INQUIRY AND ASSESSMENT UNIT

ORANGES

Will they sink or float? What's happening?

Christine Harrison

ORANGES

WILL THEY SINK OR FLOAT? WHAT'S HAPPENING?

Overview

KEY CONTENT/CONCEPTS

- Density
- Archimedes principle

LEVEL

- Lower second level

INQUIRY SKILLS ASSESSED

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

ASSESSMENT OF SCIENTIFIC REASONING AND SCIENTIFIC LITERACY

- Scientific reasoning (recording data and observations)
- Scientific literacy (critiquing experimental design)

ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Worksheets
- Student devised materials (documentation of the inquiry process, reports)
- Presentations

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

1. INQUIRY AND ASSESSMENT UNIT OUTLINE – ORANGES

The **Oranges** SAILS inquiry and assessment unit focuses on studying floating oranges as a model system to relate the physics concept of density and Archimedes principle with students' daily lives. This unit was designed as an inquiry activity that allows teacher to assess during the process of the inquiry. Students work in groups to develop hypotheses about the behaviour of oranges in water, and verify their hypotheses by experimentation. This unit is recommended for implementation at lower second level and the unit activities are presented as an *open inquiry*; however, it has been implemented across the range from *guided* to *open inquiry*.

Implementation of this unit is suggested for the assessment of students' skills in *developing hypotheses* and *planning investigations*, as well as enhancing their *scientific literacy* as they learn to explain the science behind the observed phenomena. Proposed assessment methods include classroom dialogue and evaluation of student devised materials.

This unit was trialled by teachers in Germany, Hungary, Poland, Sweden and the United Kingdom – producing eight case studies of implementation. In Sweden, the implementation was with a group of in-service teachers, while the other case studies were all with lower second level students. In different country contexts, the teachers had varying pedagogic aims and so adapted the unit to suit their classes. *Planning investigations* and *developing hypotheses* were assessed in most cases, while *working collaboratively* was assessed in four of the eight case studies. Key assessment methods used include classroom dialogue, teacher observation and evaluation of student artefacts.

2. IMPLEMENTING THE INQUIRY AND ASSESSMENT UNIT

2.1 Activities for inquiry teaching & learning and their rationale

The teaching and learning activities described in the **Oranges** SAILS inquiry and assessment unit were developed by the team at King's College London as part of the SAILS project. This unit was designed initially for teachers in England because they were keen to move away from assessing inquiry skills through laboratory reports and wanted to start assessing during the process of the inquiry. One of the skills they were eager to encourage in their learners was raising their own questions and then devising appropriate methods to test their ideas. Further skills that they were keen to begin encouraging and assessing was teamwork and collaboration, which the teachers felt were important life skills that an inquiry approach can engender. Therefore, this activity is designed to allow students (11-14 years) to raise scientific questions. This unit can be implemented in a single lesson and is valuable for introducing the concepts of inquiry to students.

Concept focus	Density and Archimedes' principle
Inquiry skill focus	Planning investigations Developing hypotheses Working collaboratively
Scientific reasoning and literacy	Scientific literacy (explain phenomena scientifically)
Assessment methods	Classroom dialogue Teacher observation Student devised materials

Rationale

In this activity, students are asked to consider the factors that influence the behaviour of an orange in water – why does it float or sink? The activity is introduced as an open inquiry, and students develop hypotheses about what will happen and why. They then devise an investigation to study their research question.

Suggested learning sequence

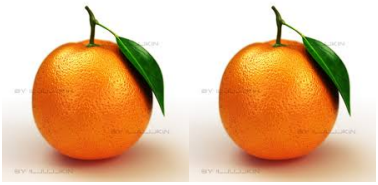
Materials needed: solid oranges or satsumas and some soft oranges of about the same size, beakers, measuring cylinders, glass rods, thermometers, rulers, string, balance.

1. Students should work in groups of 3-4 students.
2. The teacher provides each group of students with two types of orange and introduces the inquiry question: "Do you think both of these oranges will float? Discuss your ideas and test out any that seem reasonable." This can be achieved using a simple worksheet, which will provide students with the challenge question, but not direct their inquiry (Figure 1).
3. Students explore any ideas they have using general laboratory equipment like beakers, measuring cylinders, thermometers and balances to help them focus on ideas.

Floating orange

Science is about being curious about the world around you. In this activity you are asked to think of some questions and then to work out how you might find some answers to those questions.

Look at and feel the TWO oranges. How are they different? If you placed them in water might they float differently?



Talk with the others in your group and decide on a question you might ask about the oranges. Try out some of your ideas using the apparatus provided. Try and give reasons for any ideas and results that seem to answer your question.

Figure 1: Sample student worksheet

The teacher should circulate around the class, and observe their actions. It is likely that various misconceptions may be revealed such as:

- It depends on the depth of the water
- It depends on the size of the orange

4. The teacher should not intervene but allow students to test these hypotheses. It is an important scientific skill to be aware that disproof is as valuable as proving hypotheses correct.
5. Students may test a whole range of questions. For example:
   - Does the waxy skin help it float?
   - Does the heavier orange float lower in the water?
   - Do the oranges float the same in hot and cold water?
   - Is the air in the orange helping it float?
   - How can you make a floating orange sink?
6. They may also do it by seeing how the two different oranges float and then decide to take measurements. If they do start to think about density, let them work out how to measure the volume. Similarly if they are comparing depth of floating, can they work out how to measure it?
7. After 15-20 minutes of open inquiry, the teacher should stop the class and collect a list of questions. The class should then discuss the questions and give comments and advice on which they think are likely to be testable questions.
8. Allow the groups another 15-20 min to test out their question encouraging them to do duplicate investigations and to tabulate or analyse any data they have.
9. Each group can then present their question and findings, either to the whole class or to another group, depending on the time available.

2.2 Assessment of activities for inquiry teaching & learning

In this section we present some tools for formative assessment, aimed at verifying the development of inquiry skills of *developing hypotheses*, *planning investigations* and *working collaboratively*, as well as their ability to communicate what they did and why they did it. This is a very open activity, and can be adapted for evaluation of a variety of skills. The assessment methods include classroom dialogue, teacher observation and evaluation of student artefacts, and may be extended to include peer- and self-assessment.

A suggested 4-level rubric is provided, which details success criteria for students at the emerging, developing, crafting and extending performance levels (Table 1).

Table 1: Assessment of skills developed in the Oranges SAILS unit

Skill	Emerging	Developing	Crafting	Extending
Developing hypotheses Asking inquiry questions	The group discuss a number of questions and agrees on one they feel is testable. E.g. "Does the skin/ shape/amount of air in the fruit make it float/ sink?"	The group raise a testable question with reasoning from previous science ideas they have encountered. E.g. "Is it the amount of air that makes the fruit float because this lowers its overall density?"	The group raise a testable question that forms a hypothesis. E.g. "How does the amount of air in the fruit alter its ability to float?"	The group raise a testable question that forms a hypothesis and explains what results to look for to prove or disprove the hypothesis. E.g. "Does removing the peel cause it to sink?" relates to the hypothesis that the waxy skin helps the fruit to float.
Planning investigations Testing hypotheses	The group place the fruit in water and then make a change in the fruit (e.g. squashing it flat or making holes in it) and describe what happens.	The group mark the water level on the fruit or container and then make a change in the fruit (e.g. squashing it flat) and take a second measurement of water level or measure the difference in the way it floats after treatment	The group select one variable to test and take measurements of the water level as they make changes in that variable.	The group attempt to set up a fair test that measures changes in the output variable as they change the input variable. They take at least five readings for each.
Communication	The group describe what they did to test their idea	The group describe what they set out to test and present their results	The group explain and present their ideas and results and how they tried to be rigorous.	The group explain what they set out to test, present their results and discuss their confidence in their findings. They also suggest improvements for doing their investigation.

Feedback through classroom dialogue

It would be useful to provide feedback to students on the range of questions raised in this inquiry and discuss with them, as a class, which questions were more useful than others in taking ideas forward. For individual or group improvements, help them see how the behaviours in the next column to the right in the rubric builds on what they achieved in this inquiry.

3. SYNTHESIS OF CASE STUDIES

This unit was trialled in five countries, producing eight case studies of its implementation – **CS1 Germany**, **CS2 Germany**, **CS3 Hungary**, **CS4 Poland**, **CS5 Sweden**, **CS6 United Kingdom**, **CS7 United Kingdom** and **CS8 Hungary**. The activities were carried out with lower second level students in all of the case studies, except **CS5 Sweden**, which details implementation with in-service teachers who had limited experience of the assessment of inquiry activities. Classes were of mixed gender, and students were aged 11-15 years. In the examples with lower level students, the case studies were implemented by teachers who had some experience of teaching through inquiry but the students involved had generally not been taught through inquiry. In general, the case studies concern a single class period of around an hour, with the exception of **CS2 Germany** and **CS3 Hungary**, who carried out the inquiry over nine or three 45-minute lessons, respectively.

The case studies focus primarily on development of inquiry skills and on the assessment of skills in *planning investigations* and *developing hypotheses*. In addition, *working collaboratively* was assessed in four of the eight case studies. Commonly used assessment methods include classroom dialogue and teacher observation, as well as evaluation of worksheets or student devised materials.

3.1 Teaching approach

Inquiry approach used

The inquiry approach used across the case studies ranged from *open* to *guided inquiry*. In **CS2 Germany**, **CS5 Sweden**, **CS6 United Kingdom**, **CS7 United Kingdom** and **CS8 Hungary** an open inquiry approach was taken, where the participants were provided with apparatus to explore ideas and generate a question, which they then investigated. In **CS3 Hungary** and **CS4 Poland**, the teacher set the inquiry question through an introduction and worksheet instructions that guided the students towards generating a question and working out how to test this. **CS1 Germany** took a *bounded inquiry* approach by the teacher providing a broad inquiry question – Do different citrus fruits have the same floating characteristics – which the students then had to plan an inquiry to answer.

Implementation

The **Oranges** SAILS inquiry and assessment unit outlines a single open activity, which teachers can tailor to better suit their student groups. In each of the case studies, the students explicitly or implicitly dealt with density. This led them to take measurements of the way the oranges and other fruits floated in water. Some students adapted the apparatus by drawing scales on the sides of beakers or on the fruit itself to try and get a more accurate measure of how the floating behaviour changed as they changed parameters, such as depth of water, temperature of water, salinity of water or as they changed the fruit by either removing the skin, breaking it into smaller pieces or making holes in the fruit. In all cases they used observational and measurement skills and from these data made inferences that led them to investigate further and find an answer to the question they raised.

In all cases the skill of *planning investigations* was addressed, although in **CS7 United Kingdom** the teacher did not assess this skill. The students showed that they could recognise variables and, in some cases control and manipulate variables. Even when the teacher posed the questions to be investigated, students raised sub-questions, which often served for them to identify variables. In **CS2 Germany**, the students took a broad range of approaches to their inquiry and several of the students needed guidance from the teacher to come up with a relevant inquiry idea. For most of the other classes, the majority of the students were able to decide how they would take measurements of the variables they had identified, with the exception of **CS3 Hungary**, where the students had some difficulty deciding how they would do this and had to be prompted by their teacher. This was a surprise to the Hungarian teacher who decided that the novelty of inquiry perhaps intimidated his students.

All implementations involved working in groups during the inquiry (Table 2), although in most cases the students were required to produce individual written artefacts as well (**CS1 Germany**, **CS2 Germany**, **CS3 Hungary**, **CS4 Poland**, **CS7 United Kingdom** and **CS8 Hungary**). In **CS7 United Kingdom**, the students' posters were not assessed, instead after reviewing the poster the teacher posed a further question to extend the students' learning. In **CS8 Hungary** the emphasis in the class was on verbal descriptions of the process and the teacher encouraged students to make written records simply so that they would begin to develop skill in this area.

CS4 Poland details implementation with two classes, one of which was a workshop for home-schooled children, aged 10-13 years. The teacher found only small differences between the home-schooled cohort and the regular school class. In **CS8 Hungary**, the implementation was in an alternative secondary school, in which the classes contain students that demonstrate a range of ability, including students with behavioural, emotional or learning difficulties. This range of ability is evident in the written artefacts, but the teacher assessed students on the basis of oral descriptions. In **CS5 Sweden**, the implementation was with a group of teachers, rather than students. They carried out the investigation as outlined in the unit, while undergoing peer-assessment.

Table 2: Summary of case studies

Case Study	Duration	Group composition
CS1 Germany	One lesson (90 min)	• Groups of 3-4 students (24 students) • Student selected; mixed ability and gender groups
CS2 Germany	Nine lessons (45 min each)	• Groups of 2-3 students (6 girls, 8 boys) • Student selected; mostly single sex groups
CS3 Hungary	Three lessons (45 min each)	• Six groups of 4 students (24 students) • Student-selected; mixed ability and gender groups
CS4 Poland	One lesson (60 min)	• Groups of 4-5 students (student selected; single sex) • Two implementations – one workshop with home-schooled children
CS5 Sweden	One lesson (80 min)	• Implemented with a group of teachers • Two mixed gender groups of 3 or 4 members
CS6 United Kingdom	One lesson (40 min)	• Seven groups of 3-4 students (31 in total) • Higher attaining students
CS7 United Kingdom	One lesson (60 min)	• Groups of 2-3 students (30 students) • Teacher assigned; mixed ability and gender
CS8 Hungary	Two lessons (130 min in total)	• Four groups of 4-5 students (19 students) • Student-selected, mixed ability and gender

Adaptations of the unit

While there were some changes made to the inquiry to fit the context of the specific classroom or adapt to particular learning needs of students, the skills of raising testable questions and planning an inquiry were carried out and assessed in all case studies. It was clear that teachers had begun to look at formative routes for assessment. It is interesting that the teachers seemed able to assess students' skill in *working collaboratively* during the process of the inquiry. Perhaps one of the most relevant findings was that students enjoyed and were motivated by the inquiry activity and the teachers seemed relatively confident in both facilitating the inquiry and assessing it.

In some case studies the teacher made simple adaptations, such as use of tangerines, clementines or mandarins instead of oranges (**CS3 Hungary**, **CS5 Sweden**) or even providing both fruits within the class (**CS4 Poland**). In **CS1 Germany**, the students investigated lemons, limes and oranges, and the teacher started the learning sequence with the question: "Do different citrus fruits have the same floating characteristics?" **CS2 Germany** also used a variety of fruits, although details of which specific fruits were used were not provided.

In some case studies, the teachers made changes to the worksheet, or chose to omit it entirely. In **CS3 Hungary**, the teacher revised the worksheet so that it was slightly easier to follow and more relevant to the implementation (replaced the image of an orange with one of a tangerine). **CS4 Poland** adapted the worksheet to the greatest extent, changing the implementation from that of open to *guided inquiry*. This was to enable the teacher to evaluate student worksheets that were in a consistent format.

3.2 Assessment strategies

Almost all case studies focused on the planning aspects of inquiry, as suggested in the unit. However, given the open nature of the activity, it was possible for teachers to choose particular aspects for development, as shown in Table 3. *Planning investigations* and *developing hypotheses* were assessed in most case studies, while *working collaboratively* was also widely assessed. Other skills chosen for the assessment were *forming coherent arguments* (in **CS4 Poland** and **CS8 Hungary**), *scientific literacy* (critiquing experimental design in **CS5 Sweden** and explaining phenomena scientifically in **CS8 Hungary**) and *scientific reasoning* (collection of data and observation in **CS5 Sweden**). While **CS5 Sweden** looked to assess all aspects of an investigation, it is important to note that this implementation was with teachers rather than school students and so could take a broader look at the assessment.

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

CS1 Germany	• Planning investigations • Working collaboratively
CS2 Germany	• Planning investigations (including implementation)
CS3 Hungary	• Developing hypotheses • Planning investigations
CS4 Poland	• Developing hypotheses • Planning investigations (including implementation) • Forming coherent arguments • Working collaboratively
CS5 Sweden	• Developing hypotheses • Planning investigations • Scientific reasoning (data collection and observations) • Scientific literacy (critiquing experimental design)
CS6 United Kingdom	• Developing hypotheses • Planning investigations • Working collaboratively
CS7 United Kingdom	• Developing hypotheses • Working collaboratively
CS8 Hungary	• Developing hypotheses • Planning investigations • Forming coherent arguments • Scientific literacy (use of scientific language, ability to explain phenomena scientifically)

All case studies used a criterion-referenced approach to the assessment and mainly used rubrics, with some using the rubric proposed in the inquiry and assessment unit (**CS3 Hungary**, **CS4 Poland**). The teacher in **CS2 Germany** was aware of the rubric and kept the criteria in mind, but did not apply it formally.

Other case studies describe the use of teacher-devised rubrics, for example a 3-level rubric was developed in **CS5 Sweden**, which was designed for the assessment of grade 6 students (Table 4). This rubric could be used for the assessment of *developing hypotheses, planning investigations, scientific reasoning* (data collection and observations) and *scientific literacy* (critiquing experimental design).

The teacher in **CS7 United Kingdom** presented a rubric for assessing students' skills in *working collaboratively*, which will be applied throughout the year. This rubric outlines success criteria at performance five levels for three skills – participation, communication and explanation (Table 5). In this implementation, only the assessment of participation was noted.

Table 4: Assessment of skills developed in CS5 Sweden

Skill	E	C	A
Developing hypotheses **Forming a research question**	The student contributes to formulating simple questions and planning which can be systematically developed.	The student formulates simple questions and plans which can be systematically developed after some reworking.	The student formulates simple questions and plans which can be systematically developed.
Planning investigations	The student uses equipment in a safe and basically functional way.	The student uses equipment in a safe and appropriate way.	The student uses equipment in a safe and effective way.
Critiquing experimental design (scientific literacy)	The student contributes to making proposals that can improve the study.	The student makes proposals that after some reworking can improve the study.	The student makes proposals that can improve the study.
Documentation and observations (scientific reasoning)	The student draws up simple documentation of their studies using text and pictures.	The student draws up developed documentation of their studies using text and pictures.	The student draws up well-developed documentation of their studies using text and pictures.

Table 5: Assessment of working collaboratively in CS7 United Kingdom

Level	Participation	Communication	Explanation
1	Thoroughly involved in a thoughtful and polite way.	Talks politely and helpfully to other group members and takes instructions well.	Is heard clearly explaining the practical to others or is able to clearly and concisely answer teacher questions using appropriate language.
2	Wants to be very involved but not allowing others to get involved.	Talks to other group members about what is going on, may be a little bossy.	Is heard trying to explain the practical but with some hesitancy and or mistakes or can answer questions posed by the teacher to a certain extent.
3	Will try to help but needs to be encouraged by peers.	Does not say much but follows instructions.	Finds explaining the practical difficult but does try to give a good description of the activity.
4	Will get involved if asked by the teacher.	Says very little and does not respond to others.	Cannot explain practical but does try to describe what the group is doing.
5	Does not help with the practical.	Does not say anything and does not listen to others in the group.	Cannot explain practical and is not sure how to describe what it is the group is doing.

In most case studies, the teachers engaged in on-the-fly assessment during the process of the inquiry, although **CS3 Hungary** and **CS4 Poland** assessed using the worksheet and report on the inquiry. However, in all the case studies where students' skill in *working collaboratively* was assessed, this was achieved through direct teacher observation during the inquiry.

For some skills, the assessment was carried out after class and was based on a written artefact produced in class. Others involved formative assessment that guided the student learning during the class. For example, **CS1 Germany** used "fist to five" and "traffic light cups" during the inquiry for students to signal to the teacher how confident or not they felt with that aspect of the inquiry. The teacher in **CS2 Germany** gave verbal feedback at different stages in the inquiry process. In **CS6** and **CS7 United Kingdom**, the teachers used a range of questions designed to probe understanding during the inquiry process, while, at the same time trying not to lead the students towards a specific route within the inquiry. For example, they asked, "What was your reason behind that choice?" or "Why choose that specific method? Were there others you considered?" In **CS3 Hungary**, the teacher gave feedback at the end of the first lesson, based on his observations of the class activities, and at the beginning of the second lesson, based on the written plan of the inquiry that the students had produced. In this case study, the teacher chose to extend the implementation by an additional lesson period, to allow time for the students to fully develop their understanding of the concept of density.

In **CS4 Poland** and **CS1 Germany**, the teachers reported that the students enjoyed the inquiry activity. In **CS6** and **CS7 United Kingdom**, the students used peer-assessment to both report back on how they had responded to the inquiry but also to set themselves targets for future inquiry activities. **CS5 Sweden** also used peer-assessment with its teacher group. **CS2 Germany** also reports use of peer-assessment when establishing research ideas. In **CS4 Poland**, the teacher provided a written feedback sheet after the inquiry had been assessed.

In **CS1 Germany**, the teacher noted that some groups required different amounts of time during the planning phase, as some groups raised a question and decided to work with that while other groups were more willing to generate a range of questions and then decide which would be best to pursue. Similarly in **CS7 United Kingdom**, the teacher observed that some groups made decisions regarding their research questions quickly, while others struggled to do so.

The teacher in **CS1 Germany** used a variety of assessment methods and tools to enrich the implementation, including the "fist to five" "traffic light cups" methods. For the assessment of skill in *planning investigations* and *working collaboratively*, the class engaged in self-assessment. The students completed questionnaires on work attitude (Table 6), communication skills (Table 7) and the inquiry process (Table 8). The teacher provided formative feedback and supported the students throughout the process.

Table 6: Self-assessment of work attitude used in CS1 Germany

Behaviour	Always	Almost always	Sometimes	Almost never	Never
1. I concentrated on the task					
2. I worked autonomously					
3. I worked methodically					
4. I worked in a team					

Table 7: Self-assessment of communication skills used in CS1 Germany

Behaviour	I achieve this goal totally	I achieve this goal partly	I don't achieve this goal
1. I let my schoolmates finish their argumentations and did not disrupt them.			
2. I did not make inappropriate comments in response to my schoolmates' argumentations.			
3. I did not put my schoolmates under pressure or force them to do what I wanted.			
4. I informed all group members about planned investigations or upcoming inquiry processes.			

Table 8: Self-assessment of the inquiry process from CS1 Germany

Behaviour	I agree totally	I partly agree	I disagree
1. I investigated the relationship between the floating properties of citrus fruits and temperature			
2. I investigated if parts of the fruit show the same floating properties as the entire fruit			
3. I investigated the relationship between the floating properties of citrus fruits and their mass			
4. I investigated the relationship between the floating properties of citrus fruits and volume			
5. I have determined the density of the fruits			
6. I can describe our inquiry process			
7. I can give reasons for our inquiry process			