4.6 Case study 6 (CS6 Slovakia)

Concept focus	How can chemists distinguish acid from base?
Activities implemented	Activity D
Inquiry skills	Developing hypotheses
Scientific reasoning and literacy	Scientific reasoning (drawing conclusions) Scientific literacy (explaining phenomena scientifically)
Assessment methods	Classroom dialogue Self-assessment Worksheets
Student group	**Grade:** 8th grade (lower second level chemistry class) **Age:** 13-14 years **Group composition:** co-ed (18 students), groups of 3-4 **Prior experience with inquiry:** One prior experience (**CS5**)

This case study describes a lesson focusing on bases, in which a modified version of Activity D: Identifying salts was implemented. The students investigated the inquiry question, "How can chemists distinguish an acid from a base?" The teacher provided a worksheet, to guide the students through the inquiry process and to use for evaluation after the lesson. Key skills assessed were *developing hypotheses*, *scientific reasoning* and *scientific literacy*.

(i) How was the learning sequence adapted?

The teacher chose to implement Activity D: Identifying salts from the **Acids, bases, salts** SAILS unit, with some modifications, as detailed in the teacher's plan (Figure 1). This activity built on a previous inquiry activity, during which modified versions of activities B and C were implemented. A student worksheet was prepared, so that the explored samples were solutions of acids and bases that are used in the laboratory (Figure 2 and Figure 3). The questions on creation of hypotheses and conclusions were focused on the colour changes of the samples of acids and bases after adding the indicator.

Students participated in this activity after a lesson that dealt with theoretical knowledge about hydroxides. With the inquiry method they not only revised their knowledge about acids, but they also consolidated and expanded their knowledge about hydroxides. During their own inquiry they practically tried out how chemists distinguish acids from hydroxides.

During teaching I used these questions and stimulations:

- What do you already know about acids and about hydroxides?
- Where can we find acids and hydroxides in our everyday lives?
- Are these substances important for our life?
- What is an indicator used for?
- What are the safety rules for working with acids and hydroxides?
- What is the first aid after an acid spill or hydroxide spill?

Students worked in groups and realised inquiry-based activities on topic "How do we distinguish acids from bases?" They determined colour changes of solutions and measured the pH of acid and base solutions. They have already had experience with inquiry-based method from the previous lesson, during which they explored acids. For this lesson, bases were added. Students again worked according to the instructions in the worksheet (Figure 2 and Figure 3).

(ii) Which skills were to be assessed?

During teaching I aimed at verification of development of the following skills: *developing hypotheses, scientific reasoning* and *scientific literacy*.

Developing hypotheses was analysed and evaluated by student answers in their worksheets, and using a scale developed by the teacher. *Scientific reasoning* was analysed by students' answers at the end of the worksheet and a designated scale. Development of *scientific literacy* (understanding) was analysed by metacognition. Assessment of the skills took place after the lesson ended, and the inquiry activities were completed.

How can chemists distinguish an acid from a base?

Learning aims:

- Explore hydroxides used in the laboratory,
- Find out different colouring of indicators in the solutions of acids and bases,
- Get to know safety rules for working with hydroxides

Tools and chemicals:

5 tubes, tube holder, 2 droppers, 5 syringes, 5% solution of sodium hydroxide, 5% solution of potassium hydroxide, water, 10% solution of hydrochloric acid, 10% solution of nitric acid, litmus paper, universal pH paper, phenolphthalein solution, red cabbage extract

Suggestion of procedure:

Introduction: We revise the students' basic knowledge of hydroxides/bases and the safety rules of working with them. We ask a motivational question: "How do you think chemists can distinguish an acid from a base?"

Exposition: We divide the students into groups of 2-3 members, we determine their workplace, distribute the tools, chemicals and worksheets. Students' worksheets guide them to develop hypotheses, suggest and realise experiments, answer questions and formulate conclusions.

Fixation: At the end of the lesson, students clean up their workplace and then the individual groups present the results of their work.

Questions for students:

1. What are indicators?
2. What indicators do we know?
3. How do individual indicators colour acidic solutions?
4. How can we distinguish an acid from base?

Type of inquiry:

Guided inquiry

Features of inquiry:

Observation, experimentation, formulation of hypothesis, exploring of assumptions, search for information, presentation of results, formulation of conclusions discussion about results.

Figure 1: Teacher's plan detailing methodology for activity

How can chemists distinguish an acid from a base?

Tools: 5 tubes, tube holder, 2 droppers, 5 syringes

Chemicals: 5% solution of sodium hydroxide, 5% solution of potassium hydroxide, water, 10% solution of hydrochloric acid, 10% solution of nitric acid, litmus paper, pH paper, phenolphthalein solution, red cabbage extract.

Tasks:

1. Read the following procedure of work and try to develop a hypothesis about what will happen during the realisation of the experiment. Will the indicator colour solutions of hydroxides the same as solutions of acids?

....

2. Make experiments according to the given procedure, write down your observations into the prepared table and try to answer corresponding questions. At the end, formulate conclusions in which you assess the results of your observation.

Procedure:

1. With syringe pour approximately 5 ml of the sodium hydroxide solution, potassium hydroxide solution, water, hydrochloric acid solution, nitric acid solution into each of five tubes in the holder. Then, immerse a piece of litmus paper into each of the tubes and write down its colouring into the table.
2. Then, immerse pH paper into each of the tubes and write down its colouring and pH value into the table.
3. Then, rinse the tubes and pour samples into them again like in step 1. Drip 2- 3 drops of phenolphthalein solution into each tube and write down the colouring into the table.
4. Rinse the tubes again and add samples like in step 1, and with the dropper, drip 2-3 drops of red cabbage extract. Write down the colouring into the table.

Indicators/Samples	Litmus paper colour change of paper	pH paper colour change & corresponding pH	Phenolphthalein colour change of solution	Cabbage indicator colour change of solution
Sodium hydroxide ($NaOH$, 5% solution)				
Potassium hydroxide (KOH, 5% solution)				
Water (H_2O)				
Hydrochloric acid (HCl, 10% solution)				
Nitric acid (HNO_3, 10% solution)				

Figure 2: Student worksheet, page 1

Observations

1. What was the colour of litmus paper in...
   a. acidic surrounding (in acidic solutions)?

   ………

   b. alkaline surrounding (in basic solutions)?

   ………

   c. neutral surrounding?

   ………

2. What was the colour of the universal pH paper in...
   a. acidic surrounding (in acidic solutions)?

   ………

   b. alkaline surrounding (in basic solutions)?

   ………

   c. neutral surrounding?

   ………

3. How did the phenolphthalein solution colour ...
   a. acidic surrounding (in acidic solutions)?

   ………

   b. alkaline surrounding (in basic solutions)?

   ………

   c. neutral surrounding?

   ………

4. How did the red cabbage extract colour in...
   a. acidic surrounding (in acidic solutions)?

   ………

   b. alkaline surrounding (in basic solutions)?

   ………

   c. neutral surrounding?

   ………

Conclusions:

………

………

………

………

………

………

Figure 3: Student worksheet, page 2

(iii) Criteria for judging assessment data

Developing hypotheses

At the beginning of the worksheet, students were asked to formulate a hypothesis, i.e. an expectation of what was likely to happen during the lesson activity (task 1, Figure 2): “Read the following procedure of work and try to formulate a hypothesis about what will happen during the realisation of the experiment. Will the indicator colour solutions of hydroxides the same as solutions of acids?" Student answers were evaluated using the score scale shown in Table 1.

Table 1: Teacher rubric for assessment of developing hypotheses

Inquiry skill	1 point	2 points	3 points
Developing hypotheses	Student was not able to formulate a hypothesis, not even with the teacher's help	Student was able to formulate a hypothesis with the teacher's help	Student was able to formulate a hypothesis individually

Scientific reasoning

At the end of the worksheet, each student was supposed to formulate the conclusion and compare it with the hypothesis, which was formulated at the beginning of the worksheet. The task to formulate the conclusion was summarised in the question "What are the indicators for?" Student answers were evaluated using the score scale shown in Table 2.

Table 2: Teacher rubric for assessment of formulation of conclusions

Inquiry skill	1 point	2 points	3 points
Formulation of conclusions (scientific reasoning)	Student was unable to formulate a conclusion with the teacher's help	Student was able to formulate a conclusion with the teacher's help	Student was able to formulate a conclusion individually

Scientific literacy

Assessment of understanding or "What have I learnt about acids and hydroxides?" was based on metacognition, which enables students to review what they did and why they did it during the lesson. After the lesson, students filled in a questionnaire with the following questions:

- What did I have trouble with during the lesson?
- What did I learn in the lesson?
- What else would I like to learn?
- What do I remember well?
- Where can I use what I did at the lesson?

(iv) Evidence collected

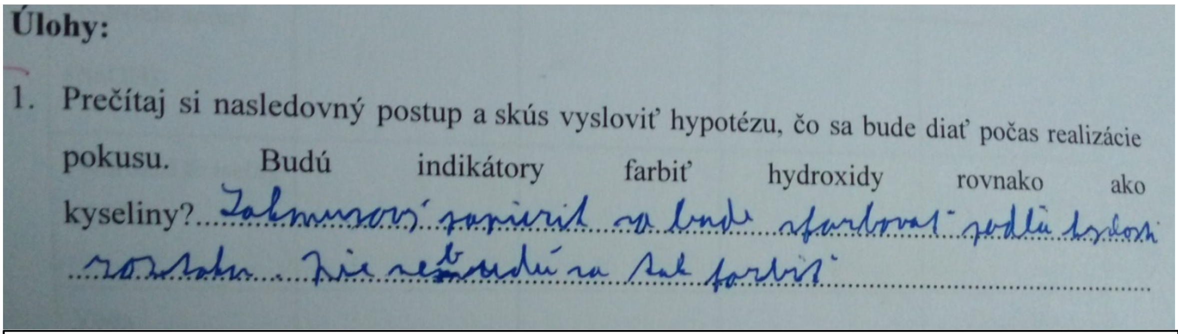
Developing hypotheses

Teacher's opinion: Most of the students – 64% – were able to formulate a hypothesis without teacher's help. A further 20% of students formulated a hypothesis, but with the teacher's help. However, 16% of students could not formulate a hypothesis, even with the teacher's help. These students probably did not have sufficient theoretical rudiments for formulation of a hypothesis.

Observer notes: Students were very brief in their formulation of hypotheses. This is because they are not used to formulating hypotheses. It is necessary to remind the students that scientists certainly assume something before they start exploring – what might happen or what results can be expected.

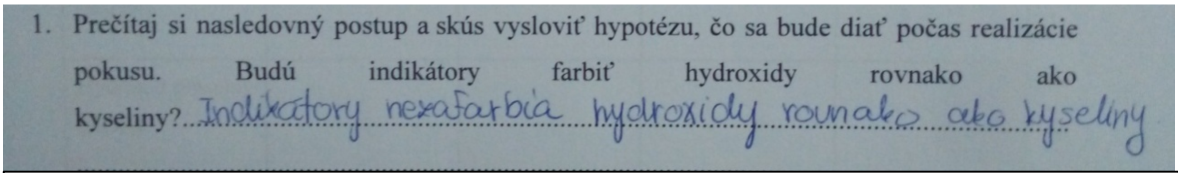
SAILS
Strategies for Assessment of Inquiry Learning in Science

Sample student artefacts

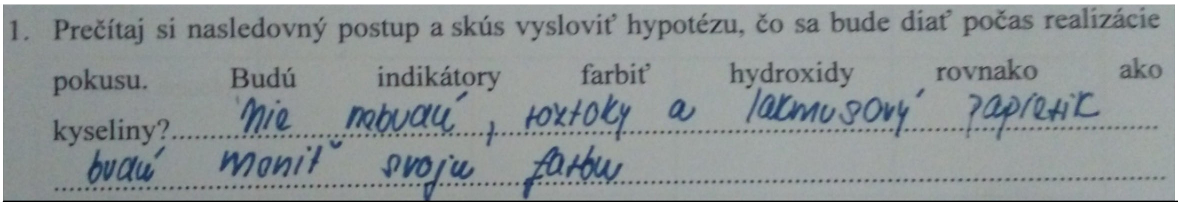

Úlohy:

1. Prečítaj si nasledovný postup a skús vysloviť hypotézu, čo sa bude diať počas realizácie pokusu. Budú indikátory farbiť hydroxidy rovnako ako kyseliny?...Lakmusový papierik sa bude sfarbovať podľa kyslosti roztoku. Nie nebudú sa tak farbiť

Read the following procedure and try to formulate a hypothesis about what will happen during the experiment. Will the indicators colour hydroxides the same way as acids? ***Lithmus paper will colour according to acidity of the solution. No, they will not colour that way.***


1. Prečítaj si nasledovný postup a skús vysloviť hypotézu, čo sa bude diať počas realizácie pokusu. Budú indikátory farbiť hydroxidy rovnako ako kyseliny?..Indikátory nezafarbia hydroxidy rovnako ako kyseliny

Read the following procedure and try to formulate a hypothesis about what will happen during the experiment. Will the indicators colour hydroxides the same way as acids? ***Indicators will not colour the hydroxides the same way as acids.***

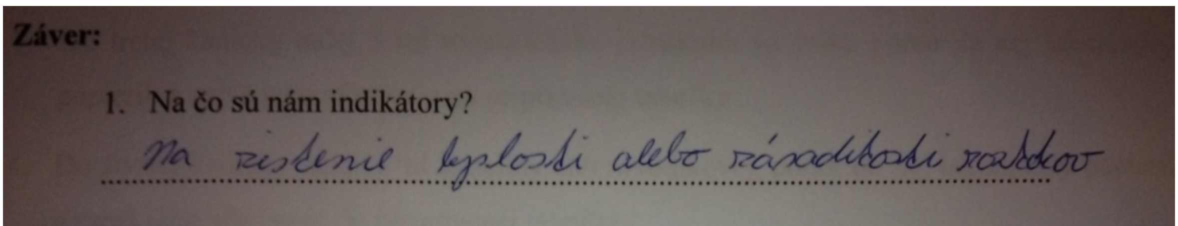

1. Prečítaj si nasledovný postup a skús vysloviť hypotézu, čo sa bude diať počas realizácie pokusu. Budú indikátory farbiť hydroxidy rovnako ako kyseliny?.......Nie nebudú, roztoky a lakmusový papierik budú meniť svoju farbu

Read the following procedure and try to formulate a hypothesis about what will happen during the experiment. Will the indicators colour hydroxides the same way as acids? ***No, they will not; solutions and litmus paper will be changing their colours.***

Scientific reasoning (forming conclusions)

At the end of the worksheet, students answered the question “What are the indicators for?” 62% of students answered without help, 20% of students answered with the teacher’s help and 12% of students were unable to formulate the conclusion with the teacher’s help.

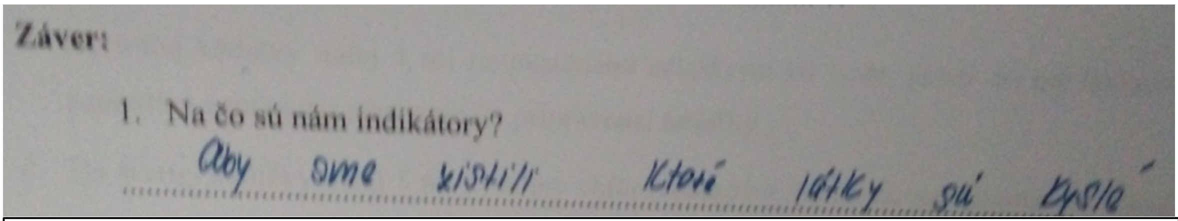
Sample student artefacts


Záver:

1. Na čo sú nám indikátory?

Na zistenie kyslosti alebo zásaditosti roztokov

Conclusion: 1. What are the indicators for? ***To find out acidity or alkalinity of solutions.***


Záver:

1. Na čo sú nám indikátory?

Aby sme zistili ktoré látky sú kyslé

Conclusion:
1. What are the indicators for?
So that we can find out which substances are acid

Scientific literacy

Table 3: Student assessment of their understanding after the lesson

Question	Student answers
What did I have troubles with during the lesson?	• no trouble distinguishing sample and indicator • writing into the table • quantity of tubes
What did I learn at the lesson?	• nothing • what the indicator is for • how to distinguish acid and alkaline solution
What else would I like to learn?	• more about acids and bases • about other indicators • practical use of acids and bases • nothing
What do I remember well?	• we always pour acid into water • when the solution is acid, neutral or alkaline • what indicators exist • what acids and hydroxides we know
Where can I use what I did at the lesson?	• in practical life • at home • when I will want to find out if I have an acid or a base • I don´t know where

Teacher's opinion: From the results of the metacognition exercise, we can see that experiments and data collection did not cause the students and difficulty (Table 3). Cooperation was good, they all tried to get on well and agree on what and how should be recorded. They also communicated with the teacher. This was the first time I have used metacognition in assessment. Students' answers were very brief and their word stock was very low. It was the first time students were asked the question "What did I have trouble with during the lesson?" etc. However, I think that this kind of assessment can improve students' knowledge and skills.

Observer notes:
As we can see from the results, only a small percentage of students answered "I do not know," "nothing," etc., which suggests that these activities were interesting and students understood what they did at the lesson and what new they had learnt. Students like this way of working; they do not have trouble cooperating with classmates or with the teacher. They are relaxed and open; they feel like young researchers, who are trying to discover something new.

(v) Use of assessment data

From the results about formulation of conclusions, I found out that it is necessary to ask helping questions, to help the students form conclusions. Formulation of conclusions, and their comparison with the initial hypothesis, should confirm to students that if they have some knowledge about the topic, then they are able to individually formulate hypotheses and also individually make experiments and verify their hypotheses by inquiry. It should increase the interest of students in acquiring new knowledge. Students can see that when they learn by inquiry and practical activity, they become more familiar with prior knowledge or they discover new knowledge.

Later, we compared the hypotheses from the beginning of the worksheet with their conclusions. While *developing hypotheses*, students learned that it is necessary to assume what might happen under certain circumstances, which can help them to avoid various problems.

In future lessons, I will certainly spend some time on formulation of hypotheses, because students were not familiar with this skill. Students at the second level of a primary school need help forming questions, which help them to formulate a hypothesis. I also recommend to discuss the term hypothesis = assumption, in advance. This way we can get the feedback if the aims of the lesson were fulfilled. We can react to unanswered questions at the next lesson. We can repeat or expand the most interesting activities.

(vi) Advice for teachers implementing the unit

I would recommend to those teachers, who are going to have an inquiry-based lesson for the first time:

- Prepare in advance all necessary tools, solutions and chemicals for students
- Prepare worksheets and helping questions for students, which will motivate their active participation during the lesson,
- Think in advance what they want to assess at the lesson,
- Scrupulously explain at the beginning of the lesson what students will be doing, how they will be doing it and what will be assessed,
- To respect safety rules during the lesson.