4.4 Case study 4 (CS4 Denmark)

Concept focus	Development of inquiry skills
Activities implemented	Activities A-D
Inquiry skills	Planning investigations Forming coherent arguments Working collaboratively
Scientific reasoning and literacy	Not assessed
Assessment methods	Classroom dialogue Teacher observation Self-assessment
Student group	**Grade:** lower second level; two classes (24/21 students) **Age:** 15-16 years **Group composition:** mixed ability and gender **Prior experience with inquiry:** No prior experience with inquiry

This case study details a *bounded inquiry*, in which the students had great freedom in planning their investigations. The teacher chaired group discussions and observed the class, but provided minimal guidance. The students were free to make errors and troubleshoot their investigations. Skills assessed were *planning investigations*, *forming coherent arguments* and *working collaboratively*. Assessment methods included self-assessment, teacher observation and classroom dialogue during a whole-class debate at the end of the lesson.

(i) How was the learning sequence adapted?

For implementation of the **Which is the best fuel?** SAILS unit, the material was mainly used as described. The work method was adjusted to facilitate a *bounded approach*, with the goal of having the greatest possibility of freedom in the work and minimal prior guidance. Even though the students' choices, for example designs of experiments, may have been problematic, the teacher did not overrule their choices, and the students were able to acknowledge the shortcomings of their choices through the practical work. The following dynamic model was used:

- Short introduction by the teacher
- Work done in fixed groups with a problem – suggestions to solutions
- Class debate about the possibilities, and from here then chosen by the students
- Testing and further work – it is possible to make adjustments from learned experiences in the practical work. New problems arise and the process is repeated

The presentation and the query from the teacher's side were kept short, to let the students have the maximal opportunity to influence the process. The teacher functioned mainly as a coordinator.

Students from both classes where a little unsure of the work method, but quickly engaged with the work. Both the teacher and the observer could conclude the following:

- The students were generally more engaged in the process than seen when class is dictated by a teacher,
- Students, who did not normally participate in oral class discussions, were active in both the group activities and the class discussion afterwards.

Lesson sequence

1. Teacher introduction: "What is good fuel?"
2. Group work – students were asked to reach a decision on what the term "good" means

3. Class talk – each group's results were written on the class blackboard. "A good fuel is something that...
    a. Can ignite quickly
    b. Burns for a longer time
    c. Contains the most amount of energy
    d. Becomes the warmest
    e. Is cheap
    f. Is not poisonous for the environment – least CO_2 or harmful particles."
4. Class debate – a longer discussion about what makes "the best fuel" followed, where it was quickly discovered that certain factors limit others – a dilemma situation. It was decided to use the expression "contains the most amount of energy" as the most vital factor and thus be the focus of the experiments.
5. Teacher's talk: "Which fuels do we want to examine?" A broad list of fuels were suggested for possible debate.
6. Group work – brainstorming by the students based on the teacher's talk
7. Class talk – each group's results were collected and written on a blackboard. "Fuels that we can examine (random order): methanol, ethanol, gasoline, diesel oil, lamp oil, kerosene, acetone, wood, coal, heating oil, straw, wood pellets, natural gas, bottled gas, lighter gas."
8. Class debate – "Which should we choose?" A long debate followed because many factors were present. Students predicted which fuel contained the most energy, debated solid versus liquid substances and their energy content and other subjects. It was decided to examine the following fuels: diesel oil, lamp oil, wood pellets, and coal.
   Note that the teacher was aware of the difficulty of designing an experiment with which each fuel could be tested, but allowed the students continue their work and let them work it out.
9. Teacher's talk: design of experiment – "How do we find the energy content?"
10. Group work – design of experiment (1). Each group chose different methods. All groups decided to give up on design of the experiment – they found that it is not possible to make an experiment that works the same way for liquids and solids, for example. The conclusion was that the substances must be solids, liquids, or gases. A mutual decision was to examine liquids – the argument for the decision was that it "seems the easiest." There were seven liquid fuels identified previously: methanol, ethanol, gasoline, diesel oil, lamp oil, kerosene, and acetone. One group suggested finding data about each substance, and another group discovered that kerosene and lamp oil are very similar, so kerosene was removed from the experiment. Six liquid substances remained: methanol, ethanol, gasoline, diesel oil, lamp oil, and acetone.
11. Group work – design of experiment (2). Decisions on design, where all group thoughts were introduced.
    a. There was disagreement on the way to handle the substances when they burn, to either keep them in bowls or oil lamps. None here discovered that some fuels could not be ignited immediately or without a wick – oil lamps were eventually chosen as a form to gain "control during the experiment."
    b. It was decided that a certain amount of water should be heated – 50 ml was chosen as the amount of water.
    c. The end temperature of the water was discussed. It was eventually concluded that the water should boil, however it was uncertain if that was when the water boiled with small or big bubbles. Thus an agreement was made to keep the water at 50 Celsius instead.
    d. It was decided to use a laboratory flask instead of a beaker, because it was expected that heat loss would be greater when using a beaker.
    e. It was decided to use water from the same faucet, to achieve the same temperature for each experiment.
    f. All oil lamps were weighed before experiments started.

Note that the teacher was quite convinced that not all factors were clarified in the design, yet allowed the students to continue their work. This applies to later experiments as well.

12. Implementation of experiment (1) – the experiment was carried out; however it was proven that the water heated up more quickly than expected. The weight revealed that very little fuel had been used. The experiment was stopped – everyone agreed that more water is needed.
13. Implementation of experiment (2) – the setup was changed and the amount of water adjusted to 400 mL. Everything else remained the same. The experiment functioned without problems and several groups finished – a single group found that their water did not reach 50 °C and others found that their distance between wick and laboratory flask was too great. The experiment was again stopped, because the students agreed that they needed to carry out the experiment with the same wick-laboratory flask distance.
14. Implementation of experiment (3) – the setup was changed, so that everybody kept a 40 mm distance from the wick's top to the bottom of the laboratory flask. The experiment was finished and they calculated their results.
15. Class work, teacher ruled: collection of results – the results were collected in a form on "ActiveBoard." The results were discussed and declared unusable. The number of decimals was discussed – is it enough with only one, or are two decimals better?
16. Teacher's talk: "What do we need to know to find the amount of energy in the fuels? What is variable and what should be included in a formula?"
17. Group work based on the teacher's talk
18. Class gathering – the groups provided suggestions for the formula content. It was decided that weight change and temperature change should be included, as well as a number that tells how difficult it is to heat the water.
19. Teacher's talk – formula and calculation – table values. The formula was given to the students, who were asked to discuss and decide if the molecular weight should be included in the calculation and if the energy should be found for energy per grams or energy per molecule or something completely different. The decisions are heavily made with strong guidance from the teacher.
20. Group work – calculations and collection of the table values – the groups discover that their enthalpy is too low compared to the table valuables, yet the sequence of the substances is almost correct. A conclusion of which was the best fuel was reached.
21. Class debate – "Why is there a difference?" Agreement upon the fact that the experimental design lets too much heat escape which is not transferred to the water, and a more "closed" setup would help the experiment's goal. At last, a list was created of the factors, which would be important to change if the experiment was to be repeated.

(ii) Which skills were to be assessed?

The assessment was planned before the beginning of the implementation, and skills to be assessed were *planning investigations*, *forming coherent arguments* and *working collaboratively*. No changes were made to the assessment model or assessment content during the course. The assessment consisted of

1. An individual questionnaire with very open questions. During the questionnaire, teachers were available to answer queries regarding the wording of the questionnaire. The student responses to the questionnaire were collected and reviewed by the teacher, with special attention to similarities in answers and to answers regarding skills identified for development.
2. A joint debate between the two classes with regard to the answered questionnaire. The teacher managed the debate and added more detailed questions, which had arisen from review of the answers.
3. The teacher and the observer compared the students' marking from the written and oral assessment with the observations made from the practical work.

The assessment of developed skills was very much in the hands of the students themselves, with the teacher acting as assistant in the process of clarifying the skills needed. In this course the teacher did not assess to which extent the goals of skills were reached. There was no written dimension to the work.

(iii) Criteria for judging assessment data

A satisfying result would be for the students to improve their competence in the mentioned areas. On the factual/skill dependent part, the accurate calculation of the enthalpy and a deeper comprehension of the concept acted as a secondary goal.

To assess if the goal was reached, the students' own assessment was used to evaluate the learning, compared to what the observer saw. A correlation between the students' own assessment and the observer's evaluation was made.

(iv) Evidence collected

Teacher's opinion

The assessment form seems useful and self-assessment by the student brings clarification to the individual on what was learned. The weakness of the evaluation method is first and foremost that the students have a tendency to focus on the purely factual as the learned and thus not the actual skills and what was expected of them. Furthermore, the evaluation form had not been tried before in either class. It can be difficult for students to evaluate their own knowledge and where they are on a learning curve.

The evaluation form could be improved by adding a teacher evaluation, to provide the students with a more definite and personal feedback on their work and to show them if their own evaluation is realistic.

Observer notes

The lectures were videotaped and the tapes were reviewed by a colleague (observer). The observer noted that:

- The group discussions seemed to involve all students, no matter the individual level,
- The students seemed to master the qualification goal of design and complete an experiment, yet they seemed to find it difficult to adjust the experiment based on their former experience. When the practical work did not fit with the given theory, the students seemed uneasy and expected answers from the teacher,
- The evaluation form was useful and helped establish the learning process for the students, yet the evaluation form should be tried out more times so that students become more familiar with it.

The observer's assessment was made to see if there was correlation between the students' evaluation of their own learning and the observations made. It is here concluded that there is a correlation between the two. Furthermore, the students' oral assessments were as expected, e.g. compared to their explanations on how the work was difficult.

The observer thought that the goals were reached; however, the course could be extended to 4-5 lectures, which would have given the students more time to develop skills.

Sample student artefacts

Two modes of evaluation were employed – written questionnaire, with open-style questions, and an oral evaluation. Shown below are some of the questions from the questionnaire, and common or interesting responses.

What have you learned about fuels?
40 out of 45 (89%) described in one form or another that they learned how to calculate enthalpy:
"I have learned how to find the energy content in some fuels"
"I now know how much is inside fuel"
"You can calculate how much of a fuel can heat up a liquid"

In this lesson, what have you learned about work methods in physics/chemistry course?
38 out of 45 (84%) describe how they, in one form or another, have learned how to design an experiment
"I believe that I have learned how to make a setup with works"
"We can all change an experiment, to make it work in the best way possible"
16 out of 45 (36%) noticed the error and correction
"***We made a lot of mistakes, but I think we gained knowledge from the mistakes"***
"Our first experiment went REALLY bad, but we were pretty good at correcting the mistakes and then it went better"

In this lesson, what have you learned about making explanations and argumentation?
6 students did not answer, while 11 out of 39 (28% of the answered/24% of all) answered ***"Nothing," "nothing really," "I don't know"*** or something similar.
14 out of 39 (36% of the answered/31% of all) answered in a positive way about their argumentation skills:
"I think that I have improved in explaining when something goes awry"
"My group was pretty cool at explaining the mistakes and also providing suggestions"
"The whole class worked pretty well on given explanations and I think I have improved my skill compared to earlier work"

Overall, what did you think of the lesson?
One student did not answer. Many different answers were given – the following is the most collective thoughts compared to agreements:
31 out of 44 (70% of the answered/69% of all) found the work ***"difficult," "tough," "not easy," "more difficult than the norm,"*** and similar answers.
27 out of 44 (61% of the answered/60% of all) found the work ***"fun," "interesting," "cool," "challenging,"*** and similar answers.

In addition to the written evaluation, some oral assessment was also carried out. Shown below is a short selection of examples from the oral assessment, which went on for one complete lecture:

- The teacher inquired, "Why have some of you found it difficult to work in this way?"
  - The students made it clear that they found the independent nature of the work method to be difficult. Students were used to the teacher carrying the responsibility for the lesson direction. Several students had mixed feelings about the lesson – it was more difficult, yet also more fun at the same time.
  - In both classes, there was complete agreement that the method should be carried out again for a course, because they would be prepared for next time, which would make it a bit easier.
- The teacher asked, "What was the most important thing you learned?"
  - The majority thought that the most important thing learned had been the independence of the work. Some elaborated with not near as positive answers, which included "old-school physics education."
  - A single acute student asked, "Did you know beforehand what we would eventually conclude?" The teacher did not answer immediately and the student concluded: "Oh well, it does not matter in the end, if you did."
- The teacher asked if the students thought that the work method was the same as that used in a real workplace when working with the natural sciences.

- Very split opinions and polarised opinions. Nearly half thought that the experiments aligned with the way people worked in workplaces for science, while the other half did not believe that people tried and made errors the same way, rather people would know what results they would expect from experiments.

Some other interesting comments from the oral evaluation include: “But is this even important for the exam? We did not really learn anything of relevance,” “This is very fun and all, but it will be nice to try some real physics,” and “I’m not really sure if I understand this method. It’s more like a game – we just played with it.”

(v) Use of assessment data

To conclude the course, the teacher gave oral feedback to the students in separate classes. The focus was on the positive consequences for changing work and assessment form, and from the feedback it was decided that a similar approach should be created for future work projects, in corporation with the syllabus.

(vi) Advice for teachers implementing this unit

The topic is good for use with upper second level classes – not because the calculation of enthalpy is important, but since the topic and the material provides an ample opportunity to work with the natural sciences.

The actual execution of the course can seem very strict and, from my estimation, the course could improve by releasing the students onto the work and give them some time to experience the topic by themselves. It serves the course’s purpose to have the teacher help with providing guidance to the students so that they can achieve the goal, rather than the teacher only serves as a lecturer, especially when the objectives are as mentioned.

The suggested written report from the students was not used as a form of evaluation in this course. It is not customary to use this format; it would seem rather forced and artificial, if applied. The employment of self-evaluation with very open questions worked well – the following class debate was helpful in sorting out what the students had actually learned from the course. The evaluation method is time-consuming from the teachers’ side, yet lines up with the work structure of the course as a whole. One could say that it serves as a disadvantage for the course that no quantitative material is gained from the evaluation – I do not find this to be a disadvantage. Instead, the qualitative points are of importance when making a judgment about the achieved goals for the course.