4.1 Case study 1 (CS1 Ireland)

Concept focus	Classification of plastics Properties of plastics (density, thermal stability, combustion)
Activities implemented	Activities A-C
Inquiry skills	Planning investigations (including systematic recording of data) Developing hypotheses Forming coherent arguments Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (problem-solving) Scientific literacy (understand properties of plastics and how they are utilised in everyday life)
Assessment methods	Classroom dialogue Teacher observation Peer-assessment Self-assessment Worksheets Student devised materials (final summary)
Student group	**Grade:** 2nd year (lower second level); two classes **Age:** 14 years **Group composition:** mixed ability and gender **Prior experience with inquiry:** Very experienced with inquiry

This case study describes implementation with two classes at lower second level. Students were invited to gather and bring in a collection of plastics, which were analysed and identified by comparing their properties with those of the known plastics. Skills assessed were *planning investigations*, *developing hypotheses* and *forming coherent arguments*. Assessment was achieved through a mix of formative and summative approaches, including classroom dialogue, using the "think-pair-share" approach, worksheets, and peer- and self-assessment.

(i) How was the learning sequence adapted?

The **Polymers** SAILS inquiry and assessment unit was implemented during four lesson periods, as summarised in Table 1. While the table separates the delivery into four distinct sessions, in reality there was some fluidity between them. For example, while the primary content focus in the third lesson was combustion of plastic materials, some of the students worked on the density and thermal stability of plastics when others were at the fume hood. In this way students were able to go back and forth between activities during the delivery. The teacher chose not to implement Activity D: Electrical conductivity of plastics, and changed the order of delivery for logistical reasons. This unit was implemented with two separate classes, and not all students tested thermal conductivity.

A significant adaptation made related to the plastics that were analysed over the course of the activity. Students were invited to gather and bring in a collection of plastics. The composition of these plastics was unknown to the students. This personal collection was analysed and identified as part of the unit where students compared their data from their known plastics with experimental results from the unknown. This adaptation added extra interest for students and allowed them to see the value and use of their experimental data.

Based on teacher questioning it was decided to focus their inquiry on *planning investigations* (including systematic recording of data), *developing hypotheses* and *forming coherent arguments*, although assessment of *working collaboratively*, *scientific reasoning* (problem-solving), *scientific literacy* skills was also carried out during some activities.

Before implementation of the **Polymers** SAILS unit, teacher assigned a pre-session task, whereby students were informed that their next unit of study would be on plastics and were asked to collect a variety of clean plastics to experiment on from their recycle containers as homework over the weekend. This resulted in a large collection of different plastic wrappers, bottles, containers and even toys (unknown plastic samples). In addition to this they were given plastic cups (PP), pipettes (PE), guttering (PVC) and food trays (PS) as known samples.

Table 1: Summary of lessons

Lesson	Content focus	Skills focus	Approach	Assessment
Lesson 1 (45 min)	Classification of plastics, density of plastics	Planning investigations, developing hypotheses, systematic recording of data	Teacher demonstration, open and guided inquiry	Classroom dialogue, teacher observation, use of a rubric
Lesson 2 (75 min)	Thermal stability of plastics	Working collaboratively, systematic recording of data, forming coherent arguments, scientific reasoning	Guided inquiry (worksheet) with teacher facilitation	Teacher observation, use of a rubric, peer- and self-assessment
Lesson 3 (75 min)	Combustion of plastic materials	Working collaboratively, systematic recording of data, forming coherent arguments, scientific reasoning	Guided inquiry (worksheet) with teacher facilitation	Teacher observation, use of a rubric, peer- and self-assessment
Lesson 4 (45 min)	Density of plastics, thermal stability of plastics, combustion of plastic materials	Scientific reasoning (problem-solving), scientific literacy (evaluating scientific inquiry)	Open-ended activity with teacher facilitation	Classroom dialogue, review of final report, self-assessment

In the first lesson, students were shown a sample of crude oil and they were invited to identify the smell while being told about oil refineries and reminded about their previous work on separating mixtures. The class was given “think-pair-share” time for five minutes to come up with uses for crude oil, which were then collected on the board. These were discussed and plastics were selected from the list. The usefulness of plastics as water stable materials was then reinforced by a teacher demonstration where two different plastic items were dropped into a glass trough and then removed to show no change in properties. During this demonstration it was noted that one floated and the other sank and repeated attempts were made by the teacher to get the floater to sink to make it a “fair test” with no success. In an open, unguided activity students then experimented with their plastics for roughly five minutes, in groups of two and three, to establish whether their plastics floated or sank and what, if anything, affected floating or sinking. A brief whole-class discussion followed, where shape and type of plastic were identified as two input variables. The same smaller groups then worked for a further five minutes to eliminate the effect of shape (i.e. added volume from a hollow container) and group plastics as either floaters or sinkers. Results were compared and shared by the groups holding up examples from each category. The teacher then provided cognitive conflict by asking students to rationalise a statement made in summary, namely “all plastics are made from oil and oil floats on water”. Most responses were that the oil had been changed to make the plastic though one group suggested that not all oils float. They were then given a worksheet for Activity A: Determining density of plastic materials (PE, PP, PS, PVC) by comparing with water density, and they started to complete it in the remaining class time. No modifications were made to the worksheet. All students have iPads and Wi-Fi access but only two students looked up data on

densities. The alternate approach was used because density is not normally introduced until third year.

In the second lesson, students were given a worksheet for Activity C: Thermal stability and thermal conductivity of plastic materials, and a self-assessment questionnaire for assessment of *working collaboratively* (group work), with the 1-5 Likert scale as provided in the unit. No alterations were made to the worksheets or assessment tool. Activity C was very briefly introduced as another activity that might allow the students to distinguish between their plastic samples. Students were then allowed to form their own groups and conduct tests on their plastics as they saw fit. They were free to use any of the equipment in the lab including all glassware, balances, hot plates, Bunsen burners etc. They were asked to assess the group's progress and were invited to add any other statements to the assessment task sheet that they thought appropriate and many did. Examples of these were "we followed the instructions on the sheet," "we asked the teacher for help in planning," "we all worked well together" and "we relied on each other's ideas." During the session the students were reminded to relate their findings for particular samples to the results from the previous class.

In the third lesson, students were given the procedure and findings table (summary of plastic materials properties) from the worksheet for Activity B. However, they were instructed not to test for odour due to the potentially toxic nature of the fumes. This generated the question of how they could burn the samples without breathing in the fumes and they identified "that thing," i.e. the fume hood, as the place to conduct this part of the inquiry. The teacher remained with groups, who came up in rotation, to ensure that small pieces of plastic were used and that safety procedures were followed, particularly in using tongs to hold the copper wire. While each group was at the fume hood the other groups continued with the density and thermal properties part of the unit.

In the final lesson, students were directed to the chapter on plastics in their eBook (Exploring Science, 3rd Ed, M. O'Callaghan, S. Reilly & P. Doyle, Edco) and instructed to write up a summary of what they had discovered. This was left as an open-ended activity. The eBook contains a flow chart for plastic identification in one of the end of chapter questions (p256, fig 30.11) and some students explained this and they were reminded of their dichotomous keys that they used and made in a previous unit on classification. They were given a self-assessment tool for assessment of learning through metacognition (provided in the unit) as an exercise for homework. The self-assessment task was used to encourage students to reflect on their own learning.

(ii) Which skills were to be assessed?

This implementation focuses on *planning investigations* (planning, systematic recording of data), *developing hypotheses* and *forming coherent arguments*, although assessment of *working collaboratively*, *scientific reasoning* (problem-solving), *scientific literacy* and other inquiry skills (systematic recording of data) was also carried out during some activities.

The assessment used during this unit contained a mix of formative and summative approaches that were conducted by the teacher and the students. The majority of the formative assessment involved teacher questioning following observation. The peer- and self-assessments were conducted by the students, using tools from the original unit.

Planning investigations, *developing hypotheses*, *scientific reasoning* (problem-solving) and systematic recording of data were assessed by questioning the group during the inquiry activities with open ended questions, such as "of all the equipment available, why did you pick a 600 ml beaker to do that," "are there any other pieces of equipment that would work as well, better or worse," "how could you ensure it is a fair test," "what do you think would happen if…" or "do the objects that sink all behave the same way when burnt." The teacher also used the rubrics provided

in the original unit for assessment of *forming coherent arguments*, *planning investigations* and *developing hypotheses* when formatively assessing the students.

The teacher assessed *working collaboratively* during the activity, through observation and questioning. The group members using the self-assessment of group work questionnaire provided in the original unit also. As noted earlier, students offered amendments to the group work assessment rubric. *Scientific literacy* was assessed summatively through analysis of the final report produced by the students. Students also self-assessed their learning through metacognition, using the self-assessment questions provided in the original unit.

Table 2: Summary of assessed skills

Assessed skills	Assessment method	Timing of assessment	Level of assessment
Planning investigations (planning, systematic recording of data)	Questioning/observation/ teacher rubric	During the activity	Individual and group
Developing hypotheses	Questioning/observation/ teacher rubric	During the activity	Individual and group
Working collaboratively	Teacher observation and student self-assessment	During the activity	Group
Forming coherent arguments	Questioning/observation/ teacher rubric	During the activity	Individual and group
Scientific reasoning (problem-solving)	Questioning/observation	During the activity	Individual and group
Scientific literacy	Evaluation of final report	After the activity	Individual

Gender issues did not arise. Both classes are mixed gender and there were male and female members in all groups. A considerable amount of work had been done over the previous year and a half with both classes on collaborative learning as part of a separate research project and students are used to working with each other and ensuring equal division of responsibility. Groups were self assigned and consisted of two, three and four students, with the majority being four students in size.

(iii) Criteria for judging assessment data

Both formative and summative assessment practices were used. Summative was a grading for the write-up that each student produced at the end of the unit implementation. Students were given a full lesson (45 minutes) as well as time at home to present, in whatever manner they decided most appropriate, a summary of their work on plastics.

During the activity, formative assessment was used in a number of manners. For example, one group of students had difficulty in working out how to determine volume accurately as they were using very small sample sizes. They were told to go and temporarily join another group, who were stuffing a graduated cylinder full of water with as much plastic as possible, and exceeding the gradations. Between the two groups they came up with an appropriate strategy to resolve their individual problems. Simple comments like, “Do all white plastics behave the same way? What do you think would happen if I did this? Explain to us why you are doing it that way” were used to steer some students towards a more appropriate inquiry strategy.

There were a number of key points for assessing the inquiry process. The first came in the form of the open-ended task “Does it float or sink?” where students had to determine that the shape of the object as well as the material it was made from affected the result. This allowed the teacher the

opportunity to discuss the thought processes of the groups as they developed their hypotheses. Gentle direction in the form of "what do you think might happen if" and "so you're telling me because it is yellow it will sink" questions aided students in *developing hypotheses*. This process then led into observation of the ways in which they eliminated the variable of shape from the investigation. The expectations here were that they were able to successfully identify that the volume of plastic was different from the volume of the container. This fed into a second open ended task, i.e. that of determining the volume of the plastic sample. The skill of *planning investigations* was assessed by outcome as well as through questioning. Questions such as "On a scale of 1 to 10, how accurate do you think your measurements are" and "How would you rate your method against other groups" helped to focus the students on detail and, for some, to suggest refinements. All students have iPads with Wi-Fi access but only two individuals decided to search for information about plastic properties. The next assessment opportunity was to see whether students were able to collect data in a systematic manner across the various experiments and form coherent arguments. In essence to see if they recorded results from the experiments on each plastic source together i.e. "the Coke bottle had a density of…" and "it became more rigid/flexible in hot water and burnt with…" The expectation was that students should be able to correctly identify plastics from their recycle collection by either combustion or density and predict the property not tested as confirmation.

(iv) Evidence collected

Teacher opinion

The students responded very well to the task and particularly enjoyed burning the plastics. They are very used to inquiry based and collaborative learning strategies and so the format was familiar to them. Students worked well together in small groups. The students' grading on the assessment rubrics pretty accurately reflected the teacher's impression of performance. Students added a few questions to the rubrics as they were completing them and were comfortable in doing so without asking whether they could do so prior to the additions. The only minor problem was the logistics involved with a large number of groups and one fume hood. A suggestion might be for students to prepare a rubric for grading their presentation prior to writing it up.

The students' self-assessment tools for assessment of *working collaboratively* (group work) and the self-assessment of learning through metacognition provided in the original unit were used by the students, as was the self-assessment of learning questionnaire, which was set as homework. The suggested rubrics for assessment of *forming coherent arguments*, *planning investigations* and *developing hypotheses* were used by the teacher to determine appropriate formative intervention strategies to move the learning forward within the students' zone of proximal development. The rubrics were useful, though there were some logistical challenges using them particularly in the third session when the teachers' time was predominantly taken up by monitoring the fume-hood for health and safety reasons. When using the *forming coherent arguments* rubric the same ideas were assessed but it was used in a different context as activity D was not implemented in this adaptation.

(v) Use of assessment data

Feedback was continuous and formative throughout the unit implementation. Students did not investigate electrical conductivity, in an attempt to focus the inquiry on *planning investigations*, *developing hypotheses* and *forming coherent arguments*. As has been mentioned previously, this generally took the form of open-ended questions that attempted to move learning forward. All feedback was task-oriented rather than ego-oriented.

(vi) Advice for teachers implementing the unit

Be brave. Depending on the group and their previous experience of inquiry make the task as open ended as possible. Add blank spaces to the student-self assessment rubrics so they are encouraged to develop their own statements to be assessed.

Include a session where students are asked to develop a list of criteria/rubric for a successful project report before doing a presentation. This would be helpful in guiding them to complete their report