4.3 Case study 3 (CS3 Slovakia)

Concept focus	Features of acids and bases pH and indicators
Activities implemented	Activities B-C
Inquiry skills	Developing hypotheses
Scientific reasoning and literacy	Scientific literacy (explaining phenomena scientifically, designing scientific inquiry)
Assessment methods	Classroom dialogue Self-assessment Worksheets
Student group	**Grade:** 8th grade (lower second level chemistry class) **Age:** 14 years **Group composition:** co-ed (18 students), groups of 3-4 **Prior experience with inquiry:** None

Two activities from the **Acids, bases, salts** SAILS inquiry and assessment unit were chosen as part of the thematic unit Chemical Compounds in the Slovakian state curriculum for chemistry. The assessment focus was on *developing hypotheses* and enriching *scientific literacy*, looking at students' ability to explain phenomena scientifically and to design scientific inquiry. Assessment methods include classroom dialogue, evaluation of student devised materials and self-assessment.

(i) How was the learning sequence adapted?

The **Acids, bases, salts** SAILS unit was modified according to the requirements of the Slovakian state curriculum for chemistry. Activity B: Qualitative classification of substances using a pH indicator extracted from red cabbage was used as a starting point for this inquiry. The teacher implemented this activity as part of the thematic unit *Chemical compounds* (under the topic Acids-Bases: Examination of acidity and alkalinity of aqueous solutions), which outlines important chemical elements and compounds. The chosen activities were implemented in full. The students' first task was to describe the taste and properties of the presented substances from everyday life. Students were also given additional tasks: 1) Find out on the internet (or in an encyclopaedia or textbook) the meaning of the term "indicator" and 2) Suggest the procedure for how to prepare an indicator from cabbage – what tools will you need? These tasks were designed to help students, because they did not have experience with inquiry-based activities and they needed to know the meaning of the term indicator. Since the preparation of the home made indicator – red cabbage extract – is easy, this task was also included on the worksheet.

In the second part of the activity, the teacher modified Activity C: Measurement of the numerical value of pH, because they did not have a metre for pH measurement at school. Instead, students worked with homemade indicator (cabbage extract) and they searched for the pH values of available solutions on the Internet. To motivate and stimulate students, teacher used the following open questions:

- Are all sour-tasting substances acidic?
- What does the term indicator mean?
- How can we prepare an indicator from red cabbage?

The chosen activities were realised in a class of 18 students – 8 boys and 10 girls. The class is composed of very clever students, but also of average students, students from disadvantaged backgrounds and students with behaviour and learning disorders. However, they worked diligently and with joy to complete the worksheets (Figure 1). Since it was their first experience with inquiry-based activities in practical work, they appeared insecure.

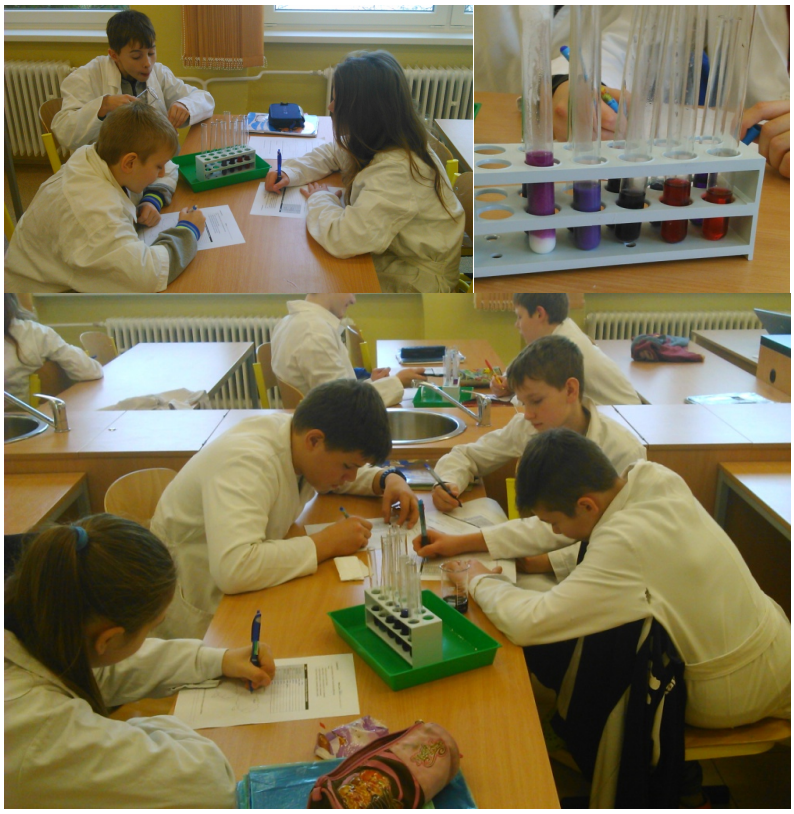


Figure 1: Students participating in the implementation of the unit

(ii) Which skills were to be assessed?

Within the realised inquiry-based activities, teacher focused in particular on the assessment of two inquiry skills: *developing hypotheses* and *scientific literacy* (explaining phenomena scientifically, designing scientific inquiry). The skill *developing hypotheses* was assessed by analysis of students' answers to tasks in the worksheet. While evaluating the student worksheets, the teacher also assessed other skills – searching for information in various sources (encyclopaedias, internet), realisation of experiment and presentation of results. A score scale of correct, with mistakes, incorrect and disinterested was used for assessment of inquiry skills.

Self-assessment was realised at the end of the inquiry-based lesson. Assessment of *scientific literacy* (explaining phenomena scientifically, designing scientific inquiry) was realised by analysis of student self-assessment cards, which were completed at the end of the lesson (Table 1, assessment tool recommended in the unit).

Gender was not taken into account during these activities. Boys and girls had the same tasks in the worksheets. They worked in mixed groups of three or four. In each group, there was one very clever student, one or two average students and one student with low results.

(iii) Criteria for judging assessment data

Since the students did not have experience with inquiry-based activities, the teacher expected that they would not be able to suggest hypotheses. Despite that, there were some students who did not have trouble; they were very skilful even in arguments. Their search for information was above teacher expectations and they cooperated in groups without problems, which was seen also during the presentation of common results of work. The teacher used formative assessment of students –

self-assessment card of a student after learning with inquiry-based method (Table 1 and Figure 2) and a grading scale of assessment of the mastered level of inquiry skills (Figure 3).

Table 1: Analysis of self-assessment cards for the assessment of scientific literacy

Self-assessment card	very well (%)	with deficiencies (%)	I can´t do it (%)
1. I understand the classification of substances based on the solution of red cabbage extract...	**39**	**33**	**28**
2. I was able to get information from the internet and encyclopaedia...	**67**	**22**	**11**
3. I was able to suggest procedure how to prepare the indicator from red cabbage...	**39**	**39**	**22**
4. I managed to get indicator from red cabbage...	**78**	**17**	**5**
5. I was able to sort out substances into acid and alkaline based on the values of pH...	**55**	**28**	**17**
6. I was able to explain the term indicator...	**28**	**39**	**33**
7. I was able to explain why water and kitchen salt solutions were not acidic or alkaline solutions...	**22**	**28**	**50**

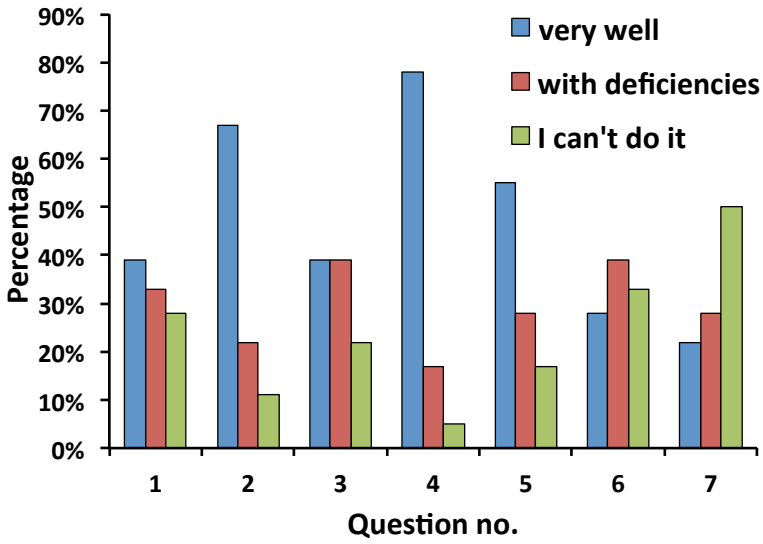


Figure 2: Analysis of student assessment cards

The teacher used a score scale from correct, with mistakes, incorrect and disinterested when assessing the level of independence of students, as shown in Figure 3. The following skills were assessed through evaluation of student worksheets:

- Developing hypotheses
- Searching for information in various sources
- Realisation of an experiment
- Presentation of results

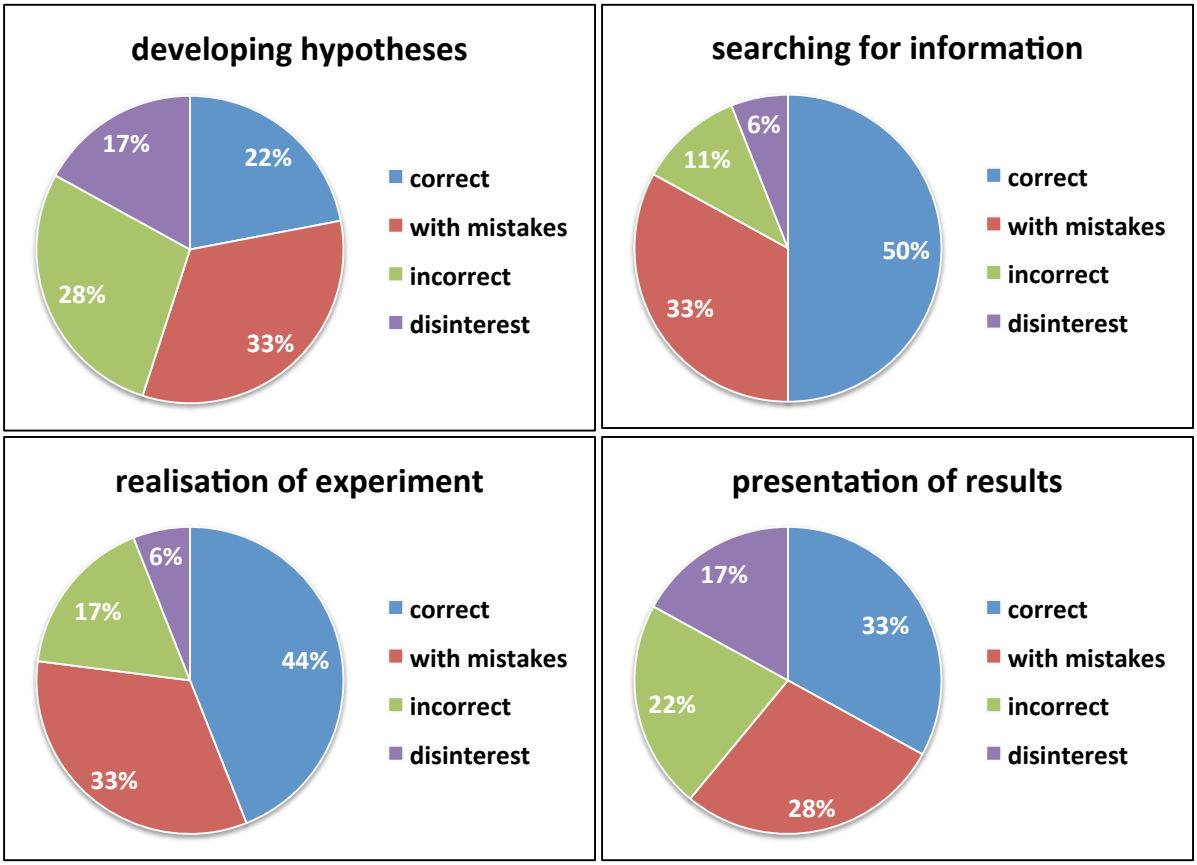


Figure 3: Charts showing results for each assessed criterion

Developing hypotheses

22% of students were able to correctly formulate hypotheses, while 33% of students made mistakes during the formulation. Up to 28% of students did not understand how to formulate hypotheses, so their formulations were wrong. 17% of students who were not able to formulate hypotheses or those who were inactive were a minority in comparison to those who managed this skill. It should be taken into account that students had no previous experience with inquiry-based activities.

Searching for information

Students searched for information in various sources (internet, encyclopaedias, and textbooks). Up to 50% of students managed to search for information correctly, which implies that students are able to search in various sources. Moreover, they were able to sort out the information and evaluate it critically, thus demonstrating development of their *scientific literacy*. 33% of students searched the necessary information with small mistakes and 17% of students did not search correctly or did not show any interest in the searching.

Realisation of experiment

A high percentage of students (77%) were able to realise the experiment without mistakes or just with small mistakes. 17% of students were unable to realise the experiment. There were also students who did not show interest and did not participate at all (6%).

Presentation of results

In comparison to the previously mentioned skills, more students had troubles with presentation of the results of their work, but the number of students with correct responses is still greater than each

of the other points on the scale. Generally, students are skilful enough at answering the questions and speaking to the class does not cause problems. Those students who had been active during all the activities and fulfilled the tasks correctly had no trouble during presentation of their own work. However, 22% of students did not master this skill, because they were shy to speak to the class.

(iv) Evidence collected

Teacher opinion

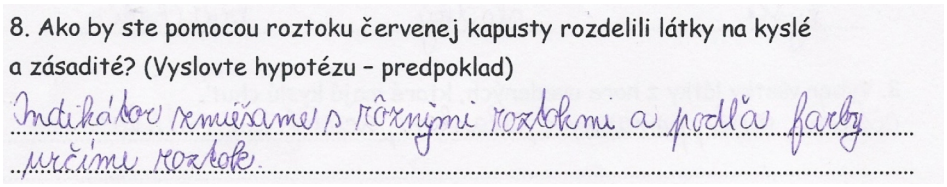
Students responded positively to this kind of teaching, they liked the inquiry. They would appreciate such lessons more often. From a teacher´s perspective, I consider inquiry-based activities beneficial for development of *scientific literacy* of students. They also develop several key competencies, such as *working collaboratively* (communication skills), *scientific reasoning*, and *forming coherent arguments* (explanation of observation).

The results show that students like inquiry-based activities and they are automatically motivated to better performance. Failure in some skills is caused by the fact that this is only the first experience with such activities. Realisation of more inquiry-based activities will gradually eliminate the deficiencies. The great advantage is that all the students are motivated.

Sample student artefacts

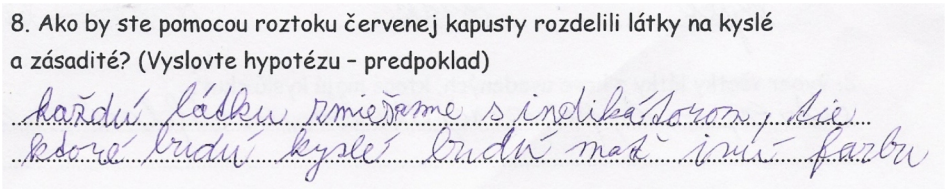
Below are some examples of students' answers to *developing hypotheses*:

Example 1: Sample of a correctly formulated assumption.
Student assumed correctly that the indicator will colour in the solutions and based on the colour we can determine if the solution is acidic, alkaline or neutral.


8. Ako by ste pomocou roztoku červenej kapusty rozdelili látky na kyslé a zásadité? (Vyslovte hypotézu – predpoklad)
Indikátor zmiešame s rôznymi roztokmi a podľa farby určíme roztok.

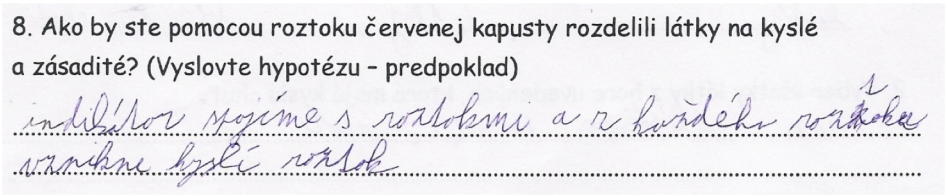
8. How can you sort out substances into acids and alkaline with red cabbage solution? (Formulate a hypothesis – assumption.)
We mix the indicator with various solutions and according to the colour, we determine the solution.

Example 2: Sample of a partly correct assumption.
Student assumed the colouring of indicator, but he focused only on acid solutions.


8. Ako by ste pomocou roztoku červenej kapusty rozdelili látky na kyslé a zásadité? (Vyslovte hypotézu – predpoklad)
každú látku zmiešame s indikátorom, ktorá kyslej bude mať inú farbu

8. How can you sort out substances into acids and alkaline with red cabbage solution? (Formulate a hypothesis – assumption.)
We mix every subtance with the indicator, those which are acids will have different colour.

Example 3: Sample of a wrong assumption.
Student formulated the assumption incorrectly. He did not understand that the indicator is a substance, which changes its colour of a solution based on acidity, alkalinity or neutrality.


8. Ako by ste pomocou roztoku červenej kapusty rozdelili látky na kyslé a zásadité? (Vyslovte hypotézu – predpoklad)

indikátor spojíme s roztokmi a z kvapôk roztoku vznikne kyslé roztok

8. How can you sort out substances into acids and alkaline with red cabbage solution? (Formulate a hypothesis – assumption.)
We mix the indicator with solutions and all the solutions will become acids.

(v) Use of assessment data

Based on the feedback, which I gained from the results of verification of inquiry skills, I will focus future inquiry teaching on the skills that caused most trouble to students; that is the skill of *developing hypotheses*. I assume that the more opportunities students have to develop this skill, the higher percentage of students will be able to manage it without problems or just with small deficiencies. Therefore I will definitely continue with inquiry-based activities and I will implement them into the next topics of chemistry at primary school.

An important element of evaluation was also the student self-assessment card, which enabled self-reflection and consideration of the level of abilities in individual phases of inquiry-based activities. Self-reflection by a student is the starting point for the teacher in planning activities focused on further progress in education.

(vi) Advice for teachers implementing the unit

I recommend to teachers who are starting with inquiry-based activities to be supporters of students at individual phases and to gradually increase the level of difficulty. Students will acquire inquiry skills more effectively and will be open to new ways of acquiring knowledge.