

4.2 Case study 2 (CS2 United Kingdom)

Concept focus	Observing/detecting UV radiation Protection from UV radiation
Activities implemented	Activity B
Inquiry skills	Developing hypotheses (asking inquiry questions) Planning investigations (to test hypotheses) Working collaboratively (communication, teamwork)
Scientific reasoning and literacy	Scientific reasoning (analysis and conclusions) Scientific literacy (critical thinking)
Assessment methods	Peer-assessment Self-assessment Student devised materials (documentation of inquiry process) Presentations
Student group	Grade: grade 9 and 10 combined; 2 classes (lower second level) Age: 14-15 years Group composition: single gender (male); 26 “top set” high ability students Prior experience with inquiry: Some prior experience with inquiry, but not with open inquiry

The unit was implemented as part of student’s studies on the electromagnetic spectrum, with high ability students at lower second level. Students engaged in self-assessment of their skills in *working collaboratively*, and peer-assessed poster presentations prepared by other groups. The teacher used a comprehensive four-level rubric for assessment of skill in *developing hypotheses*, *planning investigations*, *communication*, *scientific reasoning* and *scientific literacy*.

(i) How was the learning sequence adapted?

The **UV radiation** SAILS unit was implemented during three 45-minute lessons. Activity B was investigated and the learning sequence followed the steps described in the unit with no significant modifications. The class was divided into 6 groups of 3 students and 2 groups of 4 students, with a mix of ability in all groups (all strong in science).

The students had previously been learning about the electromagnetic spectrum and so this inquiry gave them an opportunity to investigate one of the parts of the spectrum, namely UV light. The context of the investigation was “How can we protect ourselves from UV radiation?” Some introductory slides were shown to the students with pictures of people sunbathing and some gruesome pictures of skin cancer. The different types of UV radiation (UV-A, UV-B and UV-C) were explained then the investigation introduced. This introductory theory could be set as initial research but given that we only had two lessons for the investigation, I decided that the information could be given to the students before the investigation.

As an introduction to the investigation, the principle of fluorescence was explained to them and they were shown the UV beads. We all went outside with a bead to see how they behaved in the light and then what happened when we came back inside. I also demonstrated how to use the UV LEDs and their effect on the beads. I then outlined the skills that would be assessed (but didn’t share the assessment rubrics with them). Finally, they were told that they needed to produce a poster on A3 paper that showed their thought process and evidence of the skill areas that were being assessed.

The structure for the investigation was as follows:

- Lesson 1: The teacher outlined the task; groups were formed and planned what to investigate; groups carried out preliminary experimentation with the equipment. At the end of the lesson, students used a self-assessment guide to identify the three main group skills that they felt they demonstrated (Figure 1). The teacher asked the students to justify why they felt they had shown these skills, which was a useful approach as it added to the reliability of the self-assessment. Student work was collected and teacher feedback was provided based on the planning so far.
- Lesson 2: This lesson started with the students identifying three group skills they would like to demonstrate in the lesson. They then carried out their investigations and prepared a poster of their results (all in class). The teacher marked the work and added comments.
- Lesson 3: Students carried out peer-assessment at the start of the lesson (without teacher feedback) and reviewed what they had learned from the whole process. The teacher again marked student work using a teacher adapted rubric and provided feedback.

(ii) Which skills were to be assessed?

Skills assessed in this implementation include *developing hypotheses* (asking inquiry questions), *planning investigations* (an inquiry to test hypotheses), *working collaboratively* (communication, teamwork), *scientific reasoning* (analysis and conclusion, evaluation) and *scientific literacy* (critical thinking).

All the skills except teamwork were primarily assessed via the notes made on the poster using an assessment rubric (Table 1). These skills were peer assessed by another group before then being marked by the teacher. The groups were instructed to provide constructive feedback that highlighted the positives and possible areas for development on post-it notes.

The teamwork skills were self-assessed using a grid of skills (Figure 1). Before the investigation, each student was given the grid of assessment skills to read through, and then these were discussed to ensure that everyone knew what each skill meant. The importance of these group skills was stressed to the students and linked to crucial life skills they will need when they leave school. This was done to ensure that they would take these more seriously. The students then self-assessed their group skills at the end of the planning stage (first lesson) but were restricted to identifying three skills that they think they had demonstrated (Figure 1). They also had to justify why they felt they had demonstrated that skill. At the start of the second lesson, they returned to their grid and had to identify three skills that they would try to work on in the lesson. This was again reviewed at the end of the lesson. Examples of these can be shown in Figure 2 and Figure 3.

Individual assessment:		Name: _____	
How you did in the group		Date: _____	
<p><i>Ring those achieved. Add any that have been missed out. Say if filled out by pupils or teacher. NOTE: this can be done by the pupil as a self-assessment and can then be discussed by the group to see if they agree.</i></p>			
listening positively	resolve ideas	work towards a common goal	be friendly
be supportive	share tasks	allocate tasks	collaborate
empathise	work with boys/girls/different groups	contribute to discussions without dominating	peacemaker
work under pressure	manage emotions	use resources and equipment without taking over	democratic leader
be prepared to defend viewpoint with consideration	reach agreements	take responsibility	constructive feedback
negotiate	Addition _____	_____	_____

Figure 1: Self-assessment of group skills

During the investigation, I circulated and tried to assess all the above areas as best I could. This was not always easy, but helped give me a better idea when marking their final work. The hardest area to mark was the critical thinking section as this was difficult for the students to evidence on their poster. I judged this mainly on what I had seen as I circulated round the groups.

Table 1: Teacher rubric for assessment of inquiry skills

Inquiry skill	Emerging	Developing	Consolidating	Extending
Asking inquiry questions Developing hypotheses	Discusses some testable questions and agrees on one that they feel is feasible.	Raises a testable question with reasoning from previous scientific knowledge or experiences.	Raises a testable question and forms a hypothesis, which is explained with clear reasoning.	Raises a testable question that forms a hypothesis and explains what results to look for to prove or disprove their theory. Their reasoning is backed up by scientific ideas.
Planning investigations Testing hypotheses	The method involves changing one factor and measuring the outcome but little attention has been paid to controlling variables.	The method changes only one factor and measures the effect. Controlled variables are identified but some are not present or detail of how they were controlled is not given.	The method changes one variable and identifies the major controlled variables. Some detail of how the variables are controlled is provided (but there are better methods available or all the methods aren't workable).	All possible controlled variables are identified and are carefully controlled or monitored to ensure a fair test. Takes steps to ensure that the results are as accurate as possible. The method is clear and rigorous. Uses a control to compare their results to.
Communication	Describes what they did to test their ideas.	Describes what they set out to test and presents their results.	Explains and presents their results and how they tried to be rigorous.	Explains what they set out to test, presents their results and discusses their confidence in the results and suggests possible improvements.
Analysis and conclusion	States the results and suggests a pattern (or lack of pattern).	Presents the results, identifies a pattern (or lack of) and attempts an explanation.	Presents the results clearly, correctly identifies a pattern (or lack of) and explains it using sound reasoning. Attempts to comment on the quality of the results (whether it is a clear pattern or less clear).	Attempts to quantify the outcome so that it is less subjective. Presents the results clearly and states the strength of pattern in the results clearly. Forms a conclusion and fully explains it using scientific understanding. Does not overstate results and patterns (e.g. emphasising patterns that are barely there).
Evaluation	Comments on the accuracy of the results or suggests vague errors (e.g. human error).	Identifies at least one source of error and how this could be improved in the future. Possibly considers the number of repeats.	Makes a valid comment on the reliability and accuracy of the experiment, with reference to the results. Identifies any anomalies. Identifies more than one source of error and suggests improvements.	Critically assesses the reliability of the results. Comments on the subjective nature of the outcome and suggests improvements to make it more objective. Identifies almost all of the flaws in the method and suggests improvements that will have a positive effect.
Critical thinking		When one idea is not successful, the group come up with another idea without analysing why the first has failed.	The group look critically at their ideas and consider how to improve their design, sometimes with significant changes.	The group look for ways of improving the design by refinement or by comparing with a different approach. They think critically about what will and will not work. They evaluate their experiences to inform changes.

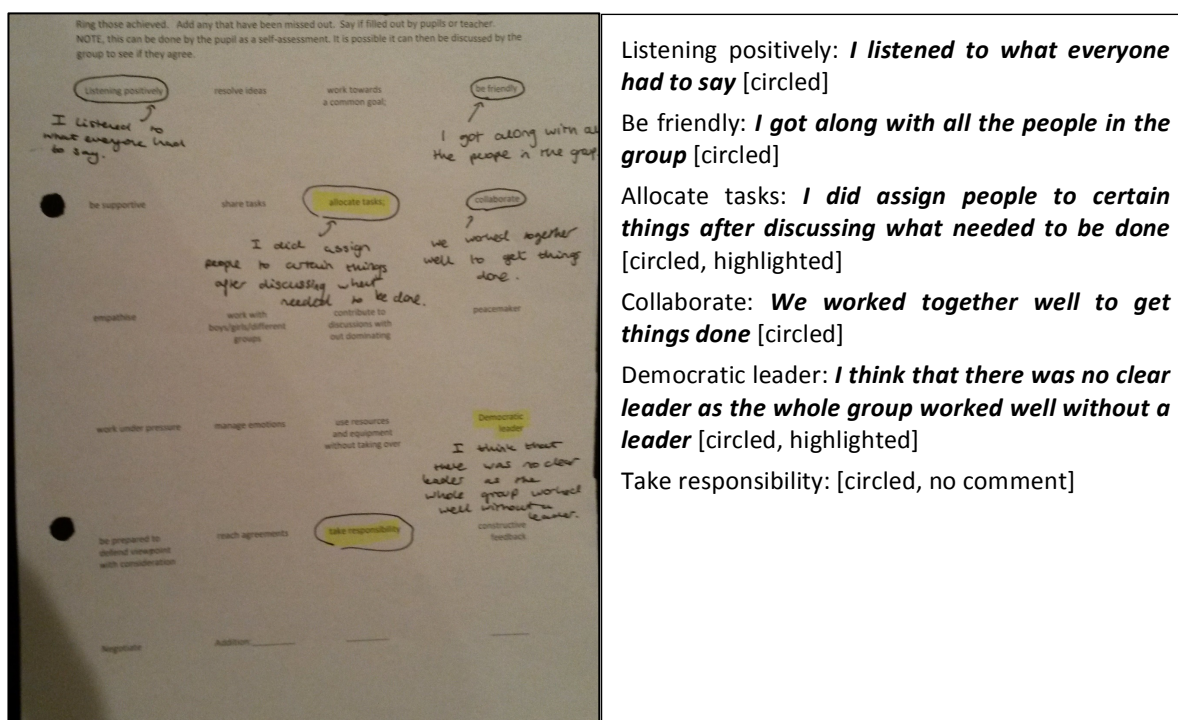


Figure 2: Example of responses to self-assessment

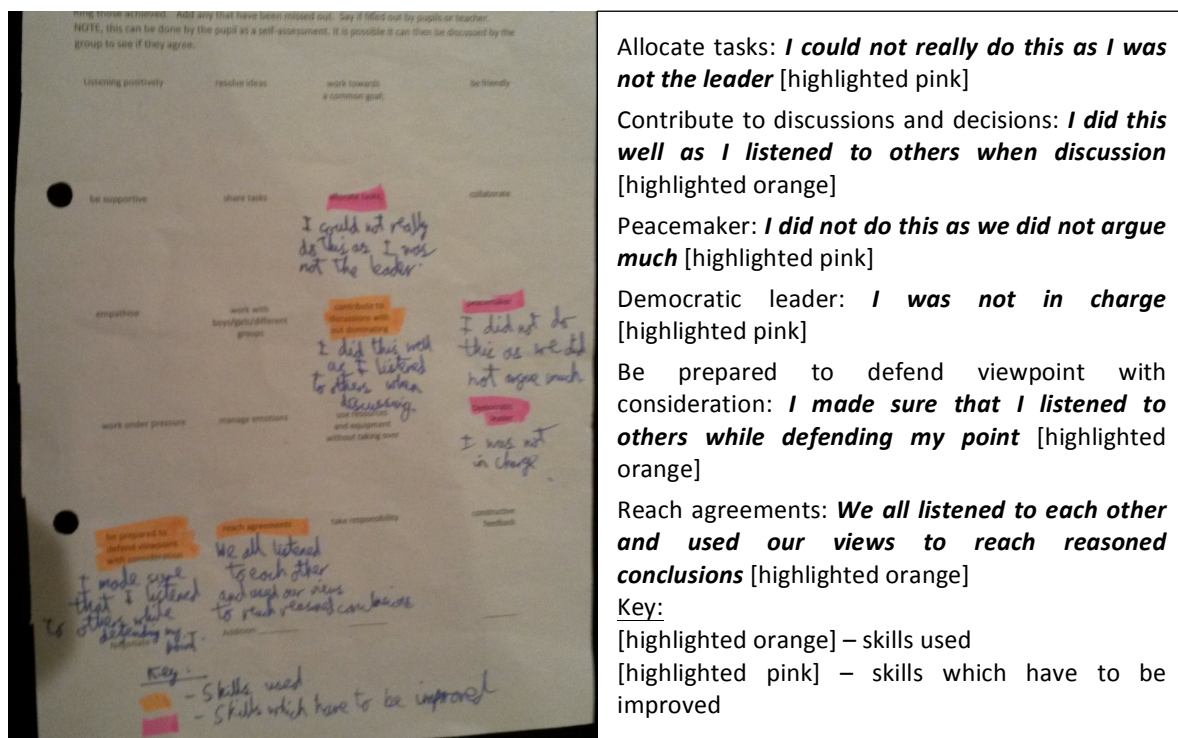


Figure 3: Example of responses to self-assessment

(iii) Criteria for judging assessment data

My overall expectation of what I wanted the students to do during the investigation was for them not to rush into the task and give plenty of thought to how to make the investigation as accurate and valid as they could (Figure 4). I expected them to document their planning process as well as the actual investigation. The planning procedure was not always as clearly documented as expected which meant that some groups weren't credited for all the skills that they actually used.

Formative assessment was used through questioning of the groups, written feedback after the planning stage and through the formulation of targets for future investigations at the end of the investigation. The allocation of a level of competency for each strand at the end of the investigation was an example of summative assessment, although the grid did show the students what they needed to do to improve further.

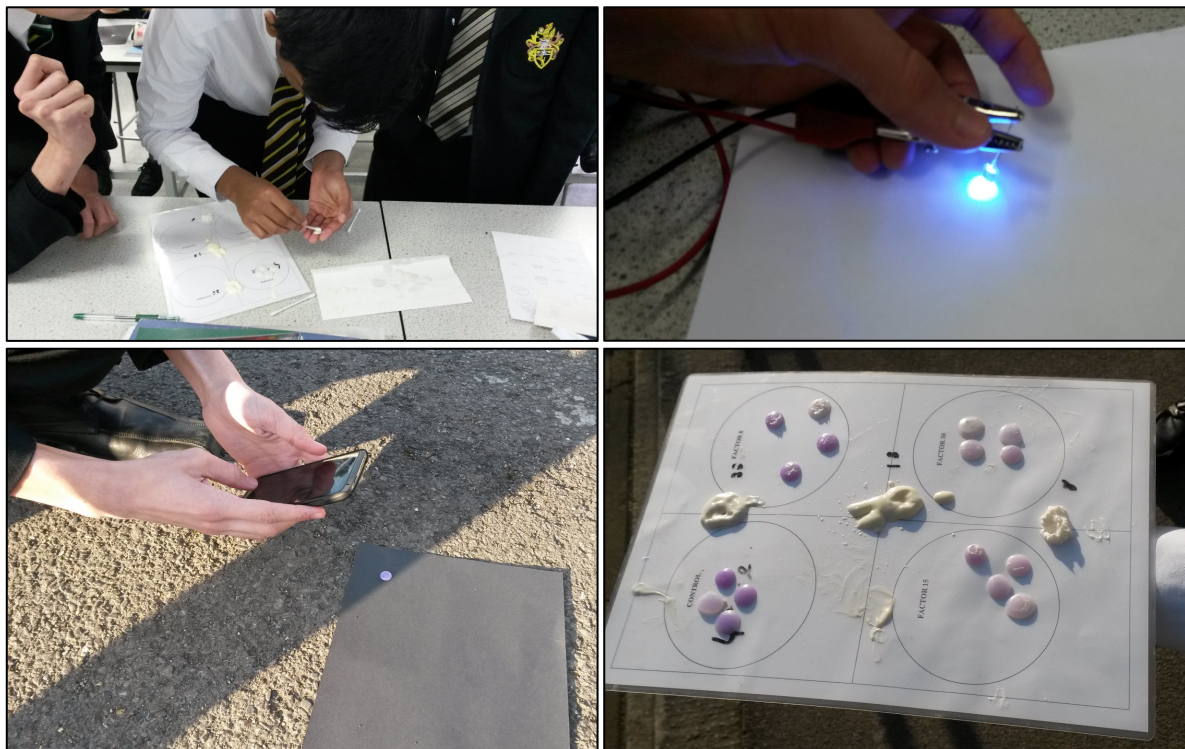


Figure 4: Images from implementation of the unit. Top left: applying sunscreen using a cotton bud, top right: using a UV LED to expose a UV bead, bottom left: using a camera phone to photograph the colour of the bead, and bottom right: testing different factors of sunscreen.

(iv) Evidence collected

Teacher opinion

The students really seemed to enjoy the inquiry task. A quick assessment at the end of the second lesson found that they felt that they had learnt a lot about how to conduct an accurate inquiry, especially the kind of detail needed to get into the *extending* category. The original UV investigation guidance sheet didn't have an assessment rubric so I used the 'floating orange' case study as a basis and added my own criteria.

The students were generally around the *consolidating* skill level, although their evaluation skills were not as strong as I had hoped. The students worked effectively in teams to produce their investigations but were quite antagonistic towards each other at times, particularly when peer assessing each other's work. This was not a big surprise as the top set students often see themselves as being in competition with each other.

I was most impressed with some of the creative ways in which the outcome was measured. A lot of groups recognised that "purpleness" wasn't a great measure and so tried to quantify it. One group used the RGB value from their camera image to get a more objective measure of "purpleness" (Figure 5).

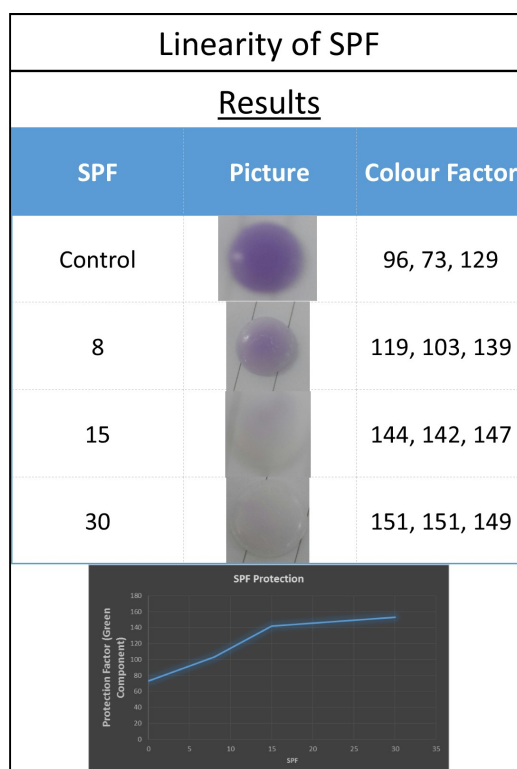


Figure 5: Example in which students used RGB scale on camera image to measure “purpleness”

I felt that the assessment of the task was relatively straightforward, although choosing which band to put some groups in was a challenge and I’m not 100% sure I got it right! Assessing their critical thinking was tricky as this wasn’t evident from their poster in most cases. To assess this, I based it on my observations of the groups as I went round the class in both lessons. When I do this task again in the future, I think I will keep much the same format (written feedback after lesson 1 and 2, peer assessment in lesson 3 and a final mark).

There were some nice questioning moments of groups where I challenged some of their ideas and they justified their reasoning. Some groups were asked probing questions like “How could ensure this is done the same way each time?” “Will the results always be like this?” “How sure are you of your results?” etc. to develop their ideas.

The rubric sheets seemed to be fairly well understood by the students but might need to be reworded for less able students.

The group skills sheets were purely self-assessed. The assessment doesn’t seem to be too reliable but it did give them an opportunity to reflect on how they interact with other people in their group. Getting the students to justify why they felt they had shown that skill was useful and added to the reliability of the self-assessment. These group work skill sheets will be used again in the future for group tasks and so they can build up evidence of the skills achieved.

Sample student artefacts

Three examples of student work are shown.

Example 1: This was a strong investigation (Figure 6). Rather than measuring “purpleness” they looked at how long it would take for the bead to return to its original colour. When I questioned if this was a valid method, they explained their reasoning very well. By timing how long it took to return to its original colour, they were able to get a quantitative result rather than qualitative. They

probably should have produced a graph of their results though. They engaged well with my feedback comments and ran a pilot experiment to test the viability of their method.

To measure the degree level of protection:
measure the amount of time it takes for the UV beads to turn back to their original colour after being exposed to UV light for a certain amount of time

1 day for means of protection:
• Suncream
• Covering it in different materials
• Different layers

Control Variables
Diameter of beads - We controlled these two by using a clamp stand to fix both the height of the light and the diameter of the light. We controlled the diameter of the bead by collecting beads with a similar diameter, although this series in this will be a source of error
Pilot Experiment
Through doing this, we tested that the beads all worked, and used the visible diameter of UV light that we would use. In the pilot experiment, we determined the length of time the beads should be exposed for

Method
1. Wash hands, cover bead in suncream factor
2. Place bead on black cloth
3. Move beads so it's underneath the UV light of diameter 1.5cm
4. Time for 2 minutes
5. Take bead from under UV light and using a compass, purple, keep the time taken for the bead to return to white
6. Repeat experiment with Factors 8, 15, and 30 suncream, and a control bead without suncream, and note results

Equipment
- 4x6 volt battery pack
- Ultraviolet light emitting tube
- Clamp stand
- Multiple beads
- Factors 8, 15, and 30 suncream
- Black cloth
- Stopwatch

Sources of error and areas for improvement
- It was difficult to control the amount of sun cream applied. Using a spatula may help this, but it still wouldn't be perfect. A spray system may be most ideal.
- It was subjective as to when the UV bead turned back to its original colour. Using a colourimeter may help this.
- The sun cream is designed for skin. It wouldn't protect UV beads in the same way.
- We could have repeated the experiment 3 times and taken the mean to make the result more reliable

Results Table
Time taken for bead to return to white

Factor	Time (min)
Control	2:56 (mean of 2)
Sps 8	3:00
Sps 15	2:36
Sps 30	2:25
Sps 40	2:20

Interpretation of Results
We found our hypothesis to be correct, as there was a clear inverse proportional relationship between the factor of suncream used, and the time taken for the bead to return from purple to white. This was the case in all experiments apart from SPF8. We believe that this result was either an anomaly, or SPF8 suncream, due to being such a low factor, was essentially useless, contributing negatively to the protection of the bead.

Final question:
To what extent do higher factor sun creams protect you more from UV radiation?

hypothesis: initially, it will be a linear relationship but it will eventually plateau because UV light is too weak. We expect that the period of time it takes, in seconds, for the beads to change from purple, due to their exposure to UV light, to white, will be inversely proportional to the strength of the sun cream used, measured in SPF

What will that look like in your results?
What do you expect to measure?

Amount of suncream: while this was hard to completely control, we put 3 coatings of cream over each bead, making sure each coat was visible. Therefore the small amount of cream cream was quite small. We applied using fingers and would hands between each different factor.

Figure 6: Example 1: Student posters with peer feedback (yellow post-it) and teacher annotation (red pen)

Initially, they hadn't mentioned what the expected results would look like so got *consolidating* for the asking inquiry questions section rather than *extending* (Figure 7). Their evaluation recognised the difficulty of how to judge when the bead had returned to its original colour, which was the biggest source of error. They didn't notice that the experiment could have been done as a blind experiment

(where the person performing the measurement doesn't know which factor is being used) to try to eliminate confirmation bias. This was discussed with the group after. Despite this, I felt that the evaluation was still strong enough to achieve a *consolidating* level.

D - what has done what could be improved

	Emerging	Developing	Consolidating	Extending
Asking Enquiry Questions	Discusses some testable questions and agrees on one that they feel is feasible	Raises a testable question with reasoning from previous scientific knowledge or experiences	Raises a testable question and forms a hypothesis. This is explained with clear reasoning.	Raises a testable question that forms a hypothesis and are able to explain what results to look for to prove or disprove their theory. Their reasoning is backed up by scientific ideas.
Plan an Inquiry to Test their ideas	The method involves changing one factor and measuring the outcome but little attention has been paid to controlling variables	The method changes only one factor and measures the effect. Controlled variables are identified but some are not present or detail of how they were controlled is not given	The method changes one variable and identifies the major controlled variables. Some detail has been given to how the variables will be controlled (but there could be better methods available or all the methods aren't workable)	All possible controlled variables are identified and have been carefully controlled or monitored to ensure a fair test. Steps have been taken to ensure that the results will be as accurate as possible. The method is clear and rigorous. A control has been used to compare their results to.
Communication	Described what they did to test their ideas	Describe what they set out to test and presented their results	Explained and presented their results and how they tried to be rigorous	Explain what they set out to test, presents their results and discusses their confidence in the results and suggests possible improvements
Analysis and Conclusion	The results have been stated and a pattern (or lack of) suggested	The results are presented, a pattern (or lack of) is identified and an attempt at an explanation made.	The results are presented clearly, a pattern (or lack of) is correctly identified and sound reasoning applied to explain it. Some attempt has been made to comment on the quality of the results (whether it is a clear pattern or less clear)	An attempt has been made to quantify the outcome so that it is less subjective. The results are presented clearly and the strength of pattern in the results clearly stated. A conclusion is made and fully explained using scientific understanding. Results and patterns are not over stated (e.g. emphasising patterns that are barely there)
Evaluation	A comment is made about how accurate the results are or vague errors are suggested (e.g. human error)	The evaluation identifies one source of error and how this could be improved in the future. The number of repeats is possibly considered.	A valid comment on the reliability and accuracy of the experiment has been made with reference to the results. Any anomalies have been identified. More than one source of error has been identified and improvements suggested.	The reliability of the results have been critically assessed. The subjective nature of the outcome has been commented on and improvements suggested to make it a more objective measurement. Almost all of the flaws in the method have been picked up on and improvements that will have a positive effect suggested.
Critical thinking		When one idea was not successful, the group came up with another idea without analysing why the first had failed	The group looked critically at their ideas and considered how to improve their design, sometimes with significant changes	The group were looking for ways of improving the design by refinement or by comparing with a different approach. They think critically about what would and won't work. They evaluated their experiences to inform changes

Good use of pilot experiment.

Figure 7: Teacher grading of example 1.

Example 2: This was another very good investigation but was missing some information in key areas (Figure 8). The hypothesis needed to be backed up scientific ideas to get to *extending*. The analysis of the results was very clever but the pattern needed to be more fully described rather than just being presented. This group used the RGB value from their camera image to get a more objective measure of "purpleness" (Figure 5).

Example 3: A good investigation but lacking in some areas (Figure 9). The hypothesis needed to be more clearly set out as they contradicted themselves. The measurement of results was not as sophisticated as other groups and just compared the different results. There was some confusion in the write up as to what was actually being measured (diameter of purple area was suggested in one part). The evaluation was probably somewhere between developing and consolidating. The rubric could be changed to make there less of a step between the two levels.

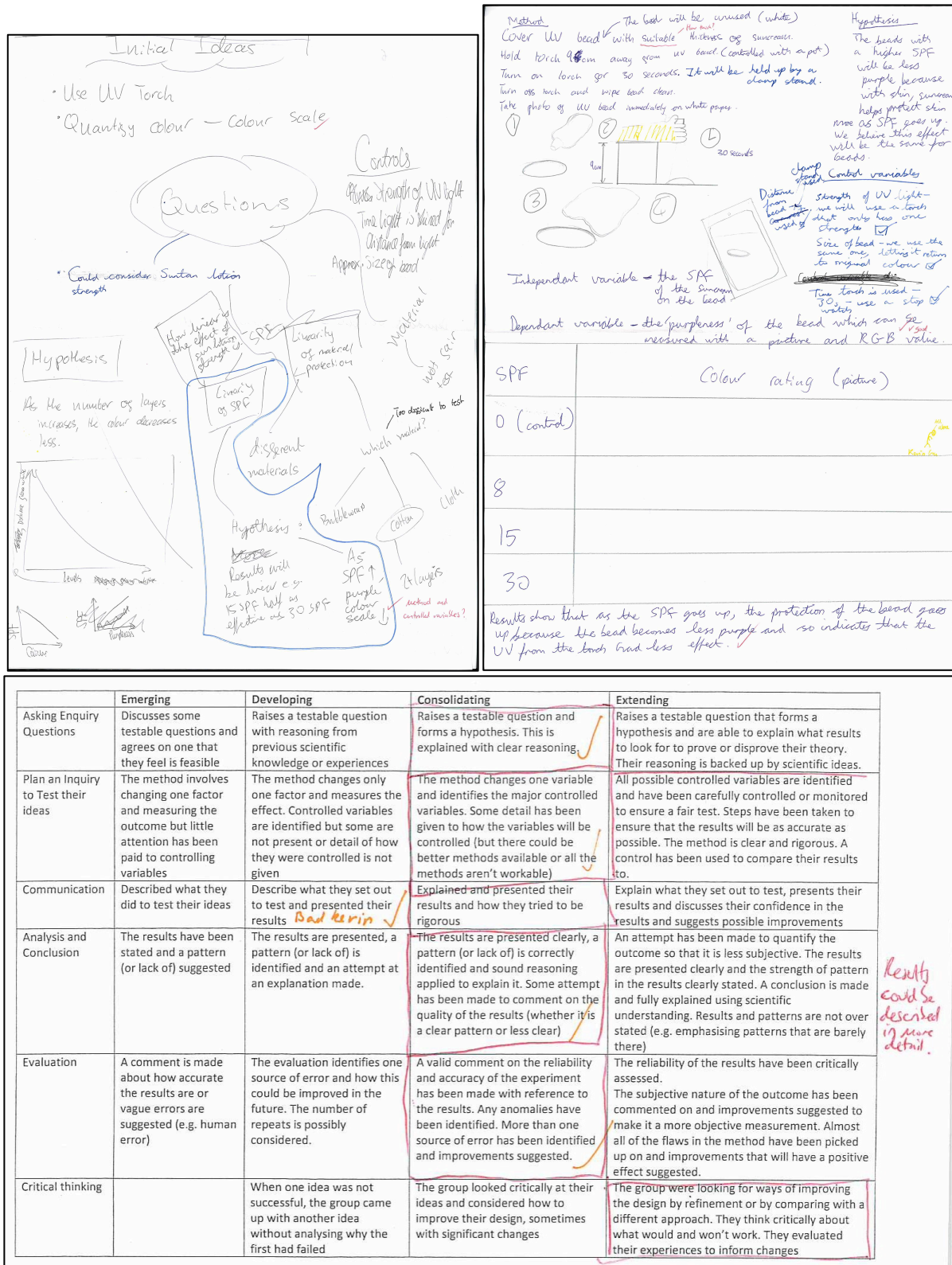


Figure 8: Example 2: Student poster with peer assessment annotation and teacher feedback (red pen); teacher grading on rubric

(v) Use of assessment data

Feedback to the students was provided in the following ways:

- Oral feedback through questioning during the lessons
- Written feedback in the form of brief questions after the planning lesson
- Peer assessment of the final poster
- Self-assessment of group skills at the end of lesson 1 and 2
- Teacher marking of the final work and a competency level allocated

Having completed this investigation, I now feel that I have a better understanding of the competency of the students in the investigation skills areas assessed. As a class, I have noted that their evaluation skills and peer assessment skills need improving, particularly in the way that they give and receive feedback, which felt like a criminal trial at times! With this information, I plan to build in more group feedback opportunities in my everyday teaching and use the peer assessment rubric to help guide the students towards given more sensitive feedback. I will also increase the opportunities to evaluate experimental procedures in our next topic.

I have kept a record of the level of competence they received in each of the areas in a spreadsheet so that I can compare it to future investigation tasks and attempt to track progress. The same group work grids will also be used again so that the students can monitor which areas they are not demonstrating and so still need to work on.

(vi) Advice for teachers implementing the unit

Safety using the UV LEDs: Make sure that the UV LEDs are only shone on the beads downwards and onto black paper to reduce the possible exposure of UV to the students' eyes. UV LEDs were purchased from the Mindset website: (<http://www.mindsetonline.co.uk/Site/Home>)

The group work skill sheets contain a lot of skills and the students will be keen to circle all of them. Giving them time to read through them all and then explaining the trickier areas helps prepare them for self-assessment. I chose to get them to only identify three main skills they had used at the end of the lesson and explain how they had demonstrated these skills. This prevents students from circling every skill in the grid. Despite explaining this, there were still some that circled most of the skills, so do stress that you only want three! Using the start of the second lesson to look at the group work skills that they wanted to work on seemed to work well and helped them to refocus on the group skills that they were trying to develop.

A lot of students came up with the idea of photographing the results using a camera phone. If clear expectations of proper use are made in advance, this works well. If this is a potential issue, use a class set of cameras. The white balance of the camera should be set to a manual setting (e.g. daylight or cloudy) rather than auto, as the camera will adjust the colour differently for each picture (affecting the validity of the results).

Encourage students to bring in their own materials (e.g. T shirts that might wear in the sun, etc.). This helped expand the possibilities and not limit them to just the material available.

Allocating specific roles to students within the group will aid the task if you have groups that don't function well (e.g. scribe, time manager, questioner/challenger, etc.)

Build in some time at the end of each lesson for them to review their group skills so that this is a meaningful exercise rather than being rushed.