

## 4.2 Case study 2 (CS2 Poland)

<b>Concept focus</b>	Fuel, heat capacity, enthalpy of combustion
<b>Activities implemented</b>	Activities B-D
<b>Inquiry skills</b>	Planning investigations Developing hypotheses
<b>Scientific reasoning and literacy</b>	Scientific reasoning (defining variables, collecting scientific data)
<b>Assessment methods</b>	Classroom dialogue Worksheets Student devised materials (documentation of inquiry)
<b>Student group</b>	<b>Grade:</b> upper second level; class with biology and chemistry at higher level; extracurricular class with voluntary participation <b>Age:</b> 17-18 years <b>Group composition:</b> mixed ability and gender; 5 students (4 female, 1 male) <b>Prior experience with inquiry:</b> Students had no prior experience with inquiry. The teacher has Ph.D. in chemistry and 9 years of teaching experience. The teacher took part in several sessions of the ESTABLISH project as participant and later as trainer. However, teacher had no prior experience in assessing IBSE.

This voluntary extracurricular class was held in the laboratory of the Faculty of Chemistry of the Jagiellonian University. The teacher provided a preparatory worksheet, which the students completed in advance of the lesson, but no worksheet was used for the implementation. The skills selected for assessment were *developing hypotheses* and two aspects of *scientific reasoning* – defining variables and collection of experimental data. The teacher used a three-level rubric to identify performance levels when evaluating student materials after the lesson.

### (i) How was the learning sequence adapted?

This voluntary extracurricular class was based on the **Which is the best fuel?** SAILS unit. The class lasted 135 minutes (3 school hours), and it was held outside of the school, in the laboratory of the Faculty of Chemistry of the Jagiellonian University. Classes were observed by JU/SAILS representative. The teacher implemented this investigation on thermochemistry for the first time.

Before the class, the students were informed about the topic to be discussed. The teacher had sent them worksheets, which they were asked to complete individually prior to the lesson (Figure 1). The teacher pointed out that the aim of the worksheet was to introduce the topic, as it wasn't possible to achieve this during the three classes, because the unit was recommended for implementation over four lessons. The teacher expected that the answers to some questions, e.g. "How can you verify experimentally which fuel is the best? Suggest a method that may be used in a laboratory (without access to specialised equipment)" would replace the introductory discussion suggested in the unit (Activity A: Introduction).

The teacher began the class with an introduction in the form of a short seminar, in which he mentioned the aspects of practical relevance of the concepts of fuel, heat capacity, enthalpy of combustion. Initially, students' activity was very cautious and characterised by uncertainty and shyness. This could be due to the fact that they were in a university laboratory for the very first time. Over time, their level of activity increased, first in the area of discussion, and then in laboratory work.

**Which is the best fuel?**

1. Complete the following graphs using associations with the keywords provided (use black or blue ink pen):

fuel

best fuel

2. On the basis of the Handbook for Year 1 or any other good literature source, provide the definition of:

a) Fuel

Source: .....

b) Energy value of fuel

Source: .....

3. On the basis of the definition of fuel, complete the graphs in Point 1 with new information, using red or green ink pen.

4. How can you verify experimentally which fuel is the best? Suggest a method that may be used in a laboratory (without access to specialised equipment) to answer this question.

**Figure 1: Worksheet for completion prior to the lesson.**

Topics for discussion:

- Laboratory equipment – measuring and measurement errors.
- Fuel in everyday life – what is important for us as the users?
- Calorimeter – how to construct it? What to pay attention to while constructing it? Analogy with Thermo® flasks.

After the discussion, the students formed two groups; group A was composed of one boy and two girls, and group B of two girls. The students formed the groups themselves. In the groups, they were asked to perform laboratory tasks. Each group had all reagents and equipment needed for the experiments prepared at their workstations. The students were free to choose reagents and equipment for the experiment they planned to carry out.

Group A investigated enthalpy of combustion for two isomers of butyl alcohol. They performed two trials for butane-2-ol and two for butane-1-ol. Group B investigated influence of the length of the carbon chain in the alcohol on its enthalpy of combustion. They made one trial for methanol, propane-1-ol, and butane-1-ol.

The collected data was noted down on pieces of paper and then during classes students calculated the enthalpy of combustion of studied alcohols. Those notes were gathered by teachers after lab and used as evidence for assessment. The teacher decided not to use the worksheet suggested in the unit, instead allowing the students to determine the information to collect and the manner in which to present it:

*I definitely wanted to see what the students understand by the concept of notes, and how they will cope with noting down certain facts, and what facts they will consider as worth noting.*

The lack of a structured worksheet during the classes gave the teacher an opportunity to draw additional conclusions about what the students considered important to note during the experiment.

### (ii) Which skills were to be assessed?

Three skills were selected for assessment during this implementation, namely *developing hypotheses* and two aspects of *planning investigations* and *scientific reasoning* – defining variables and collection of experimental data.

### (iii) Criteria for judging assessment data

The teacher designed rubrics with assessment criteria for selected skills, as shown in Table 1.

**Table 1: Assessment of skills developed in CS2 Poland**

Skill	Fail	Satisfactory	Very good
Developing hypotheses	The student does not formulate a hypothesis appropriate to the research problem raised	With teacher's assistance, the student formulates a hypothesis for the research problem raised	The student independently formulates a correct hypothesis, adequate for further experiments and referring to a correctly raised research problem
Defining variables	The student does not define variables associated with the planned experiment	The student defines some variables, and with the teacher's assistance is able to identify other relevant variables	The student independently defines appropriate dependent and independent variables
Collection of experimental data	The student prepares incomplete, unreadable notes containing information unusable in terms of finding an answer to a research question raised	With the teacher's help, s/he is able to write down some information – but not enough to present and interpret the results, e.g. obtained data without symbols and units	The student independently prepares appropriate notes, taking into account relevant units, quantities and symbols, relationships between quantities reflected in formulas, presenting a logical cause and effect sequence that contains all the necessary information, which, in the end, allows for the calculation of the combustion effect of the tested fuels

### (iv) Evidence collected

#### Teacher's opinion

It makes no sense to prepare a rubric including only three performance levels (as I did) – I should have prepared a complete scale of all school marks at once. Rubric preparation is very difficult; I did not know whether the descriptions should be quite detailed, or rather general.

The students were given a table-rubric before the beginning of the class, i.e. they were informed about what would be assessed. I do not know if the lack of variables resulted from the pressure of time or their poor skill of identifying the variables.

In conclusion, the subject of the unit was very interesting for girls and boys. It shows the practical application of some chemical concepts, such as heat capacity and enthalpy of combustion. The possibility to work independently in a laboratory revealed student involvement that had previously

been unknown to the teacher, especially for those who had low achievements in chemistry. The investigation can be run as open inquiry, but it requires large workload and more time than suggested four lessons.

### **Observer notes**

The skill of defining variables is almost entirely overlooked in the Polish education system; it is hard to find recommendations concerning practicing and shaping that skill in the core curriculum. Most probably, the students encountered the concept of a variable in the experiment for the very first time; the concept it is not established as well in the minds of teachers, hence an even greater problem for developing the students' skill. The teacher did not introduce the topic of a variable, what it is and what its types are, neither did she draw the students' particular attention to the necessity of defining variables when planning an experiment. The teacher, when asked whether it would have been reasonable to introduce variables to worksheets, replied that she deliberately had not done it. The teacher wanted to see if the students remember the necessary elements of an appropriate experimental plan. The teacher did it intentionally, as two years earlier she introduced the students to the topic of variables.

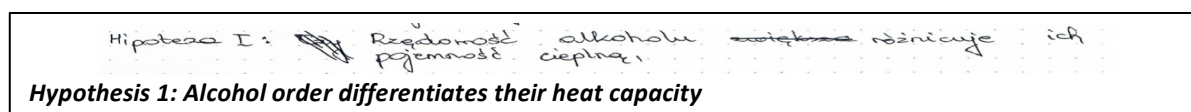
### **Sample student artefacts**

#### **Developing hypotheses**

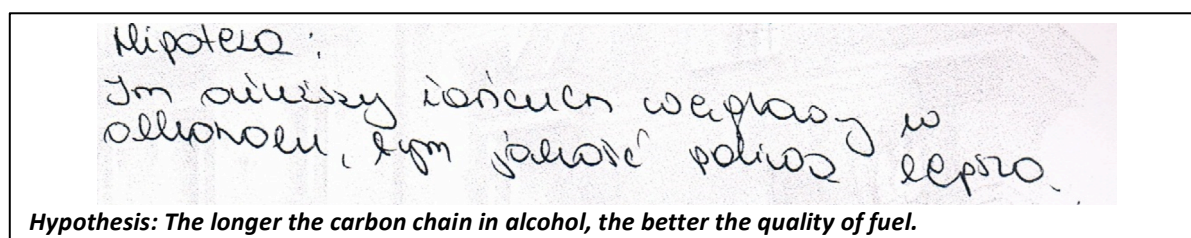
The prepared rubric emphasised the importance of relating the hypothesis to the research question. Both groups prepared hypotheses without the teacher's help, and the content is related to the research question (Figure 2 and Figure 3). Unfortunately there are some essential errors:

- Group A referred order of an alcohol (primary or secondary) to its heat capacity. Unfortunately it is not the issue they should investigate. Clearly the student confused heat capacity with enthalpy of combustion. Additionally the hypothesis doesn't predict the way order of an alcohol influence investigated parameter.
- Group B students referred length of a carbon chain in alcohol to quality of fuel. It is not clear what does it mean "best fuel."

The teacher noted that basing assessment on the prepared rubric its hard do give clear and comprehensive feedback to students. In the rubric more stress should be put on aspects of good hypothesis.



**Figure 2: Developing hypotheses, example by group A.**

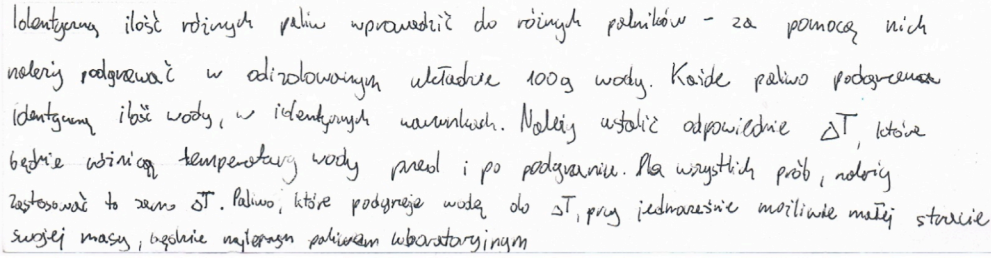


**Figure 3: Developing hypotheses, example by group B.**

#### **Scientific reasoning (defining variables)**

Both groups receive a fail mark because there were no variables listed on the collected lab notes. It should be noted that before the classes students had to fulfil worksheet and one of questions was

“How can you verify experimentally which fuel is the best? Suggest a method that may be used in a laboratory to answer this question.” Students have prepared descriptions of the method, and discussed many parameters, such as those shown in Figure 4. Unfortunately they didn’t classify those as variables.



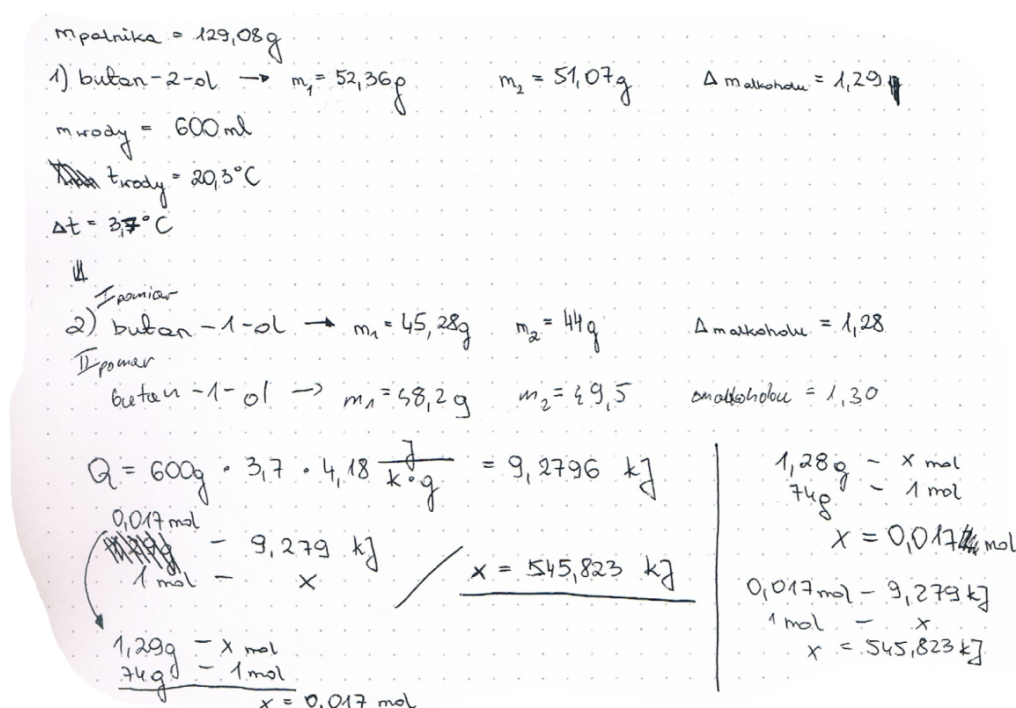
Identical quantity of various fuels should be introduced to different burners – using them, 100 g of water should be heated in an isolated system. Each fuel heats the same amount of water in identical conditions. Appropriate  $\Delta T$  should be established, which will be the difference between the temperature of water before and after heating. For all tests, the same  $\Delta T$  should be used. The fuel that heats water to  $\Delta T$  with a possibly lowest weight loss will be the best laboratory fuel.

Figure 4: Identification of variables, example by student X.

### Scientific reasoning (collection of scientific data)

Both groups should receive a “good” mark, but there was no such level included in my rubric. The students did not meet the criteria for a very good mark; they did more than for a satisfactory mark. For example the students selected relevant units and quantities symbols; they reflected on the relationship between quantities used in formulas, applying a logical sequence of cause and effect.

Additionally there was a practical problem – the need to make photocopies of students’ notes for evaluation, as the students had to keep the original notes in order to prepare their reports.



$m_{\text{palnika}} = 129,08 \text{ g}$   
 1) butan-2-ol  $\rightarrow m_1 = 52,36 \text{ g}$      $m_2 = 51,07 \text{ g}$      $\Delta m_{\text{alkoholu}} = 1,29 \text{ g}$   
 $m_{\text{wody}} = 600 \text{ ml}$   
 $t_{\text{wody}} = 20,3^\circ \text{C}$   
 $\Delta t = 3,7^\circ \text{C}$   
 II  
 I promiar  
 2) butan-1-ol  $\rightarrow m_1 = 45,28 \text{ g}$      $m_2 = 44 \text{ g}$      $\Delta m_{\text{alkoholu}} = 1,28$   
 II promiar  
 butan-1-ol  $\rightarrow m_1 = 58,2 \text{ g}$      $m_2 = 59,5$      $\Delta m_{\text{alkoholu}} = 1,30$   
 $Q = 600 \text{ g} \cdot 3,7 \cdot 4,18 \frac{\text{J}}{\text{K} \cdot \text{g}} = 9,2796 \text{ kJ}$   
 $\frac{0,017 \text{ mol}}{1 \text{ mol}} = \frac{9,279 \text{ kJ}}{x}$      $x = 545,823 \text{ kJ}$   
 $\frac{1,29 \text{ g} - x \text{ mol}}{74 \text{ g} - 1 \text{ mol}} = \frac{x}{0,017 \text{ mol}}$   
 $x = 0,017 \text{ mol}$   
 $\frac{1,28 \text{ g} - x \text{ mol}}{74 \text{ g} - 1 \text{ mol}} = \frac{x}{0,017 \text{ mol}}$   
 $x = 0,017 \text{ mol}$   
 $\frac{0,017 \text{ mol} - 9,279 \text{ kJ}}{1 \text{ mol} - x} = \frac{x}{545,823 \text{ kJ}}$   
 $x = 545,823 \text{ kJ}$

Figure 5: Example of students’ notes taken by group A.

Methanol purity palnik : 156,24g  
 woda : 700 ml  $\Rightarrow$  700 g  
 temp<sub>1</sub> : 21,4 °C  
 palnik + alko : 185,44 g  
 alko : 29,2 g  
 temp<sub>2</sub> : 22,9 °C  $\Delta T = 1,5$  °C

$Q = 4389$  J  
 $H = 21$  g/mol  
 $x_2 = 21$  g  
 $4389 \text{ J} - 29,2 \text{ g}$   
 $x_2 = 3156,4726 \text{ J} \Rightarrow \Delta H_{sp} = -3156,4726 \text{ J/mol}$

1-Propanol purity palnik : 155,60 g  
 woda : 700 ml  $\Rightarrow$  700 g  
 temp<sub>1</sub> : 23,7 °C  
 palnik + alko : 178,96 g  
 alko : 23,36 g  
 temp<sub>2</sub> : 25,4 °C  $\Delta T = 1,7$  °C  
 $H = 60$  g/mol  
 $Q = 4874,2$  J  
 $x_3 = 80$  g  
 $4874,2 \text{ J} - 23,36 \text{ g}$   
 $x_3 = 12776,198 \text{ J}$   
 $\Delta H_{sp} = -12776,198 \text{ J/mol}$

1-Butanol purity : 153,76 g  
 woda : 700 ml  $\Rightarrow$  700 g  
 temp<sub>1</sub> : 16,8 °C  
 palnik + alko : 180,82 g  
 alko : 37,16 g  
 temp<sub>2</sub> : 20,4 °C  $\Delta T = 3,6$  °C

$Q = m \cdot \Delta T \cdot c$   
 $Q = 10533,6$  J  
 $H = 74$  g/mol  
 $x = 74$  g  
 $10533,6 \text{ J} - 37,16 \text{ g}$   
 $x = 20876,4 \text{ J} \Rightarrow \Delta H_{sp} = -20876,4 \text{ J/mol}$

Figure 6: Example of students' notes taken by group B

#### Observer comment

In the students' groups, only one person was taking notes, while the rest did not particularly get involved in the process. The whole group worked together when calculating enthalpies. At the end of the class there was not enough time for discussion of the results, errors and a lack of a short recapitulation.