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Strategies for Assessment of Inquiry Learning in Science

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Science education in a changing Europe

We live in a changing world where new knowledge is constantly being generated and new applications of this knowledge developed. Our scientists continue to push the boundaries in generating, developing and adapting their knowledge and often present challenges to society. If Europe is to maintain its presence in the economic world, we need the new generation of scientists and citizens who are knowledgeable about science and the scientific process. Thus, we will have a society made up of individuals who are informed, critical and can make decisions based on evidence.

The good practice of science involves use of inquiry skills and competencies, such as planning investigations; analysing, evaluating, critiquing data and evidence; developing models and making inferences based on evidence. Additionally, work practices now involve team work, effective communication, and other 21st century skills. These inquiry and 21st century skills and competencies are seen as important in today's rapidly changing society.

Science education needs to meet these new demands, and one obvious way is to ensure that students engage with science through inquiry practices and also develop 21st century skills. This approach is more engaging for students, presents greater challenges for both teachers and students, allows students develop a deeper knowledge of the subject matter and also can be more relevant to student lives. As a result more students are likely to take up science-based careers and strongly contribute to a scientifically literate society, as encapsulated in the focus of Horizon 2020 programme Science with and for Society.

What is Inquiry Based Science Education (IBSE)?

IBSE is the classroom practice that encourages development of inquiry skills through science that learners use to make sense of the world around them. In science classrooms, these include problem solving, planning and carrying out investigations, looking for patterns in data sets, making observations and inferences, asking questions and researching and testing out ideas. The inquiry learners are creative and imaginative in their design of investigations and analysis of evidence. The IBSE approach not only helps students develop a set of skills that they will find useful in a variety of contexts, but it can also help them develop their conceptual understanding of science.

Scientific inquiry should enable students to experience the difficulties and pleasures of pursuing scientific activity, as practiced by scientists – such as generating ideas, designing trials/experiments, taking measurements, and engaging in discussions and arguments as they make sense of what they find. This involves questioning and making sense of unexpected results and observations. It requires that students engage in open-ended investigations to develop their skills of collaboration, of dialogue and of producing and interrogating data. An inquiry approach motivates students to become fully engaged in learning and so enables them to engage with the joy and wonder of science.

Inquiry skills and assessment

Assessment to most people means tests and examinations, but this is only one part of the story. In classrooms, the main purpose of assessment is to support and encourage learning. Many of the current assessment practices focus on the individual and use a limited range of opportunities. However, assessment of inquiry offers richer possibilities. Evidence of inquiry skills can be collected in many different ways, for example on audio recordings, video, written student reports, presentations, peer assessment, teacher observation, stages in production of a solution to a problem, and the final product. The nature of assessment can also involve looking at processes as well as summative (often written) documents.

The SAILS project is training teachers through workshops and online communities of practice not only to use inquiry-based approaches in the classroom but also to make them more confident in their assessment of IBSE. Through the project, teachers are gaining experience in assessing inquiry skills.

This approach has several advantages in that assessment:

- *Is more personalised:* assessment can be carried out over a period of time in an authentic context and address individuals, pairs or groups. This contrasts with the more traditional testing situation which takes place at a single moment in time. Assessment of inquiry should present a more realistic reflection on the abilities of the student.
- *Fits better with diverse students' cultural and educational background:* in inquiry, students are given tasks that are open-ended and open to different approaches. This means they can vary in different countries, regions and schools according to the local educational and cultural background.
- *Reflects today's society:* teamwork is often involved making it possible for students to learn across diversity with students discussing and debating ideas together.
- *Stimulates creativity and responsibility:* using investigation-based science inquiry has the potential for enabling students to develop into more creative and independent scientists and to help them to further the 21st century skills that Europe needs them to have to maintain and develop its place in the world.

SAILS approach to assessment of IBSE

Within the SAILS project, inquiry in the science classroom is understood to be the intentional process of providing opportunities where students are directly involved in diagnosing problems, critiquing experiments and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments.

SAILS partners are developing a series of units in which exemplar inquiry activities are described alongside opportunities for assessment of the inquiry skills. These units provide examples for teachers of how inquiry skills can be assessed, alongside content knowledge, scientific literacy and scientific reasoning and illustrate the benefits of varied types of assessments.

Within each unit, a variety of assessment possibilities are highlighted; however it is stressed that these assessment opportunities are provided so that the teacher may see the varied scope for assessment e.g. assessment of: individual or group; single skill or multiple skills; content knowledge within inquiry; multiple skills over a course of study; as formative and /or summative assessment.

Structure of the SAILS units

SAILS partners have selected and developed inquiry resources that have been used to develop students' inquiry skills. Within each unit, a number of key inquiry skills have been identified. The units now have a suggested teaching sequence which describes the assessment practices and process used for collecting and evaluating evidence of student development of inquiry skills, reasoning skills and scientific literacy as well as understanding of content knowledge. A range of assessment opportunities have been highlighted within each unit and tools such as rubrics, questions (written or oral), discourse analysis, group work have been included.

These units have been piloted by experienced inquiry teachers in each of the SAILS partner countries. Teachers have provided feedback on the effectiveness of these resources in terms of evidence for students' learning, suitability for local curricula and range of skills assessable.

Evidence of student learning such as written work, presentations, dialogue, teacher observations have been analysed in order to refine the criteria for considering students' inquiry skill level.

SAILS units will be used in SAILS workshops for both in-service teachers and pre-service teachers in order to help classroom teachers broaden assessment opportunities. These units will also be made available through the SAILS Community of Practice.

On the next pages you will find 3 examples of classroom activities with some proposed assessment opportunities for each activity.


Woodlice

Woodlice are common across Europe and are appropriate for students to handle. This inquiry task deals with environment, ecology, and animal behaviour.

Classroom inquiry activity

Students are asked to investigate the living conditions of woodlice. Suggested variables are intensity of light, amount of moisture, and food preferences. Students are expected to: (a) formulate hypotheses about preferred living conditions, (b) plan an investigation (or a series of investigations) in order to test their hypotheses, (c) design and conduct the investigation(s), (d) collect, document, and analyse data, (e) draw conclusions supported by the evidence, (f) explain any unexpected results, (g) report, compare, and discuss their own results with the results from other students, and (h) suggest how to improve their own (or other's) investigation.

Assessment opportunities

For this inquiry task a three-level rubric for assessing investigative skills is used. A rubric is a guiding document that the teacher can use to judge the level of the student in a certain activity; an example can be found in Figure 1. This task is particularly suitable for assessing aspects of inquiry such as: formulation of hypotheses; planning and designing scientific experiments; drawing conclusions; explaining unexpected results; reporting, comparing, and discussing results, and providing suggestions about how to improve investigations. The task may also be used to assess student understanding of basic ecological concepts, such as species, habitat, physical and biotic environment. In particular, student understanding of these concepts may be assessed when formulating hypotheses (e.g. checking if the hypotheses are grounded in scientific knowledge) and when explaining and discussing their results.

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.	The student can… … make a distinction between questions possible to investigate and questions not possible to investigate.	The student can… … revise own or others' questions, so that they become possible to investigate.
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.	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 makes a prediction that is scientifically well-founded.

Figure 1. A three-level rubric

Speed

Speed is a concept students encounter every day of their lives. This inquiry task helps students develop the skills of planning an investigation, generating questions and identifying variables.

Classroom activity

Students are given three tasks:

- to plan an experiment to measure how far they walk in 5 seconds,
- to plan an experiment to measure how long it would take to walk 5 metres,
- to analyse their journey from home to school both verbally and graphically.

In doing so, they consider the variables of speed, distance and time. Students are expected to: (a) identify and use an appropriate experimental procedure including selection of suitable equipment, (b) design and carry out the experiments, (c) collect and document data, (d) consider sources of error, (e) consider modifications to the experiments, (f) create a graphical representation of their own narrative.

Assessment opportunities

While students are planning their experiments, the teacher may look out for the quantity and quality of questions (e.g. are they relevant to the investigation), or that addressed issues such as accuracy or control of variables.

Students may be encouraged to do a test run of their experiment and revise their plans accordingly.

An assessment after the experiment can be made in terms of the likely accuracy of the values found. When students graph their journey to school, they represent key features of the journey in a variety of ways. This allows the teacher to assess students' understanding of graphs, in particular how the shape of a graph relates to changes in the motion identified in the narrative (see for example Figure 2 showing two students' graphs of their journeys to school) .

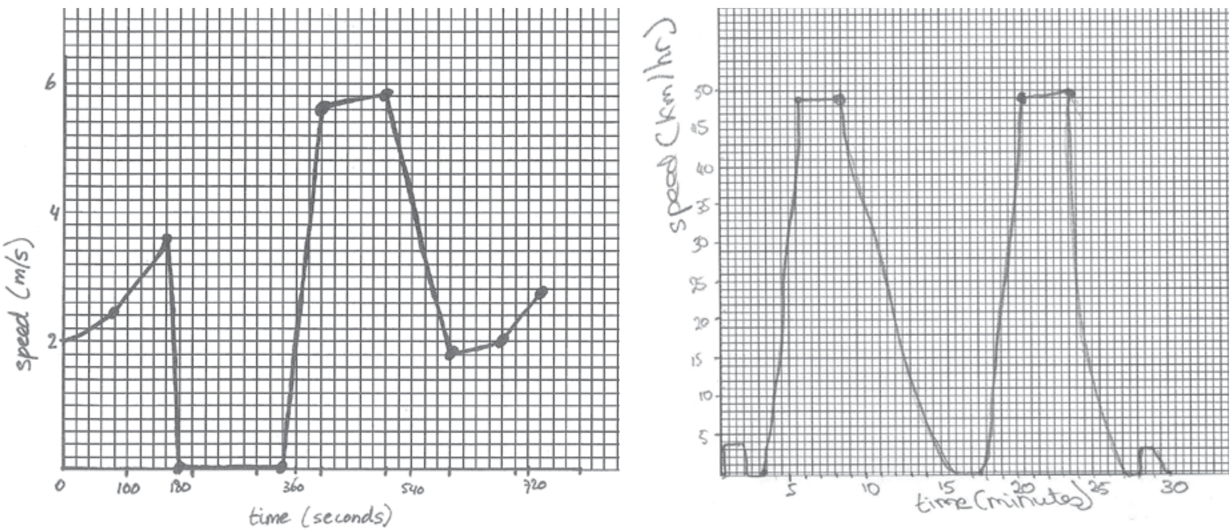
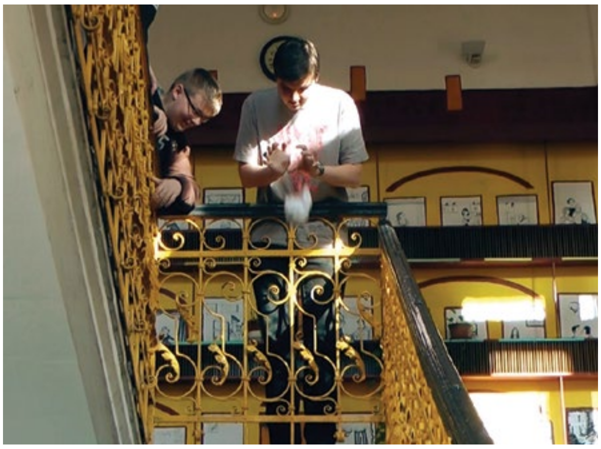


Figure 2. Students' journeys to school



Egg dropping

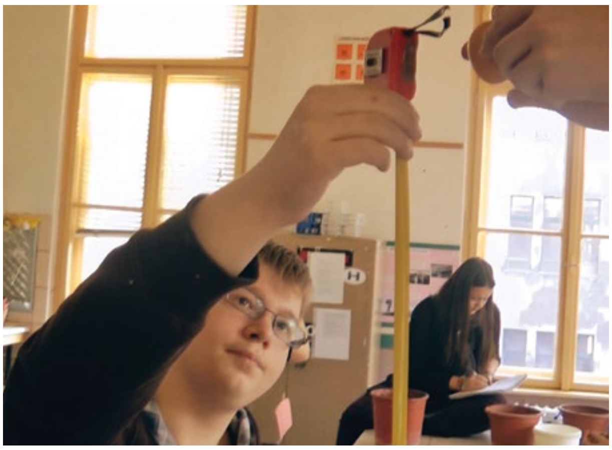
This is an open inquiry where students have to devise a way to catch eggs so that they do not break when dropped. The task is to solve an unstructured problem. The theme of the task is that of mechanics, and the connection between force and momentum.

Classroom inquiry activity

The students work in groups of four and are given a range of materials (e.g. tray, bucket, tape measure, ruler, stopwatch, eggs, digital balance, water, flour, sand, balloon) but are restricted in the amount of materials they receive. They have to devise a way of stopping the egg from breaking when dropped from a specified height - say 5 metres. Students are expected to work together to design and trial ways of solving the problem. From this data collected, they draw conclusions and evaluate their trials.

Assessment opportunities

In this case the assessment can take a variety of forms. One form is simply whether the task is completed and the egg does not break when dropped. Other forms can assess the final design, together with the supporting reasoning associated with why the group developed this particular design. The extent of the use of principles of mechanics to inform the final design can also be assessed. Peer judgments can also be made by the class as well as the teacher. The originality of the design and its potential for improvement can be assessed. The way the pupils developed their design, the input of each individual to the design, the negotiation within the group, the way they conducted the experiment, and the conclusions they drew can be assessed. It is not suggested that all of these aspects would be assessed at the same time, but that this task can present many opportunities for assessment that the teacher would select from, depending on the aspect required.



Project description

The aim of the SAILS project is to support teachers in adopting an inquiry approach in teaching science at second level (students aged 12-18 years) across Europe. This is being achieved by utilising existing resources and models for teacher education in IBSE, both pre-service and in-service. In addition to SAILS partners adopting IBSE curricula and implementing teacher education in their countries, the SAILS project is developing appropriate strategies and frameworks for the assessment of IBSE skills and competences and preparing 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 IBSE pedagogy, a sustainable model for IBSE is being achieved. SAILS partners provide teacher education workshops in IBSE across the twelve participating countries and are promoting a self-sustaining model encouraging teachers to share experiences and practice of inquiry approaches to teaching, learning and assessment by building a community of practice.

Project partners

Dublin City University, Ireland

Intel Performance Learning Solutions Limited, Ireland

Pavol Jozef Šafárik University in Košice, Slovakia

Jagiellonian University, Poland

Malmö University, Sweden

Kristianstad University, Sweden

University of Southern Denmark, Denmark

The Institute of Education of the Lisbon University, Portugal

King's College London, United Kingdom

University of Szeged, Hungary

ATiT, Belgium

University of Piraeus Research Centre, Greece

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How to get involved?

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This project has received funding from the European Union's Seventh Framework Programme for research technological development and demonstration under grant agreement no 289085