4.1 Case Study 1 (CS1 Ireland)

Concept focus	Development of inquiry skills States of matter – gelatine structure
Activities implemented	Activities A-C
Inquiry skills	Planning investigations Forming coherent arguments Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (proportional reasoning)
Assessment methods	Classroom dialogue Teacher observation Self-assessment Worksheets Student devised materials (pudding; final report) Presentations
Student group	**Grade:** transition year (an optional year offered to students at senior cycle with the purpose of providing broad educational experiences in order to increase maturity, personal development, learner responsibility, transferrable skills and decision making before proceeding to further study.) **Age:** 15-16 years **Group composition:** single sex (female), mixed ability (half of the students had not studied science before) **Prior experience with inquiry:** Limited exposure to inquiry teaching and learning approaches.

The core skills assessed in this implementation were *planning investigations*, *working collaboratively*, *scientific reasoning* (critiquing experimental design) and *forming coherent arguments*. The skills were assessed through teacher observation, classroom dialogue and by reviewing written artefacts. The teacher used a combination of formative and summative assessment, in which each student's performance was measured against pre-developed criteria. The teacher provided a student rubric, to serve as a brief instructional guide and to motivate the students.

(i) How was the learning sequence adapted?

The **Proof of the Pudding** SAILS inquiry and assessment unit outlines a range of possible inquiry skills and concepts that a teacher can explore whilst following the prescribed learning sequence. This case study focused more on the development of inquiry skills than conceptual development. The inquiry skills chosen were *planning investigations*, *developing hypotheses*, *working collaboratively*, *scientific reasoning* (critiquing of experimental design) and *forming coherent arguments*. The content that was addressed in the case study was states of matter, gelatine structure and nature of science. The adaptations made by the teacher were decided upon based on the short time available (three 80-minute lessons) and students' limited previous experience of inquiry and science. The teacher noted that he simplified the unit as he did not want to overwhelm his students and wanted to focus on inquiry ideas built around 'scientific protocol'.

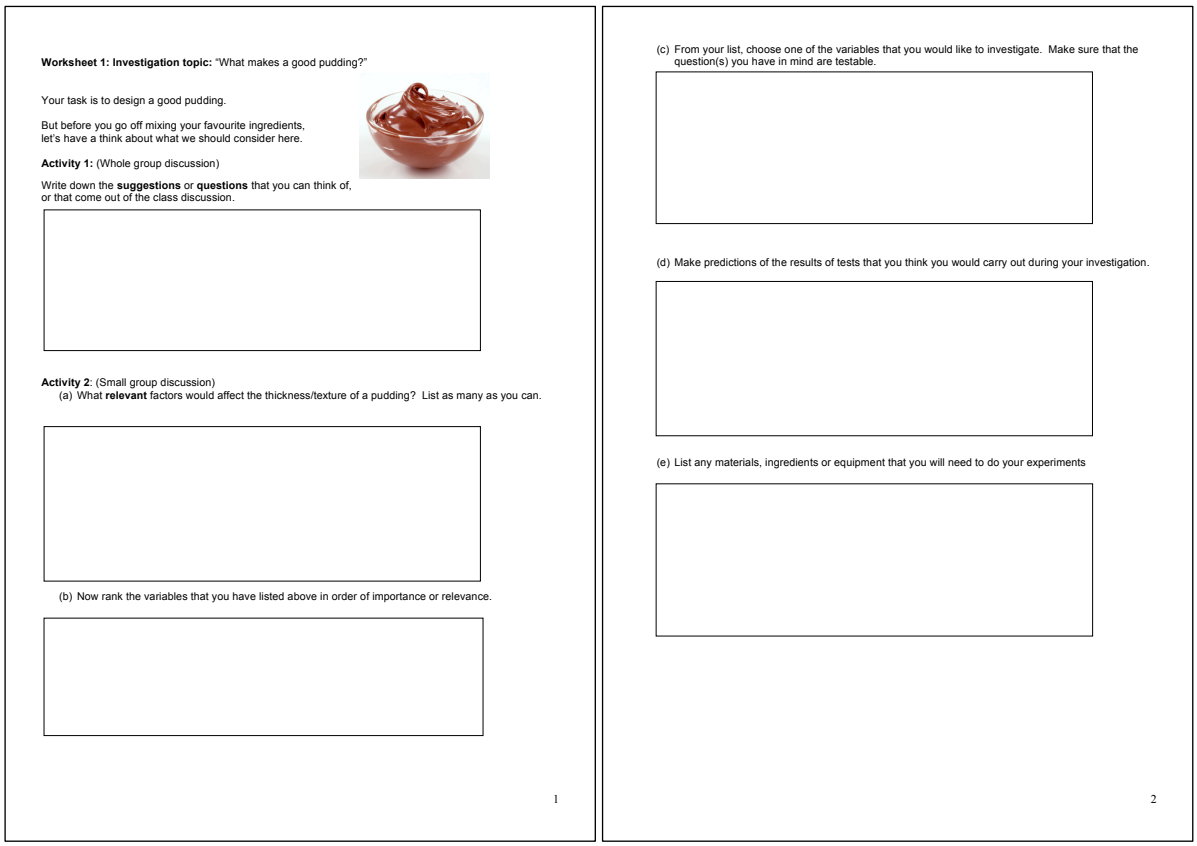
The teacher followed the general sequence outlined in the unit i.e. (1) preparation for inquiry (2) planning investigation and carrying out the inquiry and (3) evaluation and feedback. The teacher also used the context of making a pudding and some of the questions outlined in the learning sequence to frame this case study.

In the first lesson, the teacher implemented Activity A: Preparation of inquiry and the first part of Activity B: Planning an investigation. As a warm-up exercise, the students were given an outline of the forthcoming classes and then the teacher introduced the inquiry task question: "Can you design a good pudding?" Using a worksheet (Figure 1), the teacher guided the students through a list of tasks, including class level discussion on what factors make a pudding "good" (guiding them to the factor of thickness/texture). The student groups then discussed the factors that would affect thickness/texture. This lesson focused on the inquiry skill of *planning investigations*. The teacher provided formative assessment through observation and questioning, as well as evaluation of students' worksheets using a rubric. Students were given a student-accessible rubric related to *planning investigations*, in which the teacher highlighted areas that would be assessed throughout the three classes.

The teacher assigned homework to be completed before the next class:

1. Investigate gelatine – what it is, where does it come from, what is its structure?
2. Complete and individual plan to investigate "how can we achieve the best pudding?" based on the variable you selected to modify.

Note: Students were given a list of ingredients to help them identify factors that influence texture



Worksheet 1: Investigation topic: "What makes a good pudding?"

Your task is to design a good pudding.

But before you go off mixing your favourite ingredients, let's have a think about what we should consider here.

Activity 1: (Whole group discussion)

Write down the **suggestions** or **questions** that you can think of, or that come out of the class discussion.

Activity 2: (Small group discussion)

(a) What **relevant** factors would affect the thickness/texture of a pudding? List as many as you can.

(b) Now rank the variables that you have listed above in order of importance or relevance.

1

(c) From your list, choose one of the variables that you would like to investigate. Make sure that the question(s) you have in mind are testable.

(d) Make predictions of the results of tests that you think you would carry out during your investigation.

(e) List any materials, ingredients or equipment that you will need to do your experiments

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Figure 1: Worksheet 1 for CS1 Ireland

In the second lesson, the teacher implemented the second part of Activity B: Carrying out an investigation. This lesson focused on the inquiry skills of *planning investigations* and *working collaboratively*, as well as *scientific reasoning* (proportionality). Assessment methods included teacher observation and questioning, as well as evaluation of students' worksheets (worksheet 2, Figure 2) using a rubric. Two additional groups joined the class in this lesson. The homework activity (criteria for a "successful pudding" focusing on texture) was used as a resource for the teacher to lead a discussion on how the groups would approach the task. This provided an introduction for the new groups, and revision for the whole class. The students were then given a more detailed recipe

and asked to revise and refine their plans, and to note what variable they were evaluating. Students then carried out the experiment of "making the pudding", while the teacher circulated to observe and ask questions. Students were given a gelatine sachet, which recommended being dissolved in a certain amount of a specified liquid. The amount and type of liquid varied, depending on the type of gelatine, e.g. animal and vegetable gelatine. Student used proportional reasoning to determine how they would vary quantities if choosing gelatine as a variable. They also had to reason how to divide their mixture when changing over variables, e.g. temperature. Variables tested by the groups were gelatine concentration, gelatine type, liquid (milk, soya milk, water, various fruit juices) and liquid temperature. Students were assigned homework to prepare a presentation or poster that included their initial prediction/hypothesis, procedural outline, refinements made, analysis carried out and recommendations based on their analysis (Worksheet 2).

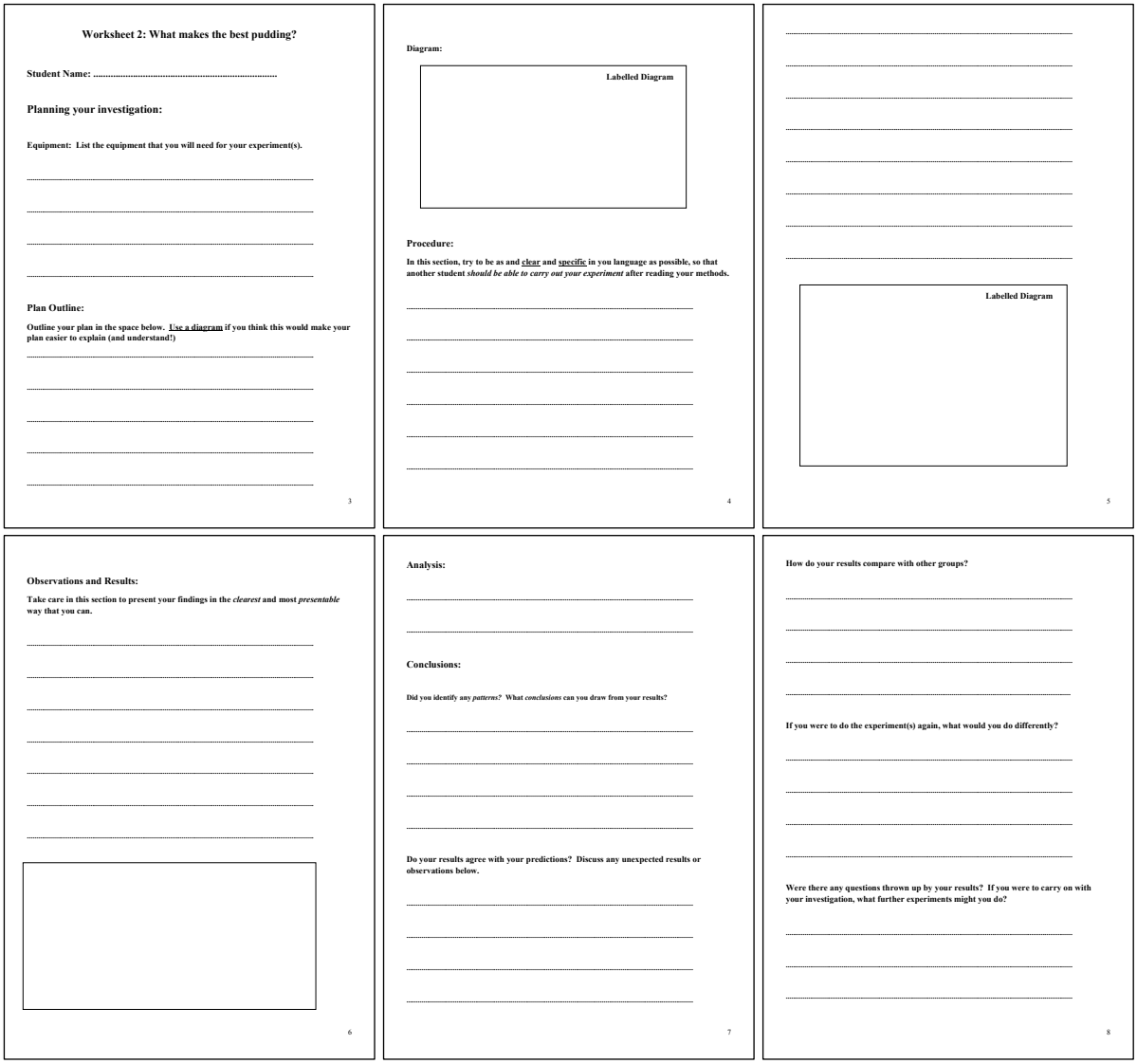
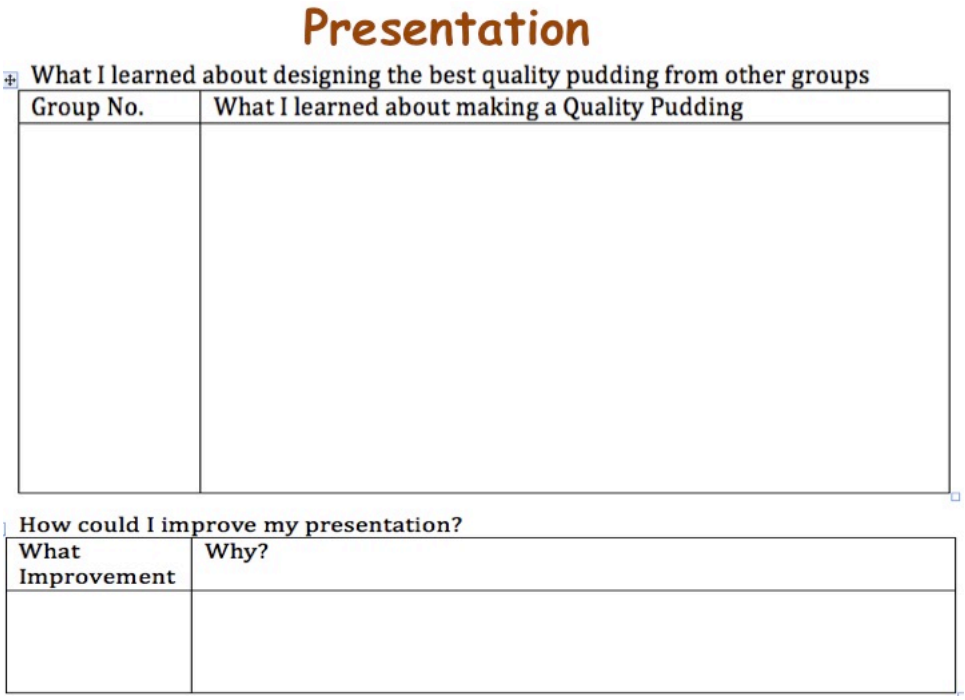


Figure 2: Worksheet 2 for CS1 Ireland

In the final lesson, teacher focused on Activity C: Evaluation and feedback. Students completed presentations and answered teacher questions on their work. They then completed Worksheet 3 individually (Figure 3). Students in groups collaborated to complete a report, in which they had to detail how they would make a quality pudding texture (Worksheet 4, Figure 4). To complete this task they had to synthesise and judge the presentations of other groups by deciding which data was valid to use in their final report. This lesson focused on the inquiry skills of *forming coherent arguments*

and *working collaboratively*, as well as *scientific reasoning* (critiquing experimental design) and *scientific literacy* (synthesis of 'good work based on evidence'). The teacher based assessment on observations, responses to questions and evaluation of students' worksheets (worksheets 3 and 4).



Presentation

What I learned about designing the best quality pudding from other groups

Group No.	What I learned about making a Quality Pudding

How could I improve my presentation?

What Improvement	Why?

Figure 3: Worksheet 3 for CS1

Report

How I would make a Quality Pudding Texture:

Figure 4: Worksheet 4 for CS1

(ii) Which skills were to be assessed?

The teacher noted that the core skills to be addressed were (1) *planning investigations*, (2) *working collaboratively*, (3) *scientific reasoning* (critiquing experimental design) and (4) *forming coherent arguments*. In addition, students gained experience in proportional reasoning and synthesis of 'good work' based on evidence, but these were not assessed.

The skills were assessed using teacher observation, questioning and review of documentation (worksheets and reports) measured against pre-developed criteria. The teacher used a mix of formative and summative assessments. These included teacher observation (during practical activities and presentations), student questioning (planning, practical, presentations) and examination of student documentation (worksheets and final report). The teacher planned to make judgements on these based on pre-developed rubrics founded on inquiry based learning constructs. The teacher provided a student rubric, to serve as a brief instructional guide and as a promoter of motivation (Table 1). Each row was displayed at different points throughout the lesson sequence. When observing the classes the teacher circulated with a flip chart containing the appropriate rubrics and recorded a "group" grade.

Table 1: Student rubric for CS1

Assessed Skill	Emerging	Developing	Consolidating	Extending
Planning an investigation	Goes for an initial idea.	Looks at different options and decides on one, but without careful consideration regarding relevance or testability.	Looks at many different options and ranks them on scientific relevance and testability. Justifies decision through critique or by scientific explanation.	Considers the evidence from trials and others' results or ideas. Refines their plan using results from experiments.
Carrying out an investigation	In need of continuous support and instruction. Using equipment unsafely or inappropriately.	Occasional support needed. Demonstrates the ability to use equipment safely and appropriately.	Able to run experiments confidently and relatively independently, in a well organised and time efficient manner.	Demonstrates the ability to continually run experiments independently and safely without need of assistance.
Recording and analysing results	Limited recording of results, or none.	Results recorded and presented appropriately.	Recording, presenting results appropriately. Some analysis of results demonstrated.	Recording, presenting, and analysing results appropriately, using critical thinking to evaluate and draw valid conclusions.

(iii) Criteria for judging assessment

The assessment was both formative and summative. Formative assessment was used during the classroom activities (observation, questioning) and summative assessments were used when the teacher reviewed student worksheets and reports. The teacher prepared a number of rubrics (Planning: Table 2, Making Your Pudding: Table 3, Presentation: Table 4), which detail the characteristics desired for each level of achievement. These rubrics are based on Kelly's Repertory Grids and can be graphed; highest score is 1 and lowest is 5. Roman numerals refer to group numbers.

Table 2: Rubric for planning investigations

Characteristic	I	II	III	IV	V	VI	VII	VIII	IX	Least preferred
Initial idea										Nebulous non-focused
Making judgements or decisions										Indecisive
Forming hypothesis										No cause and effect identified
Working collaboratively										Working in isolation
Ranking										Indecisive
Refining										No refinement

Table 3: Rubric for "Making your pudding"

Characteristic	I	II	III	IV	V	VI	VII	VIII	IX	Least preferred
Refinement										No refinement
Adheres to safety. Conducts experiment in a fashion conducive to obtaining results										Conducts experiment in chaotic fashion
Collaborative										None collaborative
Cleaned up										Did not clean
Fully documented results including quantitative and qualitative descriptors involving variable investigated and texture										Partial/lack of recording of data
Full analysis of results with reference to aspect of texture used in hypothesis										Partial/lack of analysis provided

Table 4: Rubric for presentation of results

Characteristic	I	II	III	IV	V	VI	VII	VIII	IX	Least preferred
Clear hypothesis										Non-focused hypothesis
Clear layout										Cluttered/chaotic
Succinct procedure										Partial/lack of procedural detail
Refinements indicated										No refinements indicated
Comprehensive analysis										Lack of analysis
Recommendations based on evidence – attempt to link cause and effect										No recognition of cause and effect based on evidence
Clear oral presentation										Poor oral presentation

(iv) Evidence collected

Teacher opinion

The teacher indicated that the students found the tasks quite challenging and that some were exhausted after the experience. He noted that the students were not used to having to think as much and to make decisions on the spot and adapt to the tasks as they were happening given the time constraints of the activity. Even though they were challenged, the teacher noted that they engaged well with the task i.e. they liked having to complete a task which they were responsible for, they responded in a collaborative fashion for the most part, they made a good attempt at their presentations.

In relation to the context of the task the teacher felt that it was more the challenge of making something rather than the making of a pudding that engaged them in the process. He also indicated that the inquiry approach made the learning of science accessible to the range of students in the class where sometimes science can be seen as too difficult to consider as a subject for senior cycle or as a platform for a career choice. With this approach he felt everyone felt like they were 'doing' science and working as 'real' scientists.

The teacher was quite impressed with how the students responded to the task overall. While he felt the students possibly resisted the planning stage in the first double lesson they engaged enthusiastically in the following lessons. The teacher indicated that they are not used to planning and their resistance could perhaps be due to the lack of hands-on activities during the planning phase. He noted that the making of a product was a valuable motivating factor as students' can see the cause and effect of their planning on the hands-on component.

He thought that students performed admirably in terms of *working collaboratively*. They bought into the group work and using each other's data to make their final report. This gave them a sense of joint responsibility within the investigation. He felt that students were able to plan logical sequences and were able to keep control and test variables. Students' demonstrated an ability to make predictions and decisions/judgements about how they would modify their experiments based on evidence and evaluation of findings.

The teacher commented that all groups but one collaborated well in the making of the pudding – in this one instance a dominant student called all shots which led to the exclusion of one student who had not been in the week before and who found herself lost with nothing to contribute.

He highlighted that time was an issue when completed the learning sequence as described. One such time-related issues was that most groups did not have time to write on the worksheet they received on planning and analysis due to time constraints where they needed to be hands-on.

He noted that even though students hadn't done science or inquiry previously they scored well on the rubric scales. He also noted that one more class would be helpful to tie the learning experience together where there was time to explicitly discuss the nature of science in the context of the task completed.

With regard to assessment, the teacher had both positive observations:

- The rubric was easy to fill out and to make judgements because of having a 1-5 scale
- There was no ambiguity, it allowed the teacher to have a clear mind when making grades
- It was efficient during and after the lesson

However, he also noted that it was challenging to be in eight places at once, particularly during the practical, which made it difficult to analyse everything. The teacher noted it might have been easier if he had decided to assess fewer skills, this would take a little pressure off when trying to evaluate everything

Sample student artefacts

Examples of satisfactory achievement

- Some groups decided to change whisking methods in running and to return to melting over a hot pot of water in order to further dissolve coffee granules (Figure 5a). This was evidence that they could make decisions and elaborate on basic recipe instructions if required.
- Most groups coordinated their activities well whereby one poured the mousse, another cleaned the workbench and another washed (Figure 5b).
- Students were mostly able to identify testable hypothesis and variables that could be evaluated e.g. the effect of changing volume of liquid, type of liquid, temperature of cooking, concentration and type of gelatine

(a)  (b) 

Figure 5: Examples of (a) mixing methods, and (b) working collaboratively

Example of a common error/misconception

Proportionality was a challenge for most groups. Two of groups did not recognise they would need to adhere to the scientific method – one had attempted to see the effect of liquid type on texture (water, soy milk, almond milk) but mixed all liquid types together to form one liquid mixture. Another attempted to see the effect of temperature on texture in terms of "hot/tap

temperature/fridge temperature water," but made two puddings with hot water, as they need this temperature water to form the gelatine base in the first place – this group also mentioned they felt under time pressure that affected their ability to think.

(v) Use of assessment data

The teacher used the formative assessments to help students reflect on their initial planning, their refined planning and on the scientific process during the classes. He used in-class assessment to make judgements on students' abilities (score on rubric). Given that the activity was completed in the last class before a four-week gap the teacher felt the value of an overall reflection on the learning experience in relation to the nature of science, would be less meaningful. However he would do it if the gap had being avoidable.

(vi) Advice for teachers implementing the unit

The teacher has listed a number of key pieces of advice for teachers doing the activity for the first time as outlined below:

- Think about timing, giving students clear information that is sequenced properly. If struggling for time perhaps give them the hypothesis and let them plan to test it and not just develop it
- He wouldn't suggest doing it in your first class with a new group (as he had to). He suggests it's important to know your students first.
- Encourage them – this is how good you are! Science is accessible through the approach
- Collaboration is difficult – be prepared to form other groups if necessary
- Teacher preparation takes a lot of time and is essential – research on recipe, making pudding etc.
- Inquiry must be conducted properly or becomes bad advert for science as can cause confusion, leads them to feel they are not good enough but when done properly makes science accessible and for everyone and irrespective of ability
- Give your student advocacy, they are giving presentations and engaging in science
- Don't work about pedagogical content knowledge in the sense that you entering into inquiry with your students, you are both learning, you don't have to know the answer to every question, otherwise its not truly inquiry