4.2 Case study 2 (CS2 Ireland)

Concept focus	Introduction to IBSE Designing an investigation Production and properties of CO_2
Activities implemented	Activity A
Inquiry skills	Planning investigations Working collaboratively
Scientific reasoning and literacy	Scientific literacy (critiquing experimental design)
Assessment methods	Classroom dialogue Teacher observation Worksheets Student devised materials (group work placemats) Other assessment items (homework exercise)
Student group	**Grade:** 2nd year **Age:** 14 years **Group composition:** Single-sex, males; mixed ability across a significant range of ability (22 students). **Prior experience with inquiry:** limited background in IBSE in terms of critiquing or planning experiments or experimental problem solving. Students are familiar with the concept of lower order thinking (LOT) and higher order thinking (HOT) questions.

In this implementation, the focus of the lesson was on collection and identification of gases. The teacher chose to assess students' skills in *planning investigations* and *working collaboratively*, as well as their *scientific literacy*, as evidenced by their ability to use prior knowledge of gases in this new context, as well as their ability to critique experimental design. The skills were to be assessed formatively in two ways – evaluation of worksheets and group work placemats and teacher observation of classroom dialogue.

(i) How was the learning sequence adapted?

It was envisaged that two 40-minute class periods would be used to demonstrate three methods of generating and capturing carbon dioxide (CO_2), during which the students would use individual worksheets and group place-mats to critique the various methods, leading to a collaborative experimental design. The objective was to encourage students to eventually adopt and improve one of the demonstrated methods or to research/devise an alternative that they would then test and critique, using critical thinking skills developed in the two 40-minute lessons.

As the group were not very familiar with IBSE, the two previous lessons were treated as revision lessons on prior learning with respect to acids and bases. This was necessary to scaffold the students' learning, as they were about to engage in a learning method that they would consider novel. This also allowed students to refresh their scientific vocabulary and be more confident in engaging in open learning in front of peers.

The sequence of teaching/learning was planned as follows:
Lesson 1

1. The lesson started with a teacher demonstration of the dissolution of an effervescent vitamin C tablet in a glass of water (on a trolley at the top of the room).
2. Students spent 5-10 minutes filling in a worksheet, answering the question "Write what you saw happening as the vitamin C tablet was dropped into the glass of water"

3. The demonstration was repeated at several stations around the classroom, with different size beakers and volumes of water
4. While students wrote up their observations this prompt question was asked: "If it's fizzing is it dissolving?"
5. A 15-minute brainstorming session followed, in which keywords that students used in their descriptions were noted in the students' "Brainstorm word wall"; this was designed to link explicitly with the school's recently introduced literacy policy with respect to regularly up-dated word walls in each classroom.
6. Students then formed self-selected groups of four and used a place-mat worksheet to list and agree on the factors that would allow identification of a gas. The group view on these was then fed back to the whole class and the frequency of each factor was noted in the "Identification" box on the worksheet. This task took about 15 minutes to complete.
7. Students were asked to consider some questions as they formed their list of identifying factors:
    a. What are the general properties of a gas? Students were given some reminders/hints relating to their study of the states of matter (no fixed shape, no fixed volume, odour, colour, combustion, heavier than air, water solubility).
    b. What helps me tell the difference between gases?
    c. How easy is it to check that property? (i.e. getting students to begin thinking about characteristic properties of a gas that affect eh selection of capture methods)

    During the vitamin C demonstration students had raised the issue of transparency versus colour so some food dye had been placed in a glass of water alongside the vitamin C. The vitamin C demonstrations were left standing during the lesson so that students could refer to this if they felt it was pertinent
8. Students were assigned research homework for the next lesson in the "Identifying a gas" section of the worksheet by setting two questions;
    a. Is it possible to only test one property of a gas to find out which gas it is?
    b. How do we identify oxygen, carbon dioxide and hydrogen in the laboratory?

    Students were encouraged to research these questions using sources other than their textbook (many in this group tend to view "the book" as the only suitable source of science knowledge).

Lesson 2

1. The start of the lesson included a recap of the previous lesson and then students were asked to keep in mind their research answers when observing the three gas capture methods (as detailed the original unit).
2. This part of the lesson revealed that many of the students had correctly identified the characteristic simple tests for oxygen, carbon dioxide and hydrogen gases.
3. The balloon (A), syringe (B) and gas jar (C) methods were demonstrated by the teacher (30 min).
4. Unlike many demonstrations where only a result or run-through of a method is required, it was felt important that students see how the three methods were set-up, and the organisation and physical effort required for each in order to properly critique the methods.
5. Each method was demonstrated twice to allow student observation.
6. Students posed and answered questions of the teacher and peers. The time taken to run each demonstration allowed for much comment and teacher-student interaction.
7. Prompt questions were asked to encourage students not only to critique the method but also the teacher's skill in carrying them out (as an analogue to their own dexterity/skill)
    a. How much gas was collected?
    b. Was it measureable?
    c. Was the equipment easy to use?
    d. Did the method capture all the gas produced?
    e. Were all factors fairly compared? e.g. the vitamin C tablets had to be crushed to fit into the soft drinks bottle but not so for the Buchner flasks

f. Did I (the teacher) make mistakes?
g. Is safety an issue?
h. Which method is quicker?
i. Is a fast method a good thing? Why?

8. The pros and cons of each method were summarised on the whiteboard through whole class discussion and noted by students on their worksheets.
9. Students were then set a research homework to either adopt and further develop one of the three methods based on their critiques so far, or to devise/find another method using standard laboratory equipment that they were familiar with or adaptable non-specialised equipment e.g. soft drinks bottle, or kitchen-sink science equipment. This exercise was set over a weekend to allow suitable time for student to consider their responses. It was emphasised to students that the method of gas capture was most important as that provided the sample of gas to test; the characteristic tests were important to know but not the priority of the exercise.

(ii) Which skills were to be assessed?

Three skills were identified for assessment during this implementation of the unit:

1. *Planning investigations* by critiquing a selection of gas capture methods;
2. *Working collaboratively* by sharing criticisms of methods in small groups and whole-class;
3. *Scientific literacy* – using prior knowledge of acids/bases and characteristic testing of O_2, CO_2, and H_2 in a novel setting in combination with contextual knowledge of effervescent vitamin tablets and with appropriate keywords.

The skills were to be assessed formatively in two ways:

- Completion of the various sections of the worksheet and group-work place-mat
- Teacher observation during group-work, whole-class discussion and Q&A

(iii) Criteria for judging assessment data

A specific assessment rubric was not developed for this activity, as it was the first occasion for this class group to engage in IBSE to such a significant extent. It was felt that, as this was an introductory activity for this group, it was important to familiarise the students with the process of an IBSE series of lessons and to encourage meaningful engagement by students.

This group of students are familiar with being given the criteria of success during lessons/exercises; however there has been a tendency to follow these as if they are a prescriptive recipe for "success". With this in mind the criteria for success during this activity would be benchmarked by:

- A willingness to engage in group-work and whole-class discussion;
- Evidence of engagement with the notion of critiquing investigations which showed some individual thinking/research;
- Genuine attempts at linking prior knowledge to the context at hand beyond regurgitation of the textbook or verbatim records of whole-class discussion/Q&A;
- As there is a wide range of ability present in this group the levels of attainment would be necessarily subjective.

(iv) Evidence collected

Teacher opinion

Students had been advised in advance that these lessons would take a learning approach that was different. The teacher explained that this was intended to revise some previous learning and linked the approach to prospective projects for state exam certification, that is, an introduction to how students would need to work during these projects. This, combined with the novelty of a different approach, was felt to help with student "buy-in" and to increase engagement with the tasks.

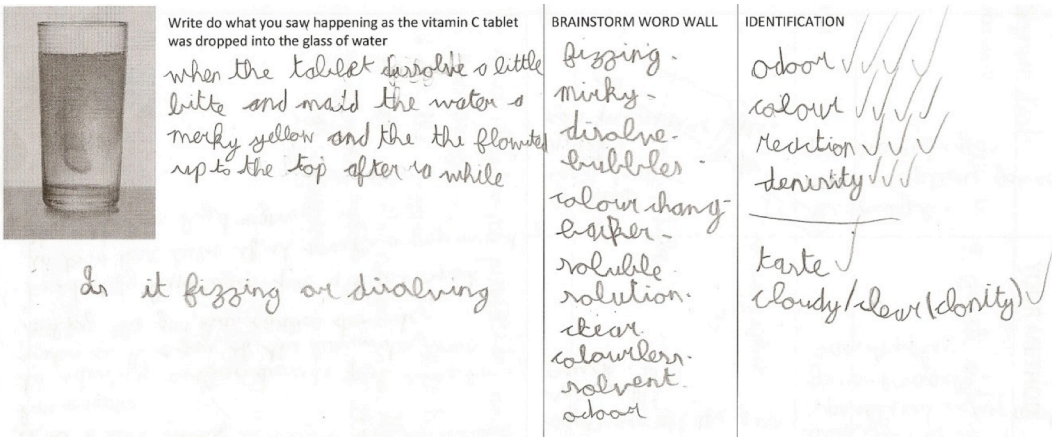
While students enjoyed the prospect of learning without "the book" the reality of engaging semi-independently with the activities evoked an uneven response across the variety of learners. Students appeared to want the safety net of a tightly prescriptive lesson, which would mean less intellectual engagement with the lessons. This was expected to some extent as the range of academic ability in the group ranged from several special educational needs (SEN)/learning support students to normally high achievers. However the lack of engagement became an impediment and the activities were not extended beyond the initial two lessons.

The majority of the students appeared to enjoy developing their own descriptions of the vitamin C dissolution, and critiquing the three demonstrated methods. However, on reflection, brainstorming the critiques as a whole class exercise to be noted by students, rather than letting students create their own written critiques and then brainstorming, was a mistake, as it may have reduced engagement and unintentionally created a teacher-lead impression for students. This was in contrast to the vitamin C demonstration, where the brainstorming afterwards allowed students to see the wide vocabulary that could be used as well as synonyms. It also gave students pause to reflect on the meanings of the words gathered in the context of the demonstration. To avoid the lack of engagement, it may have been better to allow students more time to write up their critiques, and as a consequence extend the demonstrations over two lesson periods (three in total). While students did not seem fully comfortable with a semi-open lesson structure the instinct to revert to a closed approach may have been encouraged by how the critiques of the demonstration methods were managed in the lesson.

Specific rubrics were intentionally not developed as it was intended that students would conduct a self-assessment. This route was taken as the entire exercise was the group's introduction to IBSE and it was felt that unfamiliarity with more open-ended learning combined with the ability range was best supported by a slightly less rigorous approach. Students might feel that they had to perform to an assessment rather than experience a new approach to learning and learn from that experience, and a rubric may tend to encourage a teacher to "hit the mark", rather than allow more genuinely open learning to take place. The teacher involved was anxious to not over-structure the lesson.
A group with more advanced experience of open learning would certainly benefit from a detailed rubric based on the worksheet headings.

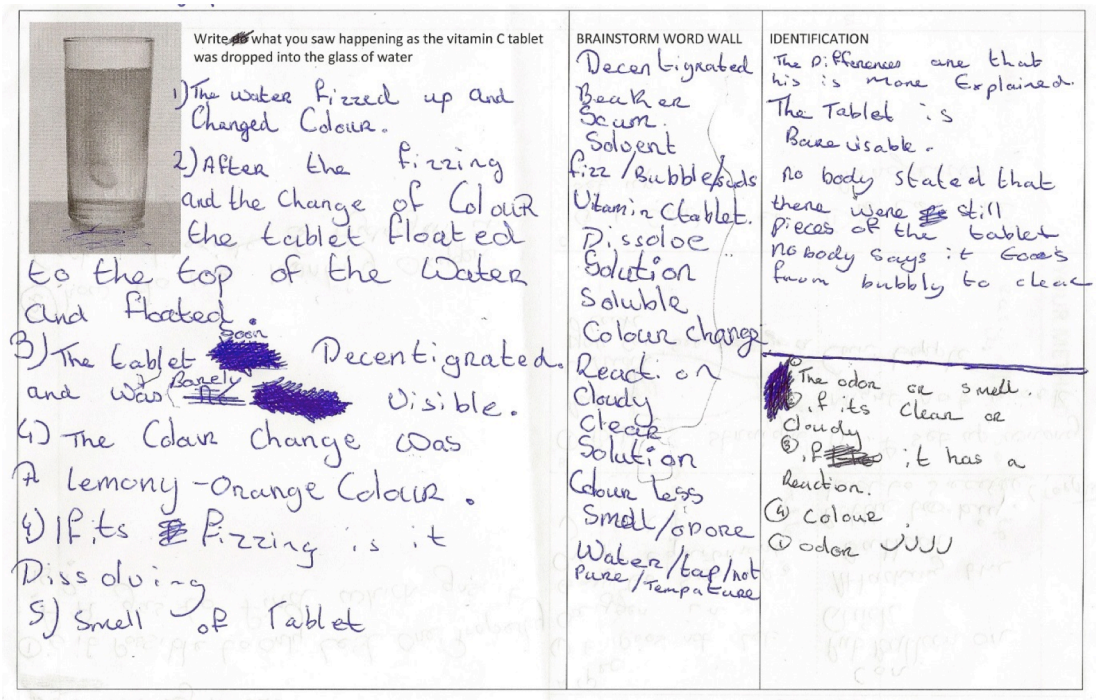
Sample student artefacts

Students A (Figure 1) and B are students with SEN/learning support needs. Student A is the more academically capable (in summative testing) but requires very structured support.



Write down what you saw happening as the vitamin C tablet was dropped into the glass of water:
When the tablet dissolve a little bit[te] and maid the water a murky yellow and the the *[tablet]* ***floated up to the top after a while***
BRAINSTORM WORD WALL
Fizzing, murky, dissolve, bubbles, colour change, darker, soluble, solution, clear, colourless, solvent, odour
INDENTIFICATION
Odour, colour, reaction, density, taste, cloudy/clear/clarity

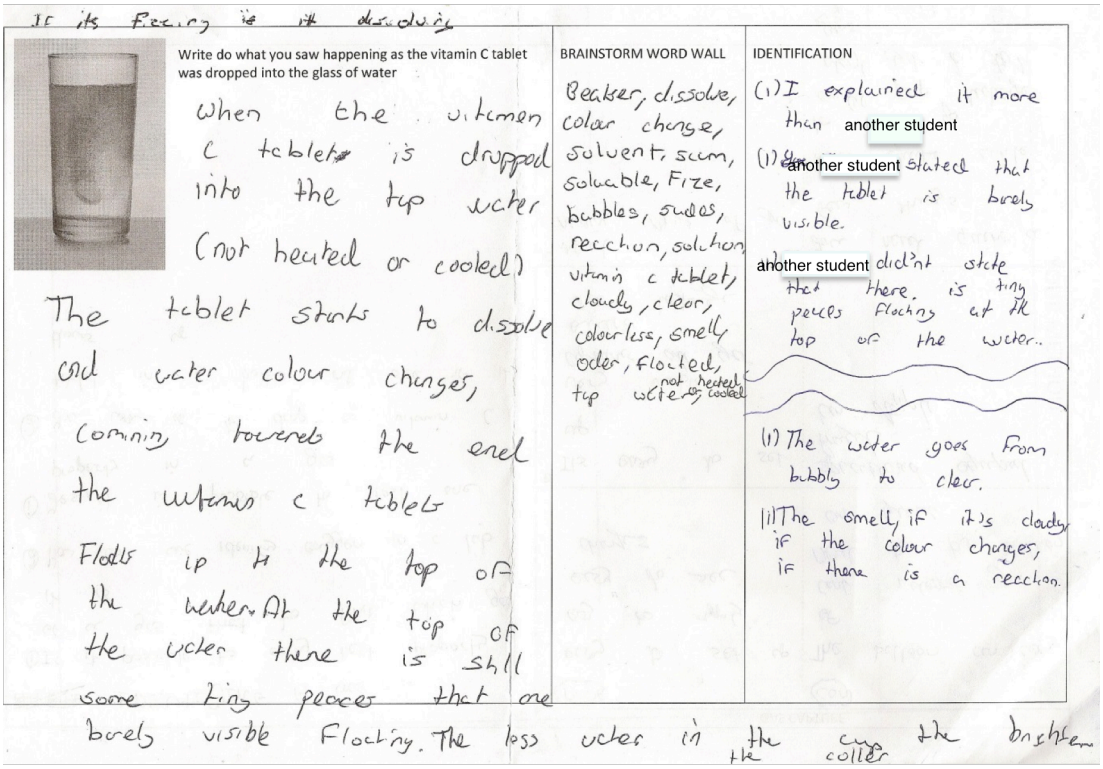
Figure 1: Student artefact from student A



Write down what you saw happening as the vitamin C tablet was dropped into the glass of water:
1) The water fizzed up and changed colour, 2) after the fizzing and the change of colour the tablet floated to the top of the water and floated, 3) the tablet soon disintegrated and was barely visible, 4) the colour change was a lemony-orange colour, 4) if it's fizzing is it dissolving, 5) smell of tablet
BRAINSTORM WORD WALL
Disintegrated, beaker, scum, solvent, fizz/bubbles/suds, vitamin C tablet, dissolve, solution, soluble, colour change, reaction, cloudy clear solution, colourless, smell/odour, water/tap/not pure/ temperature
INDENTIFICATION
The differences are that his is more explained. The tablet is barely visible. Nobody stated that there were still pieces of the tablet. Nobody says it does from bubbly to clear
1) The odour or smell, 2) if its clear or cloudy, 3) it has a reaction, 4) colour, 5) odour

Figure 2: Student artefact from student B

Students C, D and E are in ascending order of ability ranging from average achieving to high achiever (Figure 3, Figure 4 and Figure 5, respectively). All five students gave satisfactory responses when writing up their observations of the vitamin C demonstration, each according to their ability level, with student D making some conclusion regarding the strength of the demonstration solutions. The differing strengths of the demonstration solutions were not explicitly drawn to student's attention until the brainstorming part of the exercise prompted by student observations/conclusions similar to student D.



If its fizzing is it dissolving

Write down what you saw happening as the vitamin C tablet was dropped into the glass of water:

When the vitamin C tablet is dropped into the tap water (not heated or cooled) the tablet starts to dissolve and water colour changed, coming towards the end the vitamin C tablet floats up to the top of the water. At the top of the water there is still some tiny pieces that are barely visible floating. The less water in the cup the brighter the colour

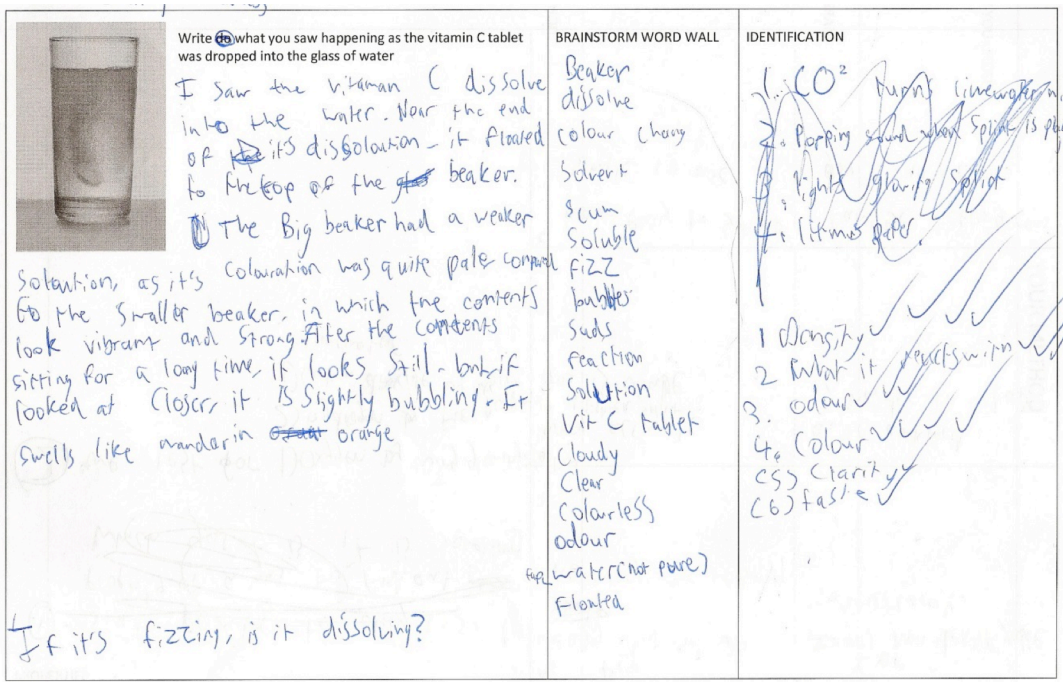
BRAINSTORM WORD WALL

Beaker, dissolve, colour change, solvent, scum, soluble, fizz, bubbles, suds, reaction, solution, vitamin C tablet, cloudy, clear, colourless, smell, odour, floated, tap water, not heated/cooled

INDENTIFICATION

1) I explained it more than *[another student]* ***2)*** *[another student]* ***stated that the tablet is barely visible, 3)*** *[another student]* ***didn't state that there is tiny pieces floating at the top of the water, 4) the water goes from bubbly to clear 5) the smell, if it's cloudy, if the colour changes, if there is a reaction***

Figure 3: Student artefact from student C



Write down what you saw happening as the vitamin C tablet was dropped into the glass of water:

I saw the vitamin C dissolve into the water. Near the end of its dissolution – it floated to the top of the beaker. The big beaker had a weaker solution, as its colouration was quite pale compared to the smaller beaker, in which the contents look vibrant and strong. After the contents sitting for a long time, it looks still, but if looked at closer, it is slightly bubbling. It smells like mandarin orange.

BRAINSTORM WORD WALL

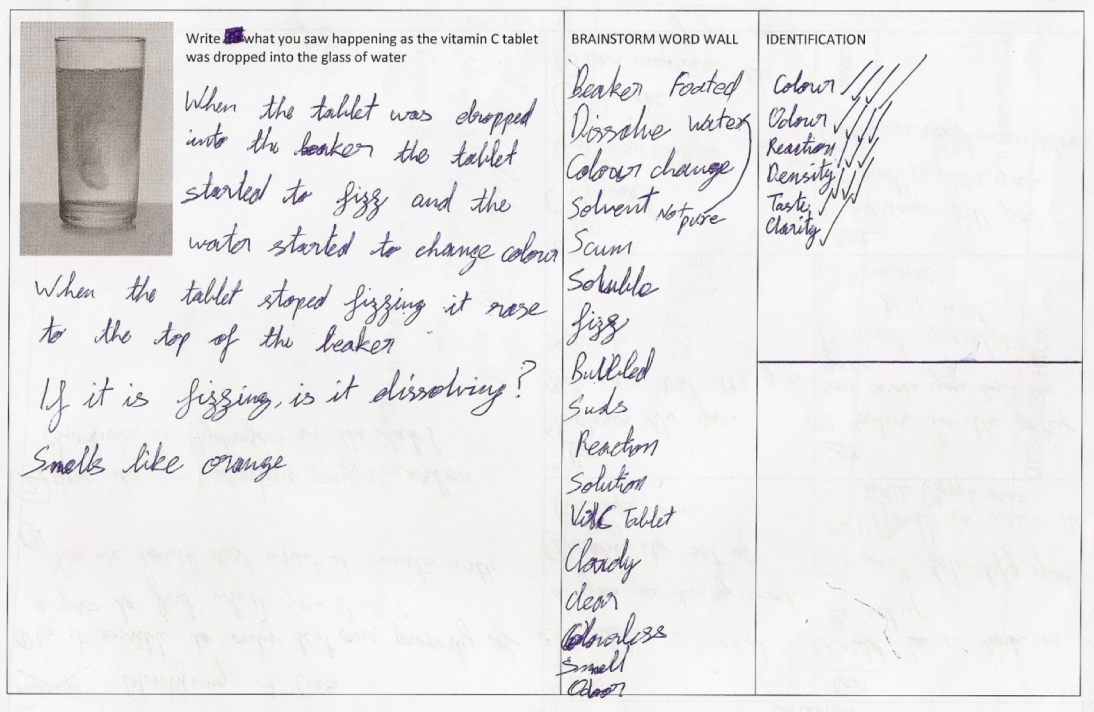
Beaker, dissolve, colour change, solvent, scum, soluble, fizz, bubbles, suds, reaction, solution, vitamin C tablet, cloudy, clear, colourless, odour, water (not pure), floated

INDENTIFICATION

~~1) CO_2 turns limewater milky, 2) popping sound when splint is placed in jar, 3) lights glowing splint, 4) litmus paper~~

1) density, 2) what it reacts with, 3) odour, 4) colour, 5) clarity, 6) taste

Figure 4: Student artefact from student D



Write down what you saw happening as the vitamin C tablet was dropped into the glass of water:
When the tablet was dropped into the beaker the tablet started to fizz and the water started to change colour. When the tablet stopped fizzing it rose to the top of the beaker. If it is fizzing, is it dissolving? Smells like orange
BRAINSTORM WORD WALL
Beaker, floated, dissolve, water (not pure), colour change, solvent, scum, soluble, fizz, bubbled, suds, reaction, solution, vitamin C tablet, cloudy, clear, colourless, smell, odour
INDENTIFICATION
Colour, odour, reaction, density, taste, clarity

Figure 5: Student artefact from student E

The "Identification" section of the worksheet was based on feedback to the class group, based on group work using a placemat (Figure 6). The frequency, indicated by tick marks, arose from collation of the group-work conclusions about what properties of a gas could allow its identification. This collation also prompted some discussion on the ease/difficulty of testing each property.

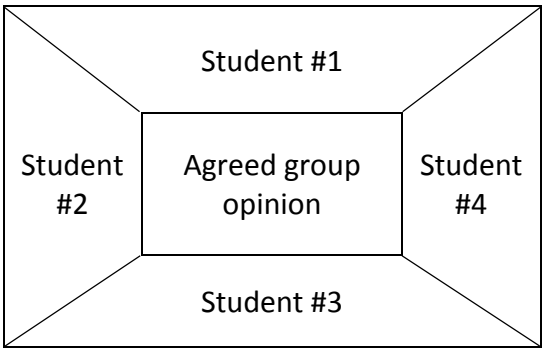


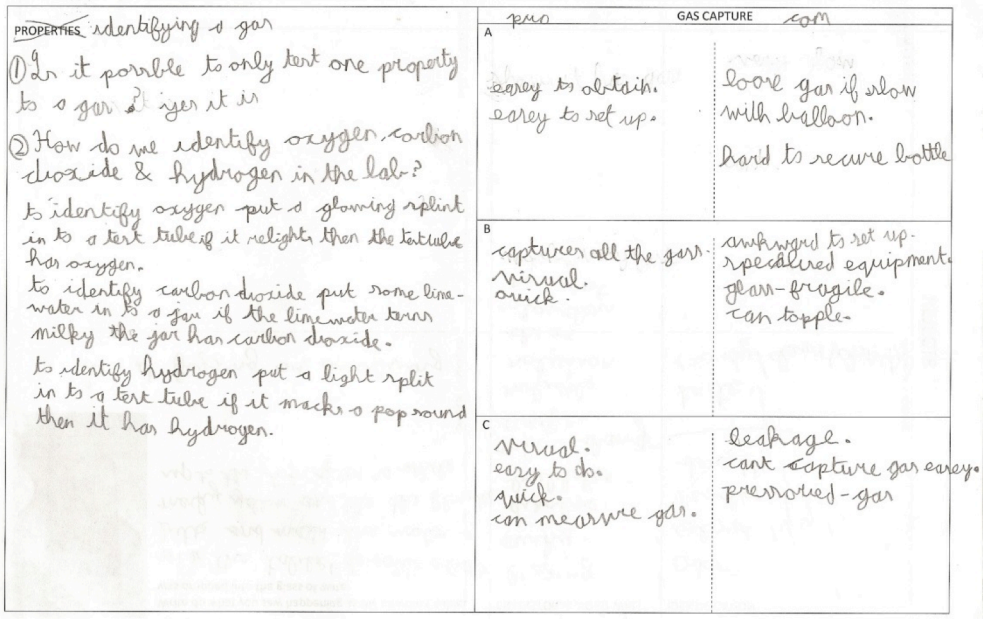
Figure 6: Example of group work placemat

Students were also asked to consider the gases that they had previously produced and the ease with which they could handle/capture/store them. This was done to encourage critical thinking during the demonstration of the gas capture methods.

The students had to respond to two questions as a homework exercise at the end of the first lesson:

- Is it possible to only test one property of a gas to find out which gas it is?
- How do we identify oxygen, carbon dioxide and hydrogen in the laboratory?

The provided student artefact, from student A, is typical of the responses from the majority of the class with a simple yes or no answer with little or no expansion (Figure 7). The lack of expansion in the first question may be due to its phrasing as students were not explicitly asked to justify their response. This was a missed opportunity. The "pro" and "con" lists for the gas capture methods were too restrictive and didn't allow for a student inspired listing and an agreed/brainstormed listing.

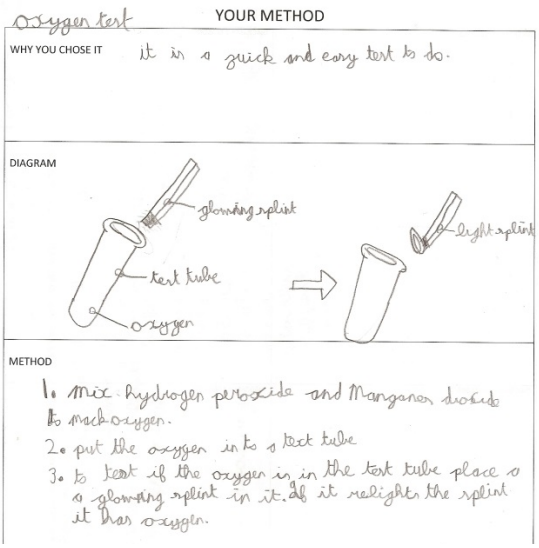


~~PROPERTIES~~ ***Identifying a gas***	GAS CAPTURE	
	pros	***cons***
1) Is it possible to only test one property to a gas? Yes it is ***2) How do we identify oxygen, carbon dioxide and hydrogen in the lab? To identify oxygen put a glowing splint in to a test tube, if it relights then the test tube has oxygen.*** ***To identify carbon dioxide put some limewater in to a jar. If the limewater turns milky the jar has carbon dioxide.*** ***To identify hydrogen put a light splint in to a test tube if it makes a pop sound then it has hydrogen***	A ***Easy to obtain*** ***Easy to set up***	***Lose gas if slow with balloon*** ***Hard to secure bottle***
	B ***Capture all the gas*** ***Visual*** ***Quick***	***Awkward to set up – specialised equipment.*** ***Glass – fragile. Can topple***
	C ***visual. Easy to do*** ***Quick*** ***Can measure gas***	***Leakage*** ***Can't capture gas easily*** ***Preworked*** [?] ***gas***

Figure 7: Student artefact from student A

This part of the second lesson was too directed and closed down open learning, which can be seen from the sample student artefact (Figure 8). Responses to the second question did vary but most were similar to student A's response. While student A obviously focused on how the gas was to be tested rather than how it was to be captured, of the minority of students who attempted this section of the worksheet all simply regurgitated one of the demonstrated capture methods and gave sparse reasons for their choice. No student took the opportunity to adapt/improve any of the three methods nor chose an alternative method from their own research. So few of the students gave a

response to this section, that the continuation into a small group critique and testing of methods could not occur, without repeating much of the second lesson. This was not possible to do in the time available, and would have truncated follow-up activities i.e. moving on to Activity 2: Determining rates of reaction, measuring and graphing rates of reaction.



YOUR METHOD

Oxygen test

WHY YOU CHOSE IT ***It is a quick and easy test to do***
DIAGRAM
METHOD ***1. Mix hydrogen peroxide and manganese dioxide to make oxygen*** ***2. put the oxygen into a test tube*** ***3. to test if the oxygen is in the test tube, place a glowing splint in it. If it relights the splint it has oxygen***

Figure 8: Student artefact from student A

(v) Use of assessment data

Based on the wide range of abilities involved and the lack of engagement/effort regarding the choice of gas capture methods of students, it was difficult to give overall positive feedback as one of the main objectives of the lessons was not achieved to even a minimally satisfactory level.

However students were given much verbal feedback on their observational skills as shown by their write-up of the vitamin C demonstration. They were also commended for their engagement in the first brainstorming activity as they engaged and discussed alternative meanings to the descriptive words used in their observations. Students also engaged positively in the brainstorming/whole-class discussion of the three gas-capture methods.

The collected student work emphasises the need for the teacher to carefully sequence activities to avoid creating a closed approach to the learning by students, i.e. brainstorming should only come after individual/small-group discussions, or be used as a prompt to encourage thinking in a subsequent activity rather than to manage the flow of classroom activities.

(vi) Advice for teachers implementing these activities

- Sequencing of teaching/learning needs to be carefully planned and balanced to foster open learning
- Worksheets should reflect this
- Teaching groups unfamiliar with IBSE need to be scaffolded carefully with suitable prompt questions throughout
- Teaching groups with a wide range of abilities may need to be introduced to less complex activities if prior learning does not scaffold the intended activities sufficiently, and to ensure that students are more comfortable and willing to engage in open rather than closed learning.
- More experienced teaching groups would require a detailed assessment rubric as they would more likely be seeking to achieve progress in comparison to previous activities rather than learning how to become more accustomed to open learning.