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Report from evaluation of implementation with pilot teachers - Part B

SAILS
Strategies for Assessment of Inquiry Learning in Science

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D3.2 Report from evaluation of implementation with pilot teachers - Part B

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1. Introduction

The aim of SAILS is to support teachers in adopting an inquiry based science education (IBSE) at second level across Europe. In addition to adopting IBSE curricula and implementing teacher education, the SAILS project will develop appropriate strategies and frameworks for the assessment of IBSE skills and competencies and prepare teachers not only to be able to teach through IBSE, but also to be confident and competent in the assessment of their students' learning. Through this unified approach of implementing all the necessary components for transforming classroom practice, i.e. teacher education, curriculum and assessment around an inquiry pedagogy, a sustainable model for inquiry-based learning will be achieved.

The focus of this work package is to conduct an evidence-based analysis of the assessment framework/strategy/instruments that have been developed to date through the SAILS project. In particular, the consortium has prepared Draft Units (DU), comprising of inquiry activities with assessment suggestions. These DUs have been trialled with teachers from across the participating countries in the SAILS project and the feedback from the teachers was collected in the form of Case Study (CS) reports. This analysis is based on the evidence collected from three main sources:

- Analysis of the Draft Units and Case Studies produced;
- Responses to questionnaires for each partner group;
- Reports and discussions at SAILS meetings.

Attention is also given to ensuring appropriate cultural perspectives in the evaluation materials produced and to raise awareness of other equity issues, such as gender, that might threaten the validity and reliability of the assessment approaches.

The outputs from this work package (WP3) will inform the tasks of work package two (WP2), through an iterative process, to enable remodelling and improving of the framework/strategy and its component assessment instruments. The outputs will also input into the development and implementation of SAILS teacher education programmes (WP4) and the Community of Practice (WP5) to inform the teacher education and participation in this project.

This report provides an overview of the activities carried out by the consortium across the twelve participating countries of the SAILS project using the assessment frameworks and instruments for IBSE skills-Part B. Each partner has collaborated with local teachers to select and develop draft units and trial these in the second level science classroom and provide feedback from these experiences.

Background

Inquiry skills are what learners use to make sense of the world around them. These skills are important both to ensure that citizens can make sense of the science in the world they live in so that they make informed decisions and also to develop scientific reasoning for those undertaking future scientific careers. The term *inquiry* has figured prominently in science education, yet it refers to at least three distinct categories of activities—**what scientists do** (e.g., conducting investigations using scientific methods), **how students learn** (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a **pedagogical approach that teachers employ** (e.g., designing or using curricula that allow for extended investigations) (Minner, 2009). For an extensive discussion of the Inquiry Skills and Competencies Framework adopted in the SAILS project, see D1.1.

Part of the reason for a slow implementation of inquiry-based learning in science classrooms is the time lag that happens between introducing ideas and the training of teachers at both in-service and pre-service level. While the many EU Inquiry projects have produced teaching materials to support classroom practice, they have not produced support materials to help teachers with the assessment of this approach. Linked to this is the low level of inquiry type items in national and international assessments which gives the message to teachers that inquiry is not valued in terms of competence in science education. It is clear that there is a need to produce an assessment model and support materials to help teachers assess inquiry-based learning in their classrooms, if this approach is to be further developed and sustained in classrooms across Europe.

This report outlines the type of assessments and approaches that teachers from the twelve partner countries in SAILS have taken to assessing inquiry-based learning in their science classrooms. In each country a group of teachers was selected to become involved in identifying and developing inquiry and assessment materials. These teachers attended workshops facilitated by the SAILS partners and were introduced and/or selected various inquiry and assessment activities. These workshops helped teachers to both plan how to do the inquiry with their learners and to decide which inquiry skills might be possible to assess during the class activity. From these discussions, teachers were able to focus on a number of skills that they intended to assess and to seek advice from their peers about how they might manage this. In some partner workshops, teachers developed rubrics to describe the criteria they would use to assess the learners as they carried out their inquiry.

The trialling of all of the draft units has been carried out by partners and in some cases using the same initial group of pilot teachers. In other countries, the pilot group of teachers has evolved to include the teachers from cohort one of the SAILS teacher education programme in that country. Through on-going communication and workshops with these pilot teachers a total of 34 draft units have been prepared and shared with all partners through the members' area of the SAILS website. Pilot teachers have reported back at subsequent workshops on the implementation of draft units and what successes and difficulties they encountered in using the assessment item and proposed assessment criteria. This approach allowed the teachers to develop their understanding of assessment criteria and discuss with the group the benefits of various modes of assessment opportunities for assessment during the inquiry activity. Teachers also reported back on modes of assessment used after the learners had completed the inquiry activity – such as individual or group written work, presentations or interviews with students about their investigation or inquiry activity. The participating teachers have also documented their experiences in the classroom in Case Study (CS) reports. Each case study report describes how the learning sequence in the draft unit was adapted, how and what skills were assessed, what evidence was collected and what criteria were adopted for this assessment. The outcomes from these discussions of draft units and case studies will inform both the development of an assessment framework (WP2) and teacher education programmes (WP4).

Partners have adopted the draft unit evaluation sheet, as shown in Appendix One, to collect feedback from teachers on how the inquiry activities and assessments went in their classrooms and these were used, alongside the discussions from the teacher workshops, to help each partner complete a pilot teacher questionnaire, as shown in Appendix Two. This questionnaire was used to collect feedback on how the confidence and understanding of the pilot teachers had developed with regard to inquiry skills. It also provides feedback on how successful or not the teachers had been in applying their chosen approach to assessment. Another aspect that was of interest was the extent to which the teachers involved their students in the assessment process.

This report on the evaluation of implementation with pilot teachers is presented in six sections. In section 1, an outline of the modes of assessment explored by the different partner groups is presented, focussing on particular skills, namely: planning investigations, developing hypotheses, debating with peers and forming coherent arguments and are described in Deliverable 2.3. Section 2 discusses how assessment of a particular skill varied across different implementations. A comparison of how teachers from different countries approach inquiry and assessment of particular draft units is discussed in Section 3, and provides an insight into understanding the cultural diversity in approach to inquiry-based learning within the project. Section 4 presents an overview on teacher feedback on the units. Section 5 outlines an evaluation on how each of the partners feel their teachers are progressing with the assessment of inquiry skills in their classrooms. A drawing together of what has been learnt so far about assessment of inquiry-based learning in classroom practice and recommendations for the next phase of the project is presented in the final section of this report.

Section 1: Modes of Assessment

1.1 Development of unit template

Within the SAILS project, SAILS Inquiry and Assessment UNITS will be used by teacher educators with both in-service teachers and pre-service teachers in order to help classroom teachers to broaden their assessment practices. A range of SAILS UNITS are therefore required to provide examples over a broad range of contexts and classroom cultures as well as a range of teacher experiences. They should also be suitable for a variety of subjects and educational levels. The SAILS UNITS will show how the assessment practices can link in with the inquiry lesson. They will show teachers the benefits of inquiry in classroom practice and also illustrate the variety of assessment opportunities/processes available to them.

In particular, the SAILS UNITS will have clear examples for teachers of how inquiry skills can be assessed, alongside content knowledge, scientific literacy and scientific reasoning and illustrate the benefits of various types of assessments. More specifically, they will show how evidence of student learning can be collected and evaluated using a variety of methods, e.g. student discussion, written evidence, diagnostic questions etc.

These SAILS UNITS are constructed to be informative to the teachers, relate to classroom practice and include examples of assessment items used with students, assessment criteria and a narrative to explain the assessment criteria. The importance here is to ensure that the assessment items produced illustrate for teachers a variety of examples of assessment practices that they can use within their own context of curriculum implementation.

To provide a structure for the development of the SAILS UNIT, a template was prepared to highlight the main sections required (Appendix Three). The template has two sections; the draft unit and the case studies as shown in Figure 1. The draft unit provides details of an inquiry teaching sequence within a particular topic and identifies the inquiry skills addressed and suggestions as to how these may be assessed. Within each draft unit, a number of key skills are identified and then a teaching sequence is suggested which describes the assessment practice and the process used for collecting and evaluating evidence of student development of inquiry skills, reasoning skills and scientific literacy as well as content understanding. The draft units are based on good examples of inquiry lessons (and many of the examples used have been developed through other inquiry projects). Each draft unit includes examples of assessment items and criteria for evaluation. Within the draft units, specific attention is given to gender issues ensuring that all materials are suited to both genders.

The case studies provide an evaluation of evidence of learning. Each case study should provide a narrative on how teachers:

- have implemented or adapted the learning sequence,
- what skills did they assess and how,
- what evidence did they collect on student learning,
- and how they judged this assessment data (criteria and explanation/justification).

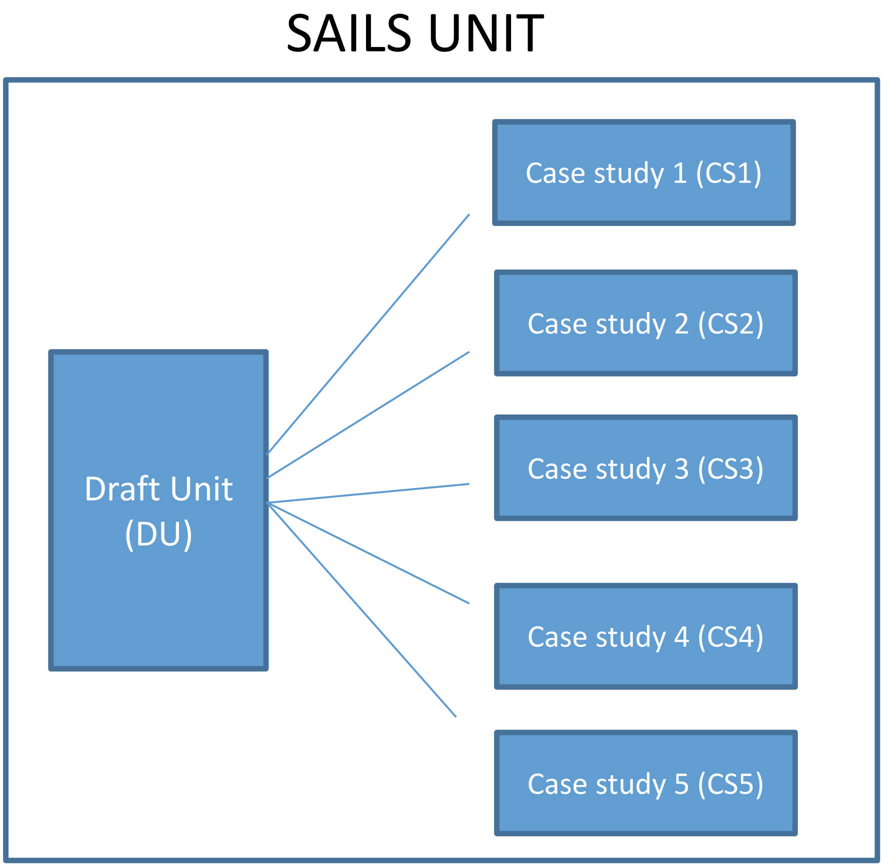


Figure 1: Outline of SAILS Unit Content.

Many of the draft units have been used by different teachers, who have tailored the inquiry activity to suit their students and their local resources which has resulted in several case studies for some draft units. The overall plan is that following evaluation and testing with teachers, the draft unit and case studies will be combined into SAILS UNITS that give details of good inquiry lessons with embedded assessment modes and criteria and also provides details of how the teaching and assessment strategies have been implemented in the classroom. These will include a description of practical use of different assessment processes and criteria (e.g. questions, rubrics, etc.) and implementation plans used for evaluating evidence of student learning, development of inquiry skills as well as scientific reasoning and scientific literacy.

1.2 Draft Units and Case Studies

Table 1 shows the range of draft units that have been developed by the consortium and also shows the case studies that have been completed to date. In some instances, teachers have developed the draft units following implementation of an inquiry and so the draft unit contains evidence of classroom assessment. To date, 34 draft units have been developed that cover a variety of topics across Biology, Chemistry and Physics, which provide examples of inquiry based teaching and are described for either individual lessons or for a small number of lessons. This was done in order to give teachers exemplars for a range of assessment strategies for assessing inquiry skills rather than giving a long teaching sequence for embedding inquiry skills.

These draft units have now been analysed in terms of the inquiry skills discussed in Deliverable 2.3 Framework, i.e. planning investigations, generating hypothesis, forming coherent arguments and debating with peers. Scientific literacy and scientific reasoning have also been identified. In Table 2A and 2B, the draft unit in which a particular inquiry skill is assessed is identified along with the mode of assessment. In some of these draft units, many other skills were also identified within the draft unit/case study but these have not been included or evaluated in this document. It is important to note here that in many cases, assessment was not done during the learning activity that the students were engaged in but on an artefact that the student, or group of students, produced after the inquiry (e.g. students may be involved in a research activity but the assessment is carried out on their oral presentation of the poster or students are involved in teamwork but the students are assessed on individual written reports).

In compiling these tables, Table 2A - assessment modes using during the inquiry and Table 2B – assessment modes used after the inquiry, the focus was on the inquiry skill that was actually assessed in the case study (if a particular skill was stated but no details given of how it was assessed, then it was not included). It should be noted that these tables have been compiled through interpretation of the details given in the case studies and some errors may be evident due to incorrect interpretation. It is envisaged that these details will be provided to avoid any ambiguity in the final SAILS UNITS. In some instances, the mode of assessment was given but no details were given as to how this mode or what assessment criteria was used. Note DU is now used for draft unit and CS for Case Study.

Table 1 Compilation of draft units and case studies.

Title	**Developer**	**Case studies**	**Case study title**	**Planning Investigations**	**Developing hypothesis**	**Debating with peers**	**Forming coherent arguments**	**Scientific literacy**	**Scientific reasoning**
Acids, bases, salts	UPRC	UPRC	CS1	DU AND CS	DU AND CS	DU ONLY			
Biotechnology	IEUL	IEUL	CS1			DU and CS	DU and CS		
Black tide: Oil in the water	IEUL	IEUL	CS1	DU AND CS		DU ONLY			
Candle	HUT	HUT	CS1	DU AND CS	DU AND CS	DU ONLY			
Chemical reaction speed	US	US	CS1	DU AND CS	DU AND CS	CS ONLY			
Collision of an egg	US	US	CS1	DU AND CS	DU AND CS		DU AND CS		DU ONLY
Constructing a galvanic cell				DU ONLY	DU ONLY	DU ONLY	DU ONLY		
Cooking an egg		US	CS1	CS ONLY			DU AND CS	DU ONLY	
Cooking food	KCL	KCL	CS1		DU AND CS	DU AND CS		DU AND CS	
Decomposition of starch in saliva	US			DU ONLY					
Electricity	JU	UPJS, HUT, JU1, JU2, DCU	CS1, CS2, CS3, CS4	DU AND CS	CS ONLY	DU AND CS	CS ONLY	DU ONLY	DU ONLY
Fish eating birds	US	US	CS1				DU ONLY	DU ONLY	
Floating orange	KCL	KCL	CS1	DU AND CS		DU AND CS			
Food labels	KCL	DCU	CS1	DU ONLY				DU ONLY	DU ONLY
Galvanic cells	JU	DCU, JU	CS1, CS2	DU AND CS	DU AND CS	DU ONLY	DU AND CS		DU ONLY
Genetic engineering	HKR	HKR	CS1				DU ONLY		

Global warming	HKR	HKR	CS1				DU AND CS		
Goats and Human, resources and sustainability: and the end of the story?	IEUL	IEUL	CS1	DU ONLY					
Height and body mass		US	CS1				DU AND CS		DU ONLY
Household vs natural environment	JU	JU	CS1	DU AND CS	CS ONLY	DU ONLY	DU AND CS		
Martian bacteria in Alentejo	IEUL	IEUL	CS1	DU AND CS		DU AND CS			
Natural selection	SDU	SDU, JU	CS1, CS2	CS ONLY		DU AND CS	DU AND CS		DU ONLY
Plant nutrition	KCL	UPJS	CS1	DU AND CS			DU ONLY		DU ONLY
Polymers	UPJS	UPJS	CS1		DU ONLY				DU ONLY
Rates of change			CS1	DU ONLY	DU ONLY			DU ONLY	
Reaction rates	DCU		CS1	DU ONLY					DU ONLY
Speed	KCL/US	DCU, IEUL, LUH, HUT	CS1, CS2, CS3, CS4	DU AND CS				DU ONLY	
Sports nutrition	HKR	HKR	CS1				CS ONLY		
Temperature of plants	KCL		CS1		DU ONLY				
The probe of the pudding	US		CS1	DU ONLY		DU ONLY			DU ONLY
Ultraviolet radiation	HKR	SDU, LUH	CS1, CS2	DU AND CS	DU ONLY				
Up there… how is it?	IEUL	IEUL	CS1	DU AND CS	DU ONLY		DU ONLY		
Which is the Best Fuel?	HUT	HUT	CS1	DU AND CS	CS ONLY	DU ONLY	DU ONLY		
Wood lice	MaH	DCU, JU, MaH	CS1, CS2, CS3	DU AND CS	DU AND CS		DU AND CS		

Table 2A Assessment modes during activity* (DU refers to draft units and CS to case studies)

Assessment Modes	Planning Investigations	Developing Hypothesis	Debating with Peers	Forming Coherent Arguments	Scientific Reasoning	Scientific Literacy
Worksheet	Acids and bases CS Which fuel is best? CS Proof of the pudding DU Galvanic Cell CS	Acids and bases CS Which fuel is best? CS Proof of the pudding DU		Proof of the pudding DU	Proof of the pudding DU	Proof of the pudding DU
Student-teacher dialogue	Candle DU/CS Collision of an egg DU/CS Which fuel is best? CS Proof of the pudding DU Speed CS Ultraviolet Radiation CS Constructing a Galvanic Cell DU	Candle DU/CS Collision of an egg DU/CS Which fuel is best? CS Proof of the pudding DU1 Ultraviolet Radiation CS	Food Labels CS	Candle DU Height and body mass CS Proof of the pudding DU Galvanic Cells CS	Height and body mass CS Proof of the pudding DU	Proof of the pudding DU
Peer assessment				Acids and bases DU/CS	Acids and bases DU/CS	
Teacher observation (Listening / Watching)	Candle DU Cooking Food CS Starch decomposition DU Proof of the pudding DU UV Radiation CS Constructing a Galvanic Cell DU Galvanic Cell U/CS	Candle DU Starch decomposition DU Proof of the pudding DU UV Radiation CS Galvanic Cell DU/CS	Which Fuel is best? CS Proof of the pudding DU Floating Oranges CS Food Labels CS Cooking food CS Constructing a Galvanic Cell DU	Constructing a Galvanic Cell DU Floating Oranges	Cooking Food CS Speed CS Galvanic Cell CS	Galvanic Cell CS
Progress Report	UV Radiation CS	UV Radiation CS				
Student experimental workings, journal, plan, predictions, results, experiment report etc.	Collision of an egg CS Floating Oranges CS Constructing a Galvanic Cell DU Galvanic Cell DU/CS	Collision of an egg CS Floating Oranges CS Galvanic Cell DU/CS				Up There How Is It? DU/CS
Traffic Light Cups	UV Radiation CS					
Debate			Biotechnology CS			

Table 2B Assessment modes after activity* (DU refers to draft units and CS to case studies)

Assessment Modes	Planning Investigations	Developing Hypothesis	Debating with Peers	Forming Coherent Arguments	Scientific Reasoning	Scientific Literacy
Worksheet	Acids and bases DU Candle DU/CS Which fuel is best? CS Proof of the pudding DU Woodlice CS Speed CS Martian Bacteria CS/DU Galvanic Cell CS	Acids and bases DU Candle DU/CS Which fuel is best? CS Proof of the pudding DU Woodlice CS Martian Bacteria CS/DU Galvanic Cell CS		Woodlice CS Global warming DU Martian Bacteria CS/DU Biotechnology CS/DU	Woodlice CS Speed CS	Global warming DU Martian Bacteria CS/DU
Summative test	Fish-eating bird CS Galvanic Cell DU	Fish-eating bird CS Galvanic Cell DU				
Portfolio	Acids and bases DU Starch decomposition DU	Acids and bases DU Decomposition of starch in saliva DU			Decomposition of starch in saliva DU	
Poster	Floating Oranges CS	Floating Oranges CS				
Peer assessment				Acids and bases DU	Acids and bases DU	
Student experimental workings, journal, plan, predictions, results, experiment report etc.	Black tide: Oil in the water DU/CS Collision of an egg CS Up There How Is It? DU/CS Galvanic Cell DU	Black tide: Oil in the water DU/CS Collision of an egg CS Up There How Is It? DU/CS		Height and body mass CS Galvanic Cell CS	Height and body mass CS	Galvanic Cell DU
Newspaper story				Black tide oil DU	Black tide: Oil in the water DU	Black tide: Oil in the water DU
Presentation	Candle DU Proof of the pudding DU Goats and Humans DU UV Radiation CS	Candle DU Proof of the pudding DU Goats and Humans DU UV Radiation CS Galvanic Cell CS	Proof of the pudding DU	Proof of the pudding (U2) Goats and Humans DU	Proof of the pudding (U1/2) Goats and Humans DU Galvanic Cell CS	

*Other assessment modes that include assessment of further inquiry skills include: mind maps, video recordings evaluation of images, guiding questions and filming process.

1.3 Modes of assessment

This evaluation will highlight two areas, namely the mode of assessment used, what was the purpose of this assessment and how it was used in the assessment. For an experienced inquiry teacher who is competent in the assessment of inquiry skills, this breakdown may appear to be somewhat pedantic; however, for the purposes of clearly indicating the criteria for assessment, it was felt that this level of detail was required. Table 1 details the DUs and CSs, showing the variety of topics covered. Table 2A and Table 2B summarise the modes of assessment that have been used in these DUs and CSs and indicate the skill that have been assessed though this mode.

In constructing these tables, both the DU and the CS have been used in this analysis as, in some cases, the DU and the CS are the same document. It is clear from the table that several modes of assessment were common and also that several different modes of assessment have been used in assessment of the same skill. Assessment was carried out both during and after the learning activity. In terms of modes of assessment of student learning during an activity, the most common were worksheets, student-teacher dialogue, peer assessment, poster generation, teacher observations and student work. After the learning activity, common modes of assessment were completed worksheets, portfolio, posters, peer assessment, student presentation, and student work.

Within the CSs, different perspectives on assessment of inquiry skills are evidenced. A number of different perspectives are now highlighted:

- Focus on whether a skill could be recognised or not either during the inquiry or within an artefact or from questioning the students
- Focus on grade as a combination of different modes (e.g. in the *Acids and Bases CS*
  Final score = [evaluation Phase 4] x 0.35 + [final evaluation test x 0.45] + [final evaluation of dossiers x 0.2]
- General criteria stated in the form of rubrics – highlighting what is required in student work (rubrics are further discussed below);
- Criteria are linked to what is to be assessed. Examples include where criteria are stated in assessment of:
  - Content knowledge
  - Skills
  - Student activity, etc.

The use of rubrics is common among the CSs; however, the terminology and the distinction between 'levels' vary between the CSs: for example:

(a) a numerical rubric: *Up there how is it? DU*

Skill	Performance level/Category			
	1	**2**	**3**	**4**
Planning Investigations	Ineffective research plan. Needs major help or it doesn't present any research plan.	Effective research plan but need reformulation. It doesn't consider variables or important limitations.	Effective research plan but lacks some material or procedures.	Research plan designed is clear, concise and complete.

(b) A three level rubric, based on levels: *Genetic Engineering DU*

Skill	Performance level/Category		
	Level 1	**Level 2**	**Level 3**
Formulating arguments	Attempts to provide scientifically reasonable justifications for arguments.	Provides scientifically reasonable justifications for arguments.	Provides scientifically valid justifications for arguments

(c) A three level rubric, based on performance: *Biotechnology CS1*

Skill	Performance level/Category		
	Needs work	**Competent**	**Excellent**
Forming coherent arguments	The student does not provide and / or does not explain the arguments in his/her own words (construction); key arguments aren't properly developed.	The student presents and explains his/her arguments, explaining the key arguments but not completely.	The student presents and explains his/her arguments in his/her own words (construction), properly developing the key arguments.

(d) A four level rubric, based on performance: *Electricity CS1*

Skill	Performance level/Category			
	Unacceptable	**needs improvement**	**good**	**excellent**
Planning investigation of conducting properties of different materials (part III.1)	Student is able to... ... list a limited number of objects made of 1-2 different kinds of materials but cannot write the plan at all or the plan is not complete	Student is able to... ... list a limited number of objects made of 1-4 different kinds of materials and the plan is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and the plan is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and the plan is complete

(e) A four level rubric: *Candle CS1*

Skill	Performance level/Category			
	Emerging	**Developing**	**Consolidating**	**Extending**
Planning an Investigation	Research plan is feasible.	Choose material according to plan.	Relationship between plan and variables	Alternative plan should possible problems arise during the research process.
Formulating Hypothesis	Hypothesis formulated	Investigable hypothesis formulated	Investigable hypothesis in appropriate form (not prediction and explanation)	Two hypothesis formulated (null and alternatives)

Also, the detail described within the rubric can be more specific to the activity:

(f) A four level rubric, specific to the activity: *Cooked Food CS1:*

Skill	Performance level/Category			
	Emerging	**Developing**	**Consolidating**	**Extending**
Using apparatus safely and carefully	Sets up heating apparatus and, with help, cooks spaghetti and removes it from the beaker.	Sets up heating apparatus and manages to lower spaghetti slowly carefully into boiling water without breaking it or allowing it to catch fire.	Successfully sets up heating apparatus and manages to get spaghetti into boiling water and out without breaking spaghetti.	Measures length of spaghetti by suitable method. Successfully heats water and cooks spaghetti. Removes cooked spaghetti from boiling water and re measures spaghetti

In the *Acids and Bases CS1*, the rubric was used by the students themselves in a peer-assessment mode rather than by the teachers and this was mode was also suggested by the pilot teachers in the *UV Radiation CS1* and the *UV Radiation CS2.* The use of Frequency tables or Observation sheets have been highlighted *(Galvanic Cell CS2)* where they have been used in assessment of student – student dialogue or student activity. In some CSs, assessment modes where teacher – student dialogue or student – student dialogue is assessed, rubrics have not been suggested as the assessment seems to rely on teacher experience and understanding of the class group.

Some teachers found the use of rubrics by teachers in the classroom difficult

e.g. comment in *UV Radiation CS2* "*Even though the teacher had a clear intention of using the developed rubrics for assessing the students' work she found it difficult to keep track on both students' work and rubrics at the same time. Her usage of the rubrics as assessment tools was therefore limited to inspiration from the rubrics in her talks with the students during their work. She found it very useful as inspiration and after the test of the UV item the teacher came up with the idea that for the next inquiry lessons she would present the rubrics to the students as self-assessment tools.*"

In all CSs, it must be made clear that the assessment criteria is dependent both on the context that the inquiry is set in and on the students in the classroom and different criteria can be used depending on level of students, age, experience etc. This will enable the teachers to use the criteria to help the make judgements about their students and provide feedback for them to improve.

Section 2: Assessment of skills

As shown in Tables 1, 2A and 2B, different modes of assessment have been used for the assessment of inquiry skills. In this section, the modes of assessment used for assessment of the particular inquiry skill of 'planning an investigation' are compared through several case studies.
"Planning an investigation" was assessed most frequently of all the inquiry skills, and so the following analysis is concerned with this skill only. The skill "planning an investigation" was assessed in various ways – through teacher observation, examination of written plans and with the use of different rubric systems can be found. In addition, different components of this skill were assessed within the draft units and case studies.

Examples:

1. Assessment by observation and questioning: "*The skill [i.e. planning investigations] were assessed by observation and questioning while students reported their accomplishments*" in the S*peed CS3*. A rubric was not used in this case.

2. Assessment by observation: "*I tried to go round the groups and check on their plans as they were doing the inquiry. Some of this I was also able to check on their posters later.*" in the *Floating orange CS1*.

3. Assessment by using a rubric containing seven objectives, and three performance levels in the *Speed CS2*.

Skills	Involved Operations	Descriptors (Performance Levels 1,2,3 and 4)	
Plan an investigation	1. Defines goals	A. Defines coherent goals according to the problem	1-Does not define goals 2- Defines coherent goals according to the problem 3-Defines coherent goals according to the problem but does not include them all 4-Defines coherent goals according to the problem
	2. Operationally defines variables	B. Operationally defines the variables of the proposed study	1-Does not define the variables to be studied 2-The variables are inaccurately defined 3-Operationally defines some of the variables to be studied Operationally defines the variables to be studied
	3. Defines strategies and procedures to achieve those goals	C. Defines strategies and procedures that enable him/her to achieve the goals	1-Does not define strategies or procedures 2-Defines strategies and procedures that do not enable him/her to achieve the goals 3-Defines strategies and procedures that enable him/her to achieve some of the goals 4- Define strategies and procedures that enable him/her to achieve the goals
	4. Conceives an experimental plan that allows variable control	D. Experimental design includes control variables	1-The experimental design does not include control variables 2-The experimental design includes inaccurate control variables 3- The experimental design includes some control variables 4- The experimental design includes appropriate control variables
	5. Knows and chooses adequate resources (e.g. instruments, materials, conditions, observations, etc.)	E. Chooses appropriate resources according to the goals and strategies	1-Does not chose resources 2-Does not choose adequate resources according to the goals and strategies 3- Does not choose all the resources according to the goals and strategies 4- Chooses all the resources according to the goals and strategies

4. Assessment by using a rubric containing seven levels of execution: *Electricity CS3*

Skill	1	2	3	4	5	6
Planning investigation of conducting properties of different materials (part III.1)	Student can't list things made of different materials for measurement and can't write down a plan for the experiment.	Student can list 2-3 things made of different materials for measurement but can't write down a plan for the experiment.	Student can list 4-5 things made of different materials for measurement and writes down an incorrect plan for the experiment.	Student can list 4-5 things made of different materials for measurement and writes down an almost correct plan for the experiment.	Student can list 6-7 things made of different materials for measurement and writes down almost a correct plan for the experiment.	Student can list more than 7 things made of different materials for measurement and writes down a correct plan for the experiment

5. Assessment by using a rubric containing four levels: *Electricity CS3*. It is important here that the rubric refers to two skills: planning an investigation and ability to cooperate.

Skill	**emerging**	**developing**	**consolidating**	**extending**
Selection of an adequate set of elements (II.1) and discussion with a peer (II.2)	Student attempts to choose the set of elements, but his/her list is not complete or inadequate and s/he is not able to complete the task even after discussion with a peer.	Student attempts to choose the set of elements, but his/her list is not complete or inadequate; s/he is able to complete the task only after the discussion with a peer.	Student is able to complete the set of adequate elements, but during the discussion with a peer is not able to argue for his/her choice.	Student is able to complete the set of adequate elements, discuss his/her choice with a peer and is able to argue for his/her choice.

6. Assessment by using a rubric containing three levels: *Natural selection CS2*.

2 points level	4 points level	6 points level
Student can present the consecutive steps of the natural selection simulation, but without details	Student can create an action plan of the natural selection simulation with legorgs, with a little advice from the teacher	Student can him/herself elaborate an instruction for the experiment based on the English language instruction films, with a proper level of detail in the descriptionof the next phases.

7. Assessing by evaluation of written notes, using a rubric with four levels. "*The commented reports were given back to the students*": *Electricity CS1*.

Skill	**unacceptable**	**needs improvement**	**good**	**excellent**
Planning investigation of conducting properties of different materials (part III.1)	Student is able to... ... list a limited number of objects made of 1-2 different kinds of materials but cannot write the plan at all or its plan of investigation is not complete	Student is able to... ... list a limited number of objects made of 1-4 different kinds of materials and its plan of investigation is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and its plan of investigation is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and its plan of investigation is complete

8. Assessing by using notes and filming: “*I took notes during the process and we filmed the work of the groups. At the planning phase, I assisted the groups by asking guiding questions.*” *(Collision of an Egg CS1*).

9. Assessment by in-class-worksheets: The most important sub-skills have been the identification of variables. (*Galvanic cells CS1*)

In-class worksheet – “List your variables changed and variables measured”

Level	Explanation	Comment
0	Nothing	No answer
1	Mention concentration / temperature / plates etc. used	Very basic answer
2	Explicitly state all variables	Fair answer
3	Explicitly state all variables changed and measured	Good answer

Two things are worth noting here:

First, in all of the Case Studies, a range of assessment methods is used. Second, the criteria and rubric systems used are very different in detail. A question we need to consider for the next phase of the project is whether to standardize these at least at the level of the units. Having a standardized system might help teachers understand how the assessments can be applied across a range of units and eventually help teachers develop their own assessment rubrics for inquiry. Allowing diversity in the rubric system enables more flexibility in the ways in which the assessment is approached.

Section 3. How teachers in different countries approached the same Unit

In this section, we report on three different inquiry units and how these are adapted and diversified as they are taken from the country they were developed in to a new context. These are reported in CSs that provide information on how the learning sequence was adapted, which skills were assessed, the criteria for assessment and finally what the teachers thought of the activity and the assessment process.

3.1 Speed inquiry

This draft unit for the speed inquiry was initially produced by the KCL and US groups and then trialled at DCU (CS1), IEUL (CS2), LUH (CS3) and IEUL (CS4). The initial unit had a number of small inquiry activities to encourage students to think about the relationship between distance, time and speed. The first few activities are shown below.

A. How fast can you go? (work individually)
   i. Write a plan indicating how you would measure how far you can walk in 5 seconds.
   ii. Write a plan indicating how you would measure how long it would take you to walk 5 metres.
   iii. When everybody has finished planning, carry out the two tasks. Record measurements for both tasks below, and write how you think the two activities are related. How are distance and time related? Remember to write any questions that arise during the activity.

CS4 shows that the teacher decided to just take one activity from the *Speed DU* – How far can you walk in 5 seconds and how long does it take to walk 5 metres? For both of these questions, the students planned an experiment and they worked in groups. The following skills were assessed:

- planning an investigation
- identifying variables
- collecting and interpreting data
- teamwork

To help them do this, a worksheet was produced to collect the evidence (see below). The teacher gave some extra hints as to what she wanted students to think about in their investigation. Here we show Activity A-i).

Name of the group:
SPEED UNIT
To find the answer to the question below, how do you design your research? Please read all stages of the activity and work with your peers.
Research Question 1: “How far you can walk in 5 seconds and how do you measure it?
Planning an Investigation: You have to explain in your investigation plan what you want to do. You can show your plan in writing or as a drawing. Your plan ought to be feasible.
Equipment:
Implementation/Experimental Process: Conduct your plan and write down your results.

Can your data answer your research question? How do you summarize your data or organize it to present it to your peers?

It can be seen that the teacher organised the inquiry activity in a guided discovery way, checking on each step with the students. This is a valid approach often preferred by teachers who have not had a great deal of experience with an inquiry-learning approach as it gives both teachers and learners confidence that their ideas are moving forward. At the end of the inquiry, the groups presented their findings to the whole class. In class, the teacher interacts with the students. For example, the following conversation shows how the teacher assessed choosing appropriate equipment to conduct their plan.

Student:	*My teacher, we will measure distance with a metre stick.* *Because 5 seconds is a very short time period to measure. Do we use a metre stick?*
Teacher:	Alright. How do we determine how much times passes?
Student:	*Using the metre stick.*
Teacher:	You measure distance with a metre stick. Ok, do you measure time when you use a metre stick? I am walking now and how do I know how much time is passing?
Student:	*Ok. I use a stopwatch to measure time.*

The teacher used the evidence from the completed worksheets and used the rubric below to make judgements. She then used this data to give feedback to the students.

Skill	Emerging	Developing	Consolidating	Extending
Planning an Investigation	Research plan is feasible.	Choose material according to plan.	Relationship between plan and variables	Alternative plan for possible problem if it arises during the research process.
Identifying Variables	Variables are mentioned	Relevant variables are mentioned (speed, time, distance)	Relationship between relevant variables & measurements is given	Also mentions control variables
Collect data and interpret	Collect some findings (not data) at the end of the implementation process	Collect data	Relationship between data and research question	Use data and interpret to answer research question
Teamwork	Working individually in groups	Work together to plan the investigation	Work together both planning and conducting the investigation	Work together to plan, conduct, and evaluate the investigation

In the *CS1* implementation, evidence was collected from notes and diagrams that the students produced after each small inquiry activity. Students worked individually planning their small inquiry activities and carrying them out. The two skills assessed in the *CS1* were:

• the identification of variables
• generating questions

To facilitate the latter, activities i) and ii) included the extra instruction "Include as much detail as you can, indicating any questions that arise during the planning." This is an example of a local adaptation of a draft unit to suit individual tastes and purposes. The two examples below show how a teacher looked for relevance in the questions and made reference to accuracy or variables.

A student's written report on activity Ai) is given below.

To calculate the speed you could measure out 2 points (using measuring sticks) (an initial point and a final point) and see how long it takes you. Then you use the formula to determine the speed by dividing the T into Distance.

To answer the question you could then multiply the S by the T to get the distance travelled.

apparatus → measuring sticks, stopwatch and markers

Questions:

- *What environmental factors do you think would affect the speed of the person?*
- *If the persons speed was 12 km/h for 6 s how far has he travelled?*

No rubric was applied in the CS1 implementation. The teacher noted in the above case that there are a few questions relating to the experiment, there is an equipment list, recognition that speed can be affected by external factors; and, with revision, it is a feasible approach. However, not many relevant questions are raised, and there is no mention of how the equipment is to be used.

An excerpt from a different worksheet is given below. This student clearly explains the experimental procedures and thinks of and answers some relevant questions. This would be considered an excellent piece of work.

1. Place on the ground a marker where you will start. Try to have it on a flat, even surface

Q. Do you think you would walk further if you started downhill.

2. When the person moves off the starting line start the stopwatch. Walk as fast as you can for 5 seconds.

Q. Would you walk further if you walk before the starting point, or just starting from the line and then walked?

3. After 5 seconds, shout stop and the person walk stops and stay in that position. Mark on the floor, where the person has stopped.

4. Using a measuring tape measure the distance from where the person started to where they finished. Record the distance travelled.

Q – How can you ensure that the person is always walking and not jogging a little? Make sure that there is always one foot on the ground.

3.2 Woodlice Inquiry

A DU linking environment, ecology and animal behaviour was developed on the topic of woodlice by MaH and this DU was trial in DCU (*CS1)*, JU (*CS2*) and MaH (*CS3*). The DU was also used in a teacher workshop in MaH and three of the teachers from the workshop trialled the inquiry with their classes, giving rise to a further case study, *CS3*. The main skills addressed in the DU, as suggested by the developers, were formulating a hypothesis, designing and conducting an experiment, collecting and interpreting data, drawing appropriate conclusions, reporting and discussing results, and evaluating investigations.

The three CSs describe how the initial learning sequence was adapted for each group. Within *CS3*, the teachers decided that the best skills to assess were planning investigations and formulating a hypothesis as part of the planning for the inquiry with students in lower second level. The students were confident in forming a plan and deciding on different living conditions to investigate: light intensity, humidity, favourite food and popular environment (stones/leaves/earth). They could formulate questions, but they had difficulties in deciding how many woodlice they should use in every experiment. Feedback during the process of inquiry provided useful formative feedback and enabled students to improve their methodology. The teachers found it difficult to do this with all the groups and so the teachers assessed the written plans and reports for judging the students' performance. These teachers also emphasized the importance of letting the students make a second attempt in carrying out the investigation.

In *CS1*, the activity was carried out with 15-16 year old students over two 40 min followed by two 80 min lessons. Over these four lessons, students:

- Identified variables and began planning
- Formulated hypotheses and finalized their plans on a structured worksheet
- Carried out the inquiry and collected data
- Retested, redesigned and produced new hypotheses

After an open discussion on the conditions that woodlice would prefer, the students were then given three possible variables to investigate, of which they chose one, from intensity of light, amount of moisture and food preferences. Students then had to formulate their hypotheses on a worksheet (extracts shown in boxes below). The worksheet supported the students in forming a hypothesis by a series of questions:

> **Formulating your hypothesis:**
>
> Now you have decided which variable you would like to investigate, use the space below to explain the *question(s) you are trying to answer* (or *the problem(s) you are trying to solve*).
>
> **<u>Questions to be answered:</u>**
>
> **<u>Predictions</u>:** Use any **scientific knowledge** you already have, answer the following questions. Try and be as <u>clear</u> as you can in your answers.

They were then guided to consider which variables they needed to control in the inquiry:

> **You have chosen one variable from the 3 suggested earlier. What other variables do you think might be important for woodlice?**
>
> **What will you do about these other variables in your investigation? Explain your answer in some detail**.

Similarly they were guided by the worksheet to form a conclusion and critique their experiment, including question relating to repeating the investigation:

> **Observations and Results:** Take care in this section to present your findings in the *clearest* and most *presentable* way that you can.
>
> **Conclusions:**
>
> Did you identify any *patterns?* What *conclusions* can you draw from your results?
>
> Do your results agree with your predictions? Discuss any unexpected results or observations below.
>
> How do your results compare with other groups?

If you were to do the experiment(s) again, what would you do differently? Were there any questions thrown up by your results? If you were to carry on with your investigation, what further experiments might you do?

In *CS2*, the inquiry was trialled by four different classes in three 45 minute lessons with 13 year old students. At the beginning, the students were informed on the aim of the DU (learning to work according to scientific method, with such elements as: planning experiment, formulating hypotheses, defining variables, data collection, formulating conclusions, identification of error sources). The students planned, carried out and analysed the results of the experiments in groups. The teacher did not suggest the variables to be considered in the investigation, giving the students the possibility to devise their own experiments. Besides the basic parameters of woodlice biology (food preferences, humidity, light intensity), students showed their interest also in: avoidance of danger, way and speed of movement and other abilities (as swimming, ability to move on various surfaces of different inclination) of the animal. Some inquiries were carried out using other invertebrates such as mealworms and crickets.

There are interesting comparisons between the rubrics adopted in the DU and in the CS. The assessment suggested in the DU is as follows for asking questions, formulating hypotheses and planning an investigation.

Asking questions This aspect is about asking questions that can be investigated systematically. Questions to guide the students: • Which questions would you like to pose about this? • What would you like to know about this? • How could you pose this question, so that you may find an answer to the question?	The student can… pose a number of questions, but does not make a distinction between questions possible to investigate and questions not possible to investigate.	The student can… with the support of others revise questions, so that they become possible to investigate.	The student can… revise own or others' questions, so that they become possible to investigate systematically
Formulating hypotheses This aspect is about collecting information and ideas about a question, so that a hypothesis can be formulated. Questions to guide the students: • What do you think will happen? • Why do you think this will happen? • Can you explain by using your scientific knowledge?	The student can… formulate a prediction about what will happen, but not explain why.	The student can… formulate a prediction about what will happen and explain why. The explanation builds on own (or others') experiences.	The student can… formulate a hypothesis, that is make a prediction that is scientifically well-founded.
Planning an investigation This aspect is about planning an investigation in order to test a hypothesis. Planning involves both identifying appropriate equipment and a functional design. Questions to guide the students: • How could you investigate this? • What kind of equipment would you need? • What would you look for? • What can you do in order to get as trustworthy results as possible?	The student can… suggest how an investigation might be designed, but not in detail.	The student can… suggest how an investigation might be designed, but where the design in incomplete in some respect (for instance by lacking some of the bullet points to the right). The design can, with some revisions, be used for systematic investigations.	The student can… plan an investigation, where the design includes: • Which variables to change and which to be held constant, • In which order to perform different parts of the investigation, • Which equipment to be used.

These rubrics were used by two of the teachers in *CS3* while the third teacher adapted it to fit with the performance of her students. *CS1* adapted this rubric to a four level rubric focused on the content of the investigation while *CS2* has used a three level numerical (marks 0-6) rubric that focusses on the general criteria (see below).

Assessment from *CS1*:

Skill	**Emerging**	**Developing**	**Consolidating**	**Extending**
Generating Questions	A question was formulated e.g. "Do woodlice swim?"	A clear investigable question was formulated, such as distinguishing between moisture, humidity, liquid water	A clear investigable question was formulated mentioning specific levels of food/light/ moisture	A clear investigable question was formulated mentioning specific levels of food/light/ moisture and how it affects the woodlice
Formulating hypotheses	A prediction is made	A testable prediction is made linked to the question	A testable prediction to the question is made that suggests a clear outcome	A testable prediction to the question is made that suggests a clear outcome based on scientific reasoning
Formulating hypotheses	Hypothesis not justified	Hypothesis based on personal experience or inference	Hypothesis based on scientific knowledge or scientific observation	Hypothesis based on scientific knowledge or scientific observation with clear explanation

Assessment from *CS2*:

Skill	2 points level	4 points level	6 points level
Asking questions	Student can put a series of questions, but he/she does not discern between those possible and impossible to be answered by means of an investigation	Student can, with a help of others, re-formulate questions, so as they are possible to be answered by means of an investigation	Student can, without external help, re-formulate questions (own or others'), so as they are possible to be answered by means of an investigation
Formulating hypotheses	Student can formulate hypotheses that are impossible to be proved by means of a school experiment	Student can formulate hypotheses that after teacher's or colleagues' revision may be proved by means of a school experiment	Student can him/herself formulate hypotheses that may be proved by means of a school experiment
Design of a scientific experiment	Student can design an experiment, but without precise description of its course and not considering its repeatability	Student can design a precise experiment (or a series of them) with a help of the teacher's advice or directing questions	Student can him/herself design a precise experiment (or a series of them) choosing the conditions and identifying variables correctly and considering its repeatability

Student work has been evaluated in *CS2* showing the strengths and weaknesses in the student answers. Selecting out two examples of student work (Student A and Student H) shows clear differences in the level of understanding shown by the students but this also highlights the difficulties in assessing a piece of written work in isolation as the student's thinking may not be evident.

Student A (student answer in italics)	**Student H** (student answer in italics)
Which variable have you decided to investigate?	
Amount of moisture	*Amount of moisture*
Formulating your hypothesis	
How much moisture do wood lice like? *Do wood lice swim?*	*In what level of moisture do they prefer to live in?* *Do wood louse prefer dry wood or wet wood?*
What do you think will happen?	
I think the wood lice will go to the slightly damp piece of wood	*That the wood louse will go to the damp wood as they like water but if there is too much they could drown.*
Why do you think this will happen?	
Because you usually find woodlice in damp rotting wood	*They like water as they are crustations but too much water could drown them so they will choose the damp wood.*

The teacher noted for student A:

The question that was formulated raises some doubts as to whether this student distinguishes between humidity, moisture, and amounts of liquid water. A discussion could draw out to what extent the question whether woodlice can swim is relevant to the investigation.

The connection between the student's question and their prediction is not very clear (moving from "moisture" to "damp piece of wood".)

The student's justification is only linked to prior experience and appears to bring in another variable. Discussion could elicit to what extent the student associates rotting with dampness.

The teacher noted for student H:

These answers could be considered as more advanced than Student A's. The student mentions moisture in the environment, and appears to distinguish it from humidity and amounts of liquid water; nevertheless, this could be probed. This student has also discovered in their research that woodlice are crustaceans. However, the argument could be clarified further, e.g. explain why they think the woodlice would drown if they are crustaceans? (Woodlice are one of the few crustaceans that are non-aquatic.)

Within *CS2*, the skill of carrying out the experiment was also considered in two parts and assessed using on teacher's observation

1) **<u>Equipment and materials preparation (rubric)</u>**

2 points level	4 points level	6 points level
Student can collect all materials necessary to conduct a basic experiment, without change of factors/variables	Student can collect all materials necessary to conduct a series of experiments, but with a help of the teacher	Student can him/herself collect all materials necessary to conduct a series of experiments, grouping them respectively to enable measurements under changing controlled parameters

2) **<u>Investigation execution:</u>**

a) data collection

- compliance with the safety rules and correct organization of the working environment (1point)
- experiment's repeatability (1 point)

b) documentation

- project of a data collection mode (e.g. table)

(max. 2 points: 1 pt – correct construction of the table with description, 1 pt – correct filling in the table)

Finally the skill of evaluation was assessed in *CS2* by analysis of the collected data and presentation of results, using the following rubric:

2 points level	4 points level	6 points level
Student can interpret data correctly (categorizing the measured variables as lesser – greater) but cannot create a proper graph based on them	Student can present the data on a graph, but the graph lacks or has poorly developed elements as axes titles, scale, legend etc.	Student can present the data on appropriate graph(s) having all necessary elements as axes titles, scale, legend etc. prepared correctly
Student can point out basic / selected sources of biased / incorrect results of the experiment	Student can enumerate all main factors that might be sources of biased/incorrect results of the experiment	Student can analyse all main factors that might be sources of biased/incorrect results of the experiment and indicate ways to avoid them in the future

Student can propose elements of a method serving to improve the experiment	Student can propose improvement of the course of the entire experiment step by step	Student can compare results of other groups, discuss data interpretation and propose methods to improve both own and the other groups' experiments

A cumulative points score for each student for the investigation was then compiled.

In this way the marks could be amalgamated to give feedback on competence in each skill that was being assessed and in the full inquiry activity. The students were also surveyed for their reaction to inquiry-learning which was in general a positive experience.

3.3 Electricity Inquiry

The electricity DU was prepared by JU and was intended as an introduction to conductivity and simple electric circuits, to take ~ one hour of classroom time at lower secondary level. This DU has been trialled by teachers in four countries: UPJS (*CS1*), HUT (*CS2*), JU1 (*CS3*), JU2 (*CS4*) and DCU (*CS5*). Firstly, students were asked to carry out a brainstorming on electricity (draw a concept map), draw a simple electric circuit in order to light up the bulb and plan and conduct an experiment to test the conductivity of different materials, summarize their results and search for information about the conductivity of air and the human body.

This particular DU indicates the assessment opportunity during the inquiry activity and suggests assessment tools (rubrics and frequency charts) to be used. A wide range of skills are discussed in this DU and CSs including use of scientific language, use of different representations (drawings, tables, text descriptions), drawing simple schematic diagrams, formulation hypothesis, planning investigations, conducting investigations, drawing conclusions from investigation and forming coherent arguments.

Assessment modes suggested include both evaluation of written work from students (including mind maps, circuit diagrams, investigation plans) and teacher observation (during initial brainstorming activity and while students are carrying out the investigation). In general teachers reported in the case studies that they followed the learning sequence suggested but only some used the assessment instruments proposed.

CS1 is a combined report from six teachers who focussed on two main skills to be assessed in trialling: Planning investigations and Searching for information. These teachers followed the suggested learning sequence over 1-3 hours of class time and they used the rubrics provided for assessment. These teachers appreciated the activity a lot but need to train students for it, since they are not used to such kind of activity. One of the teachers reported that "I was inspired by this unit and assessment tools designed for this activity. It was quite new for pupils who are not used for this kind of activities and assessment. I think they need more training in this field".

CS2 describes how the skills of asking inquiry questions formulating hypotheses and forming coherent arguments were assessed using this DU during a trial with 6th grade students. This teacher assessed student knowledge by using question-answer sessions as a rapid way of collecting information from students. This teacher did not use the proposed rubrics because of "lack of time and number of students". An observer was also present for this session and noted that

"*The lesson was flowing rapidly and time was always a concern. Teacher wanted to get through the unit sections, so she did not have time to think about a rubric, classify students' certain skills based on the rubric and provide feedback to each student based on their need. There was no time for this process. Also the rubrics needed to be studied carefully by the teacher before the class, so she could use it more comfortably, but this seemed too difficult and time consuming on the part of the teacher, especially if every unit had a different rubric*".

CS3 reports on a trial of this DU with a group of twenty 14 year old students, carried out over two lessons with the last suggested activity required them to search for information given as homework. In this case students were divided into 5 groups with 4 students in each group. The particular skills focused on were debating with peers, scientific literacy, reasoning, planning investigations and teamwork. *CS4* reported on a teacher trialling this DU with 34 students, aged 16-17 years, in upper secondary school. This teacher adjusted the proposed sequence as she only had a 45 minute lesson and used whole group rather than peer discussion as she believed the students lacked the level of content knowledge. The skills focussed on during this activity were scientific literacy, planning investigations, and use of different representations. *CS5* describes the implementation of this DU with two different class groups in lower secondary level. One group had just covered static electricity but had no prior knowledge of electric conduction or electric circuits. The second group had most of the relevant content already covered. The unit was altered slightly for both groups. In addition to the inquiry skills suggested in the DU, two other skills that were identified and assessed constructing models and debating with peers.

The first section of this DU was focussed on assessing student's prior knowledge of the concept of electricity and this understanding of it from everyday life and other sources. The proposed activity was to have the individual student draw a mindmap and then brainstorm in small groups the meaning of each word in the mindmap.

Assessing peer discussion:

Three different types of assessment goals are identified within the brainstorming activity:

- checking students' prior knowledge and understanding
- assessment of students' engagement during the brainstorming activity
- assessment of creativity during the brainstorming activity

The DU suggested the use of a frequency chart for teachers to record this information as they observed individual groups.

student	**BS1*: before part I.**			**BS2: part I.3**			**BS3: part III.5**	
	prior knowledge	engagement	creativity	engagement	prior knowledge	creativity	engagement	prior knowledge
name								

*BS# denotes No. of brainstorming; part number refers to the numbers used in the unit didactic materials

CS4 reports on the use of this table to document teacher observations on a specific group of four students both during the group brainstorm and while they were individually completing the next section. The performance of the selected students was analyzed and evaluated in terms of a four-point scale (1 to 4) on each of these categories as well an additional category of culture of discussion. However most CS does not use this assessment item, e.g. *CS1* notes that the teachers in this case study omitted assessing the brainstorming.

Assessing scientific literacy:

A four level rubric was proposed for use by the teacher in assessing individual students mind maps (Wright, 2006[2]).

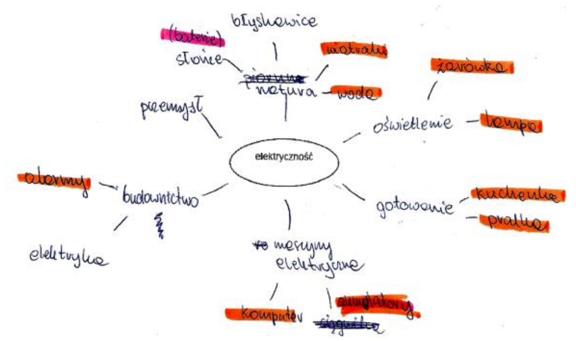
unacceptable	needs improvement	good	excellent
Student's mind map is empty or full of inadequate words, for which the student cannot describe a relation to electricity	Student is able to... ... draw a mind map containing only a few words and/or the words are listed with no relation to each other	Student is able to... ...draw a mind map with more than 10 words, both scientific and belonging to a common language, but the visualization of the relationships and categories is poor	Student is able to... ...draw a mind map with more than 10 words, both scientific and belonging to a common language, with a good visualization of the relationships and categories

CS3 discusses extension of this rubric to a 6-level rubric to assess scientific literacy in mindmaps.

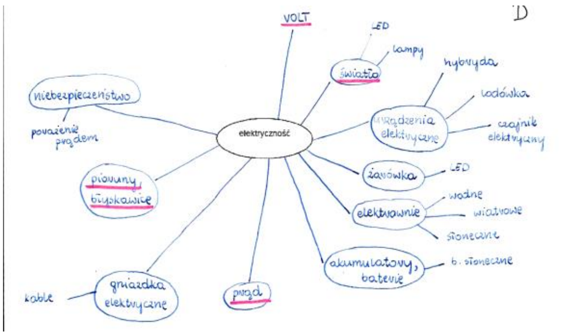
Level of implementation					
1	2	3	4	5	6
Student doesn't draw mind map or draws it putting words not connected to topic (can't explain the connection to the topic).	Student can draw a mind map containing 5 words connected to the topic, but there is a lack of connections and relations between them.	Student can draw 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 can draw 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 can draw 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 very much expanded.	Student can draw 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.

The use of this rubric for two individual students work is shown in the following two figures.

[2] Wright J. (2006). Teaching and assessing mind maps, *Per Linguam*, 22(1), 23-38. Retrieved from: http://perlinguam.journals.ac.za/pub/article/view/59/pdf



Student A – mark: 3 – mind map with more than 10 words. Mind map only included a few scientific terms.



Student D – mark: 6 - drew the mind map using more than 10 words with a lot of key words. Student used a lot of scientific terminology and showed the relations between them.

Assessing scientific reasoning:

The DU proposes a 4-level rubric for assessing drawing of electric circuits and this was adopted in and reported in *CS5* with supporting evidence of student work and judgment made. *CS3* reports on adapting this rubric to a 6-level rubric to assess student selection of items and drawing of electric circuits.

Level of implementation					
1	2	3	4	5	6
Student can choose proper components of circuit to light a bulb (II.1) but can't draw the scheme or draws it incorrectly (II.3). S/he can't draw proper circuit (III.2) and schemes of circuits (II.5)	Student can choose proper components of circuit to light a bulb (II.1) and can draw this circuit (II.3). S/he can't draw circuit or do it incorrectly (III.2). S/he can't draw schemes of circuits (II.5)	Student can choose proper components of circuit to light a bulb (II.1) and can draw this circuit (II.3). Student can draw circuit (III.2) but can't draw properly the circuits (III.5).	Student can choose proper component of circuits to light a bulb (II.1) and draws one of the circuits (II.3) or (III.2), but can't draw properly the circuits (III.5).	Student can choose proper component of circuit to light a bulb (II.1) and draw circuits (II.3) and (III.2). Student makes mistakes in drawing one of circuits (III.5).	Student can choose proper component of circuit to light a bulb (II.1) and draws circuits (II.3) and (III.2). Student can draw circuits (III.5).

In addition, the DU proposes using a Lawson multiple choice test (Lawson, 1978[3]) for the post activity assessment of formal reasoning.

Assessing planning an investigation:

The DU proposed a 4 level rubric for assessing the student's ability to plan an investigation.

unacceptable	**needs improvement**	**good**	**excellent**
Student is able to... ... list a limited number of objects made of 1-2 different kinds of materials but cannot write the plan at all or its plan of investigation is not complete	Student is able to... ... list a limited number of objects made of 1-4 different kinds of materials and its plan of investigation is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and its plan of investigation is almost correct	Student is able to... ... list a limited number of objects made of over 4 different kinds of materials and its plan of investigation is complete

[3] Lawson (1978). Development and validation of the classroom test of formal reasoning, *Journal of Research in Classroom teaching*, 15(1), 11-24. Revised version (2000) retrieved from: http://www.public.asu.edu/~anton1/AssessArticles/Assessments/Mathematics%20Assessments/Scientific%20Reasoning%20Test.pdf

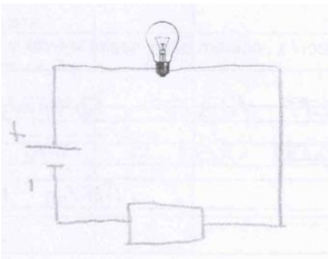
Some case studies reported adapting this rubric, e.g. *CS4* rewrote the criteria for the four levels while *CS3* reports on developing a 6-level rubric to assess groups in this skill.

Level of execution					
1	2	3	4	5	6
Student can't list things made of different materials for measurement and can't write down a plan of experiment.	Student can list 2-3 things made of different materials for measurement but can't write down a plan of experiment.	Student can list 4-5 things made of different materials for measurement and writes down an incorrect plan of experiment.	Student can list 4-5 things made of different materials for measurement and writes down an almost correct plan of experiment.	Student can list 6-7 things made of different materials for measurement and writes down almost a correct plan of experiment.	Student can list more than 7 things made of different materials for measurement and writes down a correct plan of experiment

The teacher graded the groups using this rubric and described the judgements made:

Group L – marks: 6 - student listed a few materials for conductance measurements and necessary elements of electrical circuit. They wrote down how to connect the circuit, how to perform the experiment and what they expect.
Group M – marks: 3 - students listed a few materials for conductance measurements; in plan of experiments they wrote how to connect necessary items of a circuit.

CS1 presents an example of student work in planning an investigation activity and the judgment made by the teacher.

	**Students´ answer:** There were two wires coming from battery, one connected with a bulb and the other to the investigated material. The other ends of the bulb and the battery were connected. **Task:** Draw the simplest working electric circuit enabling investigation of conducting properties of an object. **Students´ answer:** Example of students drawing the simplest closed electric circuit in order to check the conductivity. *Assessment: excellent* The picture involves all the necessary components displayed in a schematic diagram.

Assessing forming coherent arguments:

CS2 describes the criteria used to assess this skill during class discussions (mainly because of time constraints). The following criteria were shown:

Skill: Students can form coherent arguments related to inquiry question based on their observations.
Possible outcomes:
A) Students offer arguments supported by observations and data.
B) Students offer arguments partially supported by observations and data.
C) Students offer arguments that are not supported by observations and data.

Assessing teamwork:

CS3 reported on using a student self-assessment and a peer assessment sheet for assessing teamwork but did not present any student evidence for this skill.

Grade (from 0 to 6) your work during the conductance measurements experiment.

1. I was involved in planning the experiment. __________
2. I carried out the tasks. __________
3. I helped colleagues in my group. __________
4. I was involved in filling in the data collection table. __________
5. I was active during the experiment. __________
6. I communicated properly with others. _________

Self-assessment sheet

Grade (from 0 to 6) your colleagues in your group on each question	Student 1	Student 2	Student 3
1. Did your colleague take part in planning the experiment?			
2. Did your colleague take part in carrying out the experiment?			
3. Did your colleague was active during group work?			
4. Did your colleague take part in filling out the documentation of experiment?			
5. Did your colleague communicate properly in the group?			

Peer-assessment sheet

Assessing formulating an hypothesis:

CS2 reported on using the following criteria for judging the students' ability to formulate a hypothesis based on their written responses to a question in the worksheet. The teacher provided oral feedback based on one of these situations:

Skill: Student can formulate hypothesis (predictions) based on a question. Hypothesis may include comparisons (e.g. metal will provide brighter light than graphite)

Possible outcomes:

A) Student can formulate an appropriate hypothesis and state it appropriately (e.g. gold will provide the brightest lamp).

B) Student can formulate a hypothesis but with an inappropriate statement (e.g. lamp will lit with salty water)

C) Students cannot formulate a good hypothesis.

Section 4. Discussion of Trialling

Looking across the various CSs for each DU enabled us to gauge the suitability of each inquiry to a range of contexts. The adaptations that various partners made gave us insights into the range of assessment modes that could be used and their appropriateness for particular national contexts.

It needs to be recognised that the starting point for each of the countries was different. Some countries already have a recognised inquiry approach within their curriculum (e.g. MAH, JU, IEUL), others came with a fixed view of the assessment of inquiry imposed by previous assessment regimes (e.g. KCL), while for several countries the teaching through an inquiry-based approach was relatively recent innovation and so the assessment of inquiry was only just beginning to emerge (e.g. JU). Several partners worked with teachers who had been part of previous EU Inquiry projects such as

Parsel (e.g. IEUL), Primas (e.g. US and HUT) and ESTABLISH (e.g. DCU, MaH, JU and UPJS). Others worked with teachers who had worked on inquiry as part of their own national curriculum (e.g. MaH). These various experiences prior to the project influenced both the specific inquiry activities that the pilot teachers chose to trial and also the approach they took with their assessment.

The trialling of all of the draft units has been carried out in each country and in some cases using the initial group of pilot teachers who were already experienced inquiry teachers. In other countries, the pilot group of teachers has evolved to include the teachers from cohort one of the SAILS teacher education programme in that country. Through on-going communication and workshops with these pilot teachers a total of 34 draft units have been prepared and shared with all partners through the member's area of the SAILS website.

Pilot teachers have reported back at subsequent workshops on the implementation of draft units and what successes and difficulties they encountered in using the assessment item and proposed assessment criteria.

SAILS draft units were trialled by teachers with second-level students (aged 11-19 years), although the majority were focused on lower secondary students (age 11-14 years). In the trial phase, each country discussed the activities and materials used with their teachers to ensure there was no gender bias or likelihood of one gender being dissuaded from engaging with the inquiry. In the UK group, there was one boys only school and one girls only school as well as a number of mixed gender schools. The two teachers from the girls only school considered carefully how their students responded to the inquiry activities and compared this with the response from students in other schools and with their reflection of working with students previously on inquiry in a mixed gender school.

In the main, the pilot teachers focused on skills associated with investigations. These included planning, where, in some cases, the students raised or adapted the question to be investigated in an attempt to make the inquiry more open and motivating. It was thought by some teachers that allowing the students to raise scientific questions to be explored made the inquiry more relevant to the students and encouraged them to engage in working scientifically. Teachers also thought it important to sometimes allow students to pursue research questions that, at the outset, seemed unlikely to lead to data that could be easily interpreted. They found that students learnt to adapt their ideas and questions as they were inquiring, similar to how scientists work, realising errors or misconceptions in their original thinking and seeking different routes through or refining the original questions they set out to explore. In a few cases, teachers were surprised that inquiry questions they had initially considered difficult to explore revealed good sets of data that the students were able to interpret and communicate to others.

With some inquiry activities, generation of questions led to formation of a hypothesis to be tested. Some teachers noted that moving quickly from initial ideas to a decision about a testable hypothesis, sometimes prevents learners really exploring their ideas and that, within each inquiry, there needed to be time for students to tinker with the idea and the apparatus before making decisions about how to proceed. For many of the teachers, this approach was in stark contrast to the ways in which they had previously taught practical work and so this required teachers to think about how to teach differently.

Other aspects of planning investigations tended to be around choosing appropriate apparatus and designing experimental methods. This varied across the countries, partly because of resourcing and partly because in some countries students had previously carried out lots of practical work while, in others, practical work was more limited. Clearly, teachers did health and safety checks on planned inquiry both before the students started the inquiry and through the process of doing the inquiry. In some cases, realisation and articulation of the health and safety issues formed part of the assessment.

A further aspect of inquiry that teachers decided to assess was drawing conclusions. Teachers realised that, in many cases, their previous practice had been for them to lead students through to reaching a conclusion. While the teachers were confident that students could generally make observations and take measurements, tabulate and organise data and possibly present that data in graphs or other appropriate forms, they were less confident about student's ability to reach and articulate a good conclusion. In some cases, teachers required not only a logical, concise statement about the findings but also a critique of the methodology and/or some idea of confidence in the results.

Section 5. Evaluation of the Trialling

Partners have adopted the draft unit evaluation sheet, as shown in Appendix One, to collect feedback from teachers on how the inquiry activities and assessments went in their classrooms and these were used, alongside the discussions from the teacher workshops, to help each partner complete a pilot teacher questionnaire, as shown in Appendix Two. This questionnaire was used to collect feedback from on how the confidence and understanding of the pilot teachers had developed with regard to inquiry skills. It also provides feedback on how successful or not the teachers had been in applying their chosen approach to assessment. Another aspect that was of interest was the extent to which the teachers involved their students in the assessment process.

5.1 Feedback from pilot teachers

Teachers reported that their students needed considerable support and opportunity to develop their inquiry skills. Given the variation in culture, students' educational backgrounds and teachers' experiences with inquiry and assessment, teachers were given a lot of leeway in adapting and trialling the draft units. The idea was for teachers to think of what they needed to share with students to help them in their learning while keeping track of their progress for reporting to others. This also helped teachers be more experimental with their assessment. Six partners reported that their teachers were able to use their assessments in a formative way in the classroom. Some of the teachers in the KCL group and in the JU group were interested in involving the students in the assessment process.

Thinking about suitable assessment strategies led teachers to consider assessing both during and after the inquiry. This was because formative assessment required the teacher to give feedback to the students and some of the teachers realised that this was likely to have more effect if they gave the feedback partway through the inquiry rather than leaving it until the inquiry was finished. While the teachers recognised the advantage of assessing during the process of inquiry, they also realised that they needed to focus on no more than 2 or 3 skills to make assessment manageable and, in some classrooms, only on a number of students rather than the whole class. To give all students some feedback, some of the teachers assessed the product of the inquiry for the whole class and this usually took the form of a write-up or presentation.

Because of the approach that teachers took to their assessment, many decided on what their expectations for a particular skill would be in the context of that inquiry. Many therefore recorded whether a student had met expectations or not for each of the skills they were assessing in that inquiry. Other teachers decided to record which students had met expectations for a skill unaided compared to being supported by a peer or by the teacher. After a while, some of the teachers felt they needed the assessment criteria to be more finely grained and so in the teacher workshops they began developing criteria. While some of these attempts described successful attainment and then lesser attainment in terms of omissions or incorrect features, others tried to describe progression of the skill over a scale of three or four components. The expected performance was called the consolidating criteria, suggesting that the student had mastered performance of that skill. In some classrooms, the teachers called this the confident performance.

5.2 Feedback from Partners

The pilot teacher questionnaire (Appendix Two) was completed by nine partners and the combined results are indicated in Table 3. Note that this table was completed by the partners based on their impression of their teachers and therefore the data should not be considered as a trend only.

Table 3: Combined data for Pilot Teacher Questionnaire

	STRONGLY AGREE	**AGREE**	**NEITHER OR DON'T KNOW**	**DISAGREE**	**STRONGLY DISAGREE**
The pilot teachers had a good understanding of IBSE at the start of the pilot study	1	5	3		
The pilot teachers had a better understanding of IBSE at the end of the pilot study	6	3			
The pilot teachers were able to focus on 2-3 skills to assess within an inquiry	3	5		1	
The pilot teachers were able to use their assessments for ***formative purposes***	1	5	1	1	
The pilot teachers were able to use their assessments for ***summative purposes***	2	4	3		
The pilot teachers were able to assess how students were performing ***during*** the inquiry	1	6	2		
Students were helped to understand the assessment process through criteria or self- or peer-assessment	2	3	2	2	

From results in Table 3, it is clear that the teachers involved in the trialling of DU and in development of CS, had, in the partner's opinion, a good understanding of inquiry which improved during the timescale of the trialling phase. The teachers were able to focus on assessment of more than one skill during the activity and most were able to use these assessments for both formative and summative purposes.

Partners reported in the evaluation questionnaire that teachers found planning, developing hypotheses, asking questions, data analysis, and evaluating easy to assess. This may be as teachers are more familiar with assessing these skills and also that it was easier for students to produce evidence of these skills; thus allowing teachers to refer to their students notes outside of the lesson, if they had not had the opportunity to assess some individuals for that skill during the inquiry.

Partners reported in the evaluation questionnaire that teachers found creativity, searching for scientific information, interpretation of data, graphical representation, verbal expression of results, formulating arguments, discussion with peers, and teamwork difficult to assess. The latter three skills involve students interacting with one another and this makes it more problematic for teachers to assess individuals. However, over the course of the trial some teachers reported significant improvement in their assessment of these skills as they attempted more inquiries that included assessment of these. These skills will be further addressed in the next phase of the SAILS project.

Section 6. Conclusions and Recommendations

This evaluation was conducted for two main reasons. Firstly, with trialling of the draft units with teachers in classrooms, it was possible to develop case studies with evidence of assessment practices in the classroom. This in turn helps in the development of assessment criteria that can be used in assessment of inquiry skills and hence inform the final framework of assessment strategies (in WP2). Secondly, as experienced IBSE teachers were involved in this trial, the experience of the DU can feed into the further development of Teacher Education Programmes (TEP) and, in particular, how the DU and CS can be used in the final TEP on IBSE and its Assessment (in WP4).

6.2 Recommendations for SAILS UNITs

Following the analysis of the information provided in the draft units and the case studies, it is clear that while a huge resource now exists to build on for the remainder of the SAILS project, some additional information is required in order to supply more information to the users of the final SAILS UNITs. It is clear that the concept of a ‘draft unit plus several case studies’ to form an overall SAILS UNIT has created some confusion. The initial plan was that a draft unit would be developed or adapted from other sources that would be a good inquiry lesson(s) on a particular topic. Within this draft unit, several opportunities for assessment of particular inquiry skills would be identified and criteria could be proposed for these assessments. Following the development of the draft unit, several teachers would then implement these draft units or parts of them and write up a CS to show in particular how the assessment occurred and the criteria they used in that assessment. Following discussion and analysis of student evidence from several case studies on the same draft unit, a final SAILS UNIT would be produced which could then be exemplar material for use in Teacher Education Programmes.

To date, 34 draft units have been proposed with over 50 case studies. Some of these draft units have been developed by teachers within Teacher Education Programmes, which is a very valuable part of the Teacher Education Programme. However, to really develop exemplar material in the form of SAILS UNITS, there should now be a focus on a limited number of draft units and on increasing the number of case studies associated with this draft unit. In this way, a more in depth analysis of the case studies will be possible. Also, the draft units need to be used in different countries to develop and compare assessment criteria.

Within the case studies, the information supplied needs to be expanded, e.g.:

- in some cases by explicitly stating where, when and how the assessment occurred, particularly in relation to those assessments that occur during class activities.
- Teacher’s reflections are very worthwhile in the case studies but these should be noted together with full details have been given of the classroom activities and assessment.

- Within the template, while opportunities for assessment are given, modes of assessment are not given (in order not to be prescriptive) – however, maybe a mode of assessment could be included with the opportunities in the unit template.

Care needs to be taken in terms of rubric use; it is important to be able to identify the strengths and weaknesses of a particular piece of student work (either student activity or output) and to be able to provide appropriate feedback to the student. The use of rubrics only can lead to its use as a grading scale. Therefore, in further development of the case studies, it would be beneficial to have several examples where different criteria are presented, such as threshold/hurdle criteria or checklists.

6.2 Specific Recommendations for Framework Development

In addition to recommendations for the SAILS units, specific recommendations for the work of Framework develop are as follows:

- From all the draft units and case studies, develop a limited number of exemplar SAILS UNITS;
- Consider whether the framework should be specific or general in terms of each inquiry skill;
- Consider development of positively focussed assessment feedback;
- Consider whether generalised rubric headings are appropriate (such as emerging, developing, consolidating and extending or other such appropriate headings);
- Consider inclusion of an indication of learning progression in the development of each inquiry skill.

6.3 Specific Recommendations for Teacher Education Programme

Teacher education programmes will consist of a series of workshops focussed on developing teachers understanding of inquiry and also of its assessment. From this trialling, certain recommendations can be made for the development of teacher education programmes. It is clear from working with these teachers that they need to have a good understanding of inquiry teaching methods before they can consider assessment of the inquiry.

Particular aspects should be included within the TEP:

- Teachers should be introduced to inquiry first and then the assessment introduced;
- TEP should take place over several workshops if possible, to give teachers time to try out ideas in their classrooms; Teachers should become learners as part of the inquiry workshops so that they understand what it's like to be placed in an inquiry scenario.
- Exemplar SAILS UNITS should be used in the TEP
- After trialling SAILS units themselves, teachers should be involved in selecting/developing their own inquiry activities and also constructing their own assessment;
- Workshop time should be devoted to Assessment for Learning, to allow teachers to discuss different strategies of formative assessment and how they differ from the summative approaches that they may be heavily reliant on in their own practices. Teachers need to be supported as they try different approaches in their teaching and often this can be done by having supportive colleagues; therefore it is recommended that at least two teachers should attend the TEPs from the same school.

Appendix ONE Draft Units Evaluation Sheet

1. Which activity/activities did you try and with which class?

2. Which aspects of inquiry did you hope to engage your learners in through the activity and how successful/difficult was this?

3. How did your learners respond to doing this/these activities?

4. What did they learn through doing this/these activities?

5. What did you assess and did you manage to assess some or all of your learners through the activity/activities?

6. What would you change if you did this activity again?

NAME: SCHOOL

Appendix TWO Pilot Teacher Questionnaire

PARTNER	
NUMBER OF PILOT TEACHERS	

	STRONGLY AGREE	AGREE	NEITHER	DISAGREE	STRONGLY DISAGREE
The pilot teachers had a good understanding of IBSE at the start of the pilot study					
The pilot teachers had a better understanding of IBSE at the end of the pilot study					
The pilot teachers were able to focus on 2-3 skills to assess within an inquiry					
The pilot teachers were able to use their assessments for ***formative purposes***					
The pilot teachers were able to use their assessments for ***summative purposes***					
The pilot teachers were able to assess how students were performing ***during*** the inquiry					
Students were helped to understand the assessment process through criteria or self- or peer-assessment					

Were there any inquiry skills that the pilot teachers found ***easy*** to assess?

Were there any inquiry skills that the pilot teachers found ***difficult*** to assess?

What have you learnt from the pilot study that needs to be fed into WP4?

What have you learnt from the pilot study that needs to be fed back into WP2?

Appendix THREE Unit Template

Draft Unit

1: Topic

Topic. Relevance to curriculum. Education level (age group) it is suitable for. Amount of (class) time suggested.

Outline the overall approach to teaching this topic through inquiry.

2: Content - Key concepts and ideas

Outline the main scientific concepts that will be addressed in this unit.

3: Inquiry and reasoning skills and scientific literacy

Outline the main skills that are evident in this unit – or that can be developed through this unit. Focus on 2-3 main skills and describe how those skills are manifested in this topic.

4: Suggested Learning Sequence

Detail the learning sequence, giving clear directions for another teacher to carry out this sequence. Include details of the processes that will enable students to develop their inquiry skills. Include any materials that are necessary for teachers to implement these lessons (e.g. worksheets).

Learning Sequence and Activity table

Student Learning activity	Supportive Teacher activity (e.g. supportive questions)	Inquiry skills and processes

5: Assessment opportunities

Identify and detail when assessment information should be collected during the learning sequence, describe the assessment opportunity and detail the associated concept and/or inquiry skills assessed. A range of assessment opportunities should be identified in each unit. Please detail in terms of concepts, inquiry skills, reasoning and scientific literacy.

Student Learning activity	Inquiry skills and processes	Assessment (concepts, inquiry skills, reasoning and scientific literacy)

Case studies

Evaluation of Evidence of Learning

Clearly illustrate for the teacher how evidence of student learning and development of inquiry skills can be collected and evaluated using a variety of methods, e.g. student discussion, peer-/self-assessment, written work, diagnostic questions etc. This should include classroom tips - e.g., in a class of 24 students where a teacher wants to evaluate students' skill in diagnosing problems through observation of group discussion that this can be carried out by observing each group at different stages and collecting information on a smaller number of/individual students. Each unit has a number of case studies which include a number of key skills identified (important not to have all units presenting all skills!) and then describe the assessment process and criteria (e.g. questions, rubrics, etc.) and implementation plan (if useful) used for evaluating evidence of student learning, development of inquiry skills, scientific reasoning and scientific literacy.

Case studies should provide a narrative on how teachers:

- have implemented or adapted the learning sequence,
- what skills did they assess and how,
- what evidence did they collect on student learning
- and how they judged this assessment data (criteria and explanation/justification)