for assessment of student mind maps used in CS5 Poland

Assessed Skill	Emerging	Developing	Consolidating	Extending
Drawing a mind map	Student's mind map is empty or full of inadequate words, for which the student cannot describe a relation to electricity	Student draws a mind map containing only a few words and/or the words are listed with no relation to each other	Student draws a mind map with more than 10 words, both scientific and belonging to a common language, but the visualisation of the relationships and categories is poor	Student draws a mind map with more than 10 words, both scientific and belonging to a common language, with a good visualisation of the relationships and categories
Discussion with peers	Student does not take part in the discussion	Discussion between the students is limited to reading words from own mind maps and checking the neighbour's terms	Student detects differences between two mind maps and compares them (e.g. tries to judge which one is better)	Student points out significant differences and compares both mind maps; considers scientific value of scientific terms in both maps and argues, why one of them is better that the other