4.5 Case study 5 (CS5 Poland)

Concept focus	Building working electrical circuits Conductivity of everyday materials
Activities implemented	Activities A-C
Inquiry skills	Planning investigations
Scientific reasoning and literacy	Scientific reasoning (choosing components for an electrical circuit) Scientific literacy (ability to explain electrical conductivity scientifically)
Assessment methods	Classroom dialogue Teacher observation Student devised materials (mind maps, documentation of inquiry, drawings of circuit diagrams)
Student group	**Grade:** upper second level **Age:** 16-17 **Group composition:** mixed gender and ability; groups of 3 (34 students) **Prior experience with inquiry:** None

In this implementation, the teacher selected several skills for assessment, in particular *planning investigations* and *scientific literacy*, and focused on evaluation of specific pre-selected students or groups at different stages of the inquiry process. The teacher chaired a whole-class discussion to address difficulties experienced by the class. The lesson sequence was modified during the lesson, to allow the class to focus on specific key learning objectives.

(i) How was the learning sequence adapted?

At the beginning of the lesson IBSE was introduced and explained. The class asked if there would be a short exam or any standard assessment of assignment and it was denied. The teacher did not mention that she wanted to try to assess selected students using a new assessment approach. She was unable to print 34 copies of the 7-page worksheet, so she instead read aloud the text step by step and the students followed the tasks on separate sheets. The experiments were conducted in randomly selected groups of three students. Due to time constraints (45 minute lesson), Activity C was not implemented in full (ended at C.4).

During implementation, the teacher realised that half of the class were unable to complete question 2 of Activity B – even after consulting their peers those students could not establish a basic list of elements necessary to light the bulb. To speed up the lesson, the teacher proposed a whole-class discussion. Subsequently she showed the students a bulb, a battery, cables and the tape, available for the experiment. After that she asked the students to complete a drawing of a simple circuit (B.3).

The teacher decided that Activity C is the core of the lesson, so having only 12 minutes left after completing Activity B, she omitted question 1 of Activity C (writing the plan), asking the students only to list the objects suitable for the experiment and immediately proceeded to question 4. She wanted the students to examine whether the chosen objects conduct electric current or not, and if it is in agreement with what the students anticipated before the experiment. Only at the end of the lesson she asked some students, who already managed to examine a few objects, to complete drawing C.2. Such shortcuts in the scenario enabled to include performance of the experiment before finishing the lesson. However, the chosen approach disabled assessment following the proposal, so the teacher modified the rubrics and used them in the second class.

(ii) Which skills were to be assessed?

The teacher identified several opportunities for development and assessment of inquiry skills:

- Brainstorm (warm up activity) – assessment of *scientific literacy* (gathering knowledge) and *working collaboratively* (ability to cooperate)
- Mind map (question A.1) – assessment of recollection and ordering of knowledge (*scientific literacy/reasoning*), ability to cooperate
- Selection of elements to design the experiment – assessment of planning the experiment and *working collaboratively* (ability to cooperate)
- Building working electrical circuits – assessment of *planning investigations* (conducting experiments) and *working collaboratively* (ability to cooperate)
- Drawing working electrical circuits – assessment of elaboration of the experimental outcomes (*scientific literacy/reasoning*)

Teacher observation and rubrics were used to evaluate student work and to assess development of selected skills during particular activities.

(iv) Criteria for judging assessment data

Prior to the implementation of this unit, the teacher selected students (or student groups) for evaluation in each of the chosen inquiry skills. The students were not told that they were selected for assessment. In general, the teacher observed individual students, although in the case of assessment of *planning investigations* and building working electrical circuits the students were assessed as a group. Using this method, the teacher was able to assess several inquiry skills, although not all students were assessed. The teacher intends to use this method of assessment in future lessons, and will ensure that all students are evaluated in the course of the school year.

Assessment based on brainstorming activity

Teacher observation was used to assess four students during the brainstorming activity before Activity A of the lesson scenario. Immediately after the brainstorming session, when students worked on their own, the performance of the selected students was analysed and evaluated in terms of a four-point scale (1 to 4), looking at both *scientific literacy* (gathering knowledge) and *working collaboratively* (showing respect to each other), as shown in Table 1.

Table 1: Assessment during the brainstorming activity

Student	Engagement (no. of times participated)	Prior knowledge	Creativity	Culture of discussion	Mean score
Student 1	4	3	4	1	3
Student 2	0	0	0	0	0
Student 3	0	0	0	0	0
Student 4	2	3	3	4	3

Students 2 and 3 did not participate in the brainstorming at all, however this attitude was not evaluated negatively, as this is a large class (34 students), which restricts the number of participants in a short brainstorming lasting just a few minutes. In order to get a broader picture, the evaluation of the same group of students should be repeated in a few other brainstorming activities. Moreover in the course of the brainstorming it would be more appropriate to ask directly the students selected for evaluation for their opinion and this way giving opportunity to speak to the more quiet (student 2) or timid (student 3) students.

Assessment of mind maps

For assessment of mind maps, four students were assessed on:

- Design of the mind map (*scientific literacy* and *scientific reasoning*; recollection and ordering of knowledge)
- Level of discussion in pairs (discussing the meaning of each of the words in the mind map)

A four-level rubric was utilised, following the suggestion in the original unit (Table 2). The rubric table was modified by adding a row on the evaluation of engagement in discussion in pairs. An additional evaluation table was used to generate the final mark for this activity (Table 3). In this part of the lesson, a serious discussion (A.3) on the meaning of the terms used in the mind maps occurred to be the most difficult task. Students were supposed to discuss in pairs (unlike the suggestion in the original scenario). At the beginning in most cases it was limited to the reading of terms. However, triggered with some questions asked by the teacher, the discussion developed a bit. Under discussion, student 7 expressed her opinion that "light" can be in some circumstances treated as a scientific term, and in others it is not. She developed a category "half-scientific". Perhaps a part of the reason for the sluggish discussion was the small group size. It should be noted that this lesson was the students' first experience of designing mind maps.

Table 2: Rubric for assessment of student mind maps

Assessed skill	Emerging	Developing	Consolidating	Extending
Drawing a mind map	Student's mind map is empty or full of inadequate words, for which the student cannot describe a relation to electricity	Student is able to draw a mind map containing only a few words and/or the words are listed with no relation to each other	Student is able to draw a mind map with more than 10 words, both scientific and belonging to a common language, but the visualisation of the relationships and categories is poor	Student is able to draw a mind map with more than 10 words, both scientific and belonging to a common language, with a good visualisation of the relationships and categories
Discussion with peers	Student does not take part in the discussion	Discussion between the students is limited to reading words from own mind maps and checking the neighbour's terms.	Student detects differences between two mind maps and compare them (e.g. tries to judge which one is better)	Student points out significant differences and compares both mind maps; considers scientific value of scientific terms in both maps and argues, why one of them is better that the other.

Table 3: Evaluation criteria

Student	Adequacy and diversity of terms and meaning of scientific terms	Visualisation of relationship between terms/categories	Participation in discussion	Mean score (1-4)
Student 5	**4**	**3**	**2**	**3**
Student 6	**3**	**2**	**2**	**2**
Student 7	**3**	**1**	**4**	**3**
Student 8	**2**	**1**	**1**	**1**

Planning investigations

To evaluate *planning investigations*, the teacher used a four-level rubric, based on one from the original unit but modified to reflect assessment of cooperation with a peer (Table 4). The four pre-selected students were assessed on:

- Selection of objects to construct a simple electric circuit to light the bulb
- Discussion with a peer on the above mentioned selection

Table 4: Rubric for assessment of planning investigations

Assessed Skill	Emerging	Developing	Consolidating	Extending
Selection of an adequate set of elements (B.1) and discussion with a peer (B.2)	Student attempts to choose the set of elements, but his/her list is not complete or inadequate and s/he is not able to complete the task even after the discussion with a peer.	Student attempts to choose the set of elements, but his/her list is not complete or inadequate; s/he is able to complete the task only after the discussion with a peer.	Student is able to complete the set of adequate elements, but during the discussion with a peer is not able to argue for his choice	Student is able to complete the set of adequate elements, discuss his/her choice with a peer and is able to argue for his choice.

Evaluation of building working electrical circuits

To evaluate this skill, the teacher used a four-level rubric (Table 5). The four students were assessed on their ability to:

- Build working electric circuits
- Cooperate in a group during the experiment

Table 5: Rubric for assessment of building working electrical circuits

Assessed Skill	Emerging	Developing	Consolidating	Extending
Investigation of conducting properties of the selected objects (C.4), cooperation within the group	Student is hardly engaged in a team work or s/he is engaged but the group is not able to build a working electric circuit	Student is engaged, but the group is able to examine only 1-2 objects	Student is engaged and the group is able to examine a few (3-4) objects and to compare the results with hypothesis.	Student is engaged and the group is able to examine a few (>4) objects and to compare the results with hypothesis. Group shows creativity, e.g. if the result of experiment differs from hypothesis, the group searches for the sources of errors and repeats the experiment.

Evaluation of representation of electrical circuits

Four students were assessed on their ability to draw representations of working electric circuits (activities B.3 and C.2). Teacher developed a four-point rubric for assessment of the circuits drawn (Table 6).

Table 6: Rubric for assessment of representation of electrical circuits

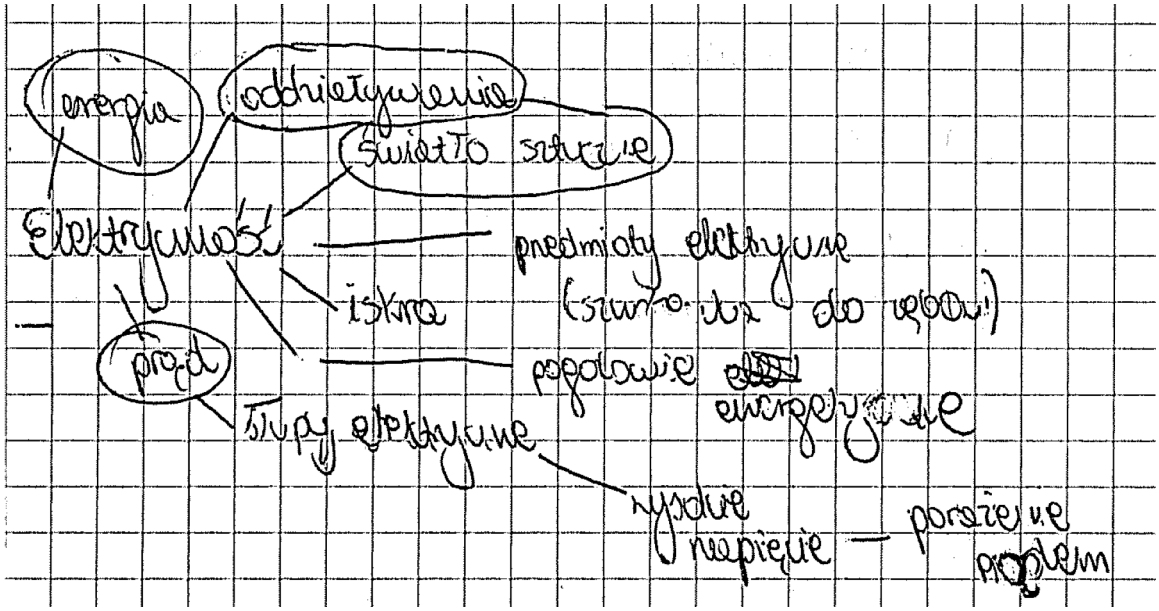
Assessed Skill	Emerging	Developing	Consolidating	Extending
Drawing two working electric circuits (parts B.3 and C.2)	Student is able to draw 1-2 schematic drawings but they are incorrect or not readable.	Student is able to draw one schematic drawing completely correctly, but the other one is incorrect or incomplete.	Student is able to draw both drawings correctly, but there are minor errors.	Student is able to draw both drawings totally correctly.

(iv) Evidence collected

Assessment of mind maps

As detailed previously, four students were chosen for assessment of mind maps. They were evaluated on design of the mind map (*scientific literacy* and *scientific reasoning*; recollection and ordering of knowledge), as well as level of discussion in pairs. Examples of student mind-maps and the grades received are shown below.

Student 5

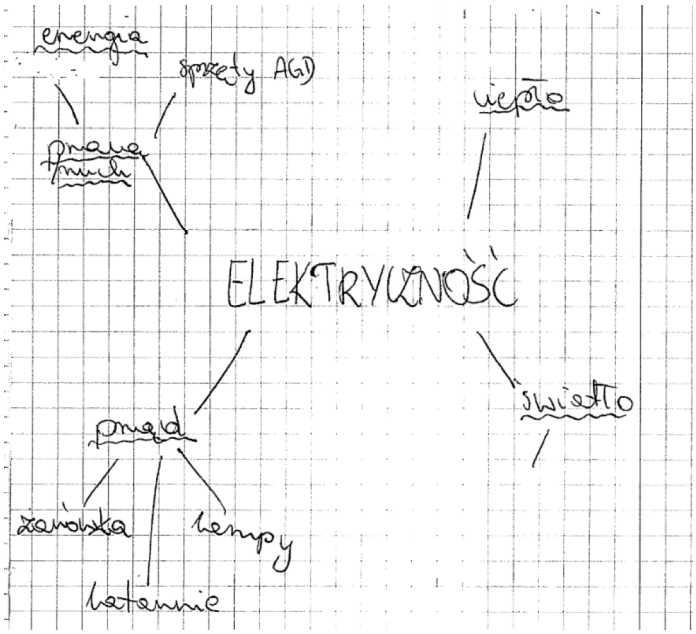


Words include: ***Electricity → energy***
Electricity → interactions Electricity → artificial light Electricity → electric devices (electric toothbrush)
Electricity → spark Electricity →electric emergency help
Electricity → current
Electricity → electric piles Electricity → high voltage → voltage shock

Adequacy and diversity of terming and meaning of scientific terms: ***4***

Visualisation of relationship between terms/categories: ***3***

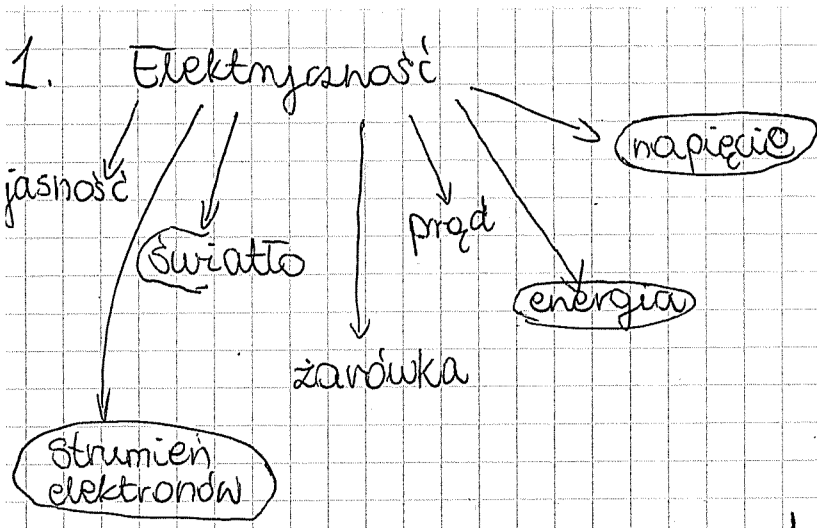
Student 6



Words include: ***Electricity*** → ***heat*** → ***light*** → ***laws of motion*** → ***current*** → ***energy, devices*** → ***bulb, lamps, street lanterns***

Adequacy and diversity of terming and meaning of scientific terms: ***3***
Visualisation of relationship between terms/categories: ***2***

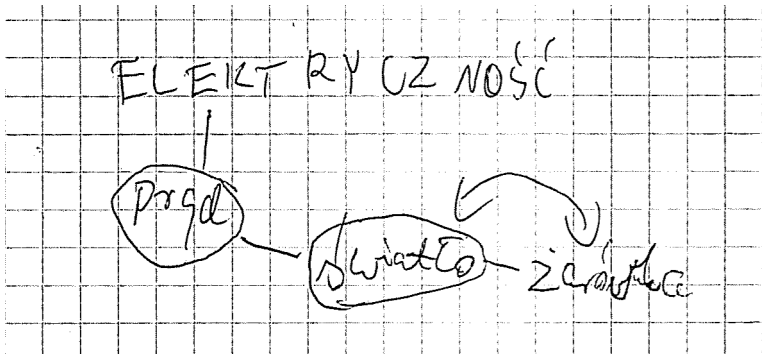
Student 7



Words include: ***Electricity*** → ***brightness*** → ***stream of electrons*** → ***light*** → ***bulb*** → ***current*** → ***energy*** → ***voltage***

Adequacy and diversity of terming and meaning of scientific terms: ***3***
Visualisation of relationship between terms/categories: ***1***

Student 8



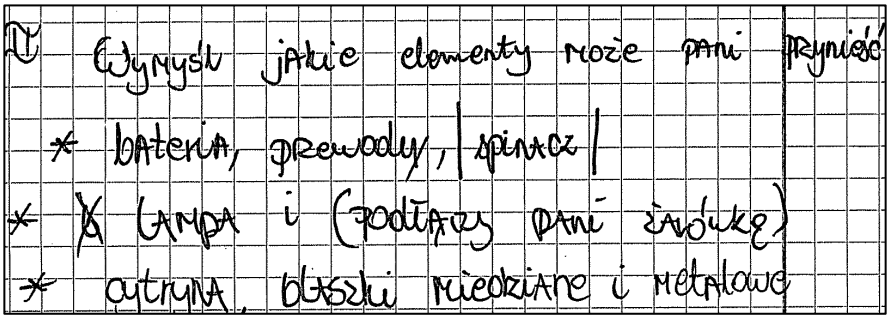
Words include: ***Electricity*** ***→ current*** ***→light*** ***→bulb***
Adequacy and diversity of terming and meaning of scientific terms: ***2***
Visualisation of relationship between terms/categories: ***1***

Planning investigations

For assessment of *planning investigations*, students were evaluated based on selection of objects to construct a simple electric circuit to light the bulb. At first students were supposed to think on task B.1 and write down a list of elements necessary to light the bulb on (part 2a – in pairs) and subsequently – to discuss their choice with a neighbour and write down joint conclusions (part 2b – in pairs).

A schoolboy, student 9, proposed 3 (!) versions of experiment and took a lively discussion with his peer. He did not however write down the results of their discussion (see student artefact below). A schoolgirl, student 10, was short in her discussion and quickly came to the basic list of elements necessary to fulfil the task. For students 11 and 12 (both female), when thinking independently, they were far away from a correct construction (artefacts below), however they managed to come to correct conclusions after a longer discussion. In this part of the lesson the discussions were discussions in question

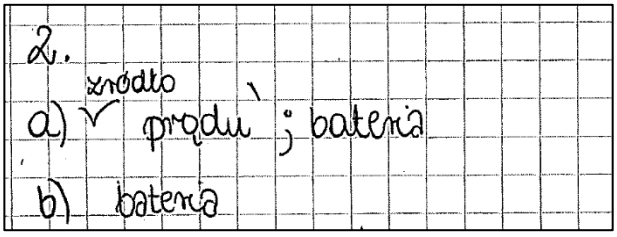
Student 9



- ***Battery, cables, paper clip***
- ***Lamp + bulb***
- ***Lemon, copper and metal plate***

Score in accordance with rubric: ***4***

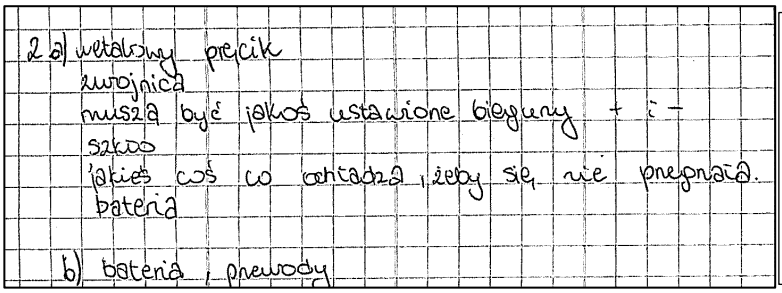
Student 10



- ***Source of current; battery***
- ***battery***

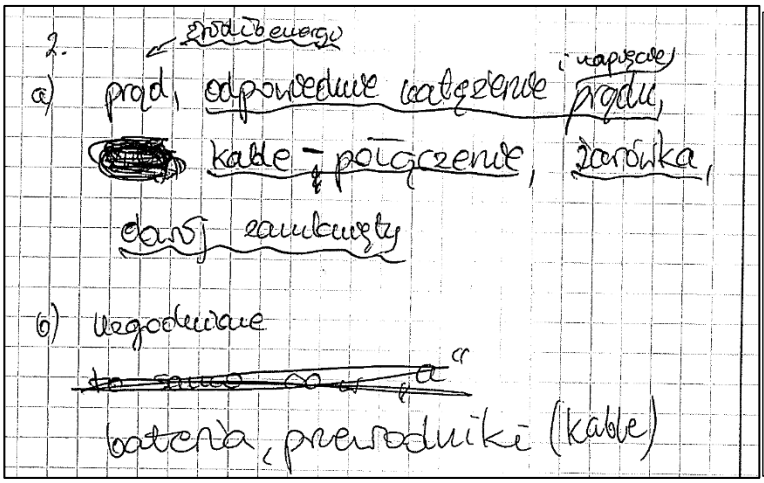
Score in accordance with rubric: ***3***

Student 11



a) Metal wire, coil, poles need to be connected somehow, glass, something to cool down in order to avoid overheating, battery
b) battery, cables
Score in accordance with rubric: ***2***

Student 12

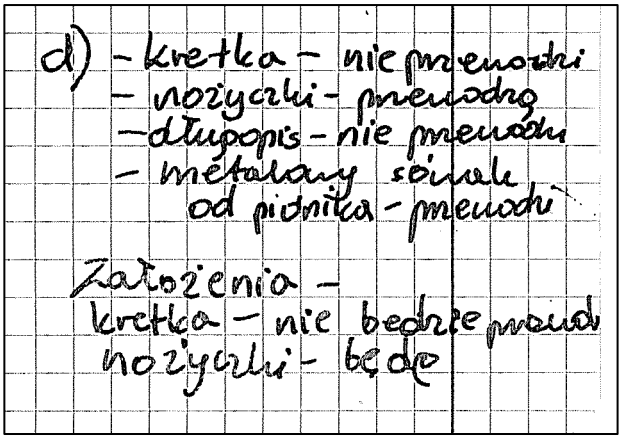


a) source of energy, current, adequate voltage and current, cable-linkage, bulb, closed circuit
b) battery, cables
Score in accordance with rubric: ***2***

Building working electrical circuits

Group B stood out among the others by proposing to investigate graphite. First failures did not discourage the students and they repeated the experiment with graphite several times coming to the conclusion that graphite conducts the electric current as anticipated. Group C was not able to complete investigation of any object, although it put forward some hypothesis on bulb lighting. The problem was in prolonging hesitation of using the bulb as indicator of the conducting in the circuit and in incorrect connection of additional objects to the electric circuit. Both groups, A and D managed to investigate a few objects, however group D wrote down the note only about investigation of the key (see artefacts below).

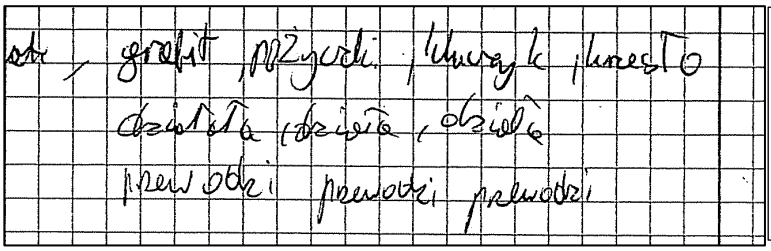
Group A



- ***crayon (non-conducting)***
- ***scissors (conducting)***
- ***ball-pen (non-conducting)***
- ***metal zipper (conducting)***

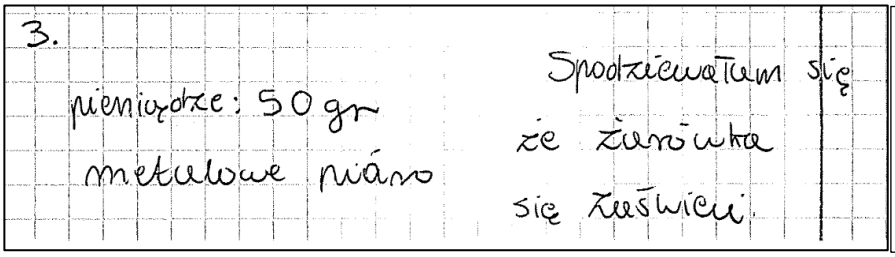
Score in accordance with rubric: ***3***

Group B



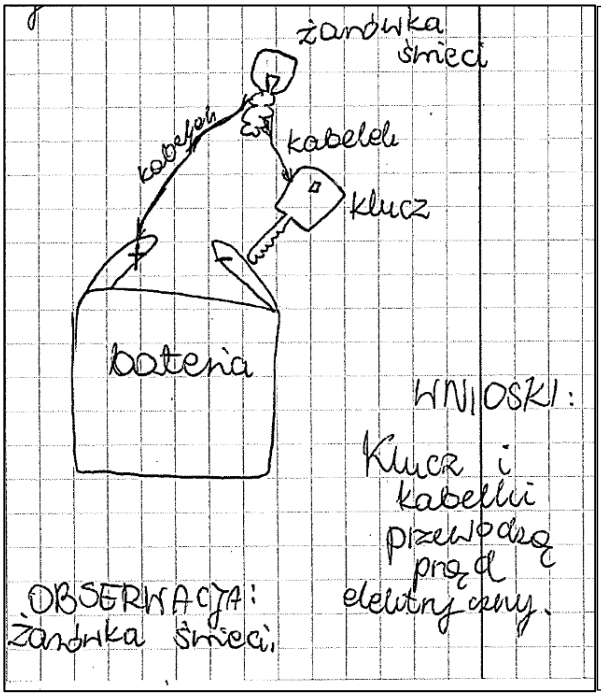
Graphite, scissors, key – all conducting
Score in accordance with rubric: ***4***

Group C



Coin: 50 g – the bulb will light up
Metal pen – the bulb will light up
Score in accordance with rubric: ***1***

Group D



Observation: the bulb lights up

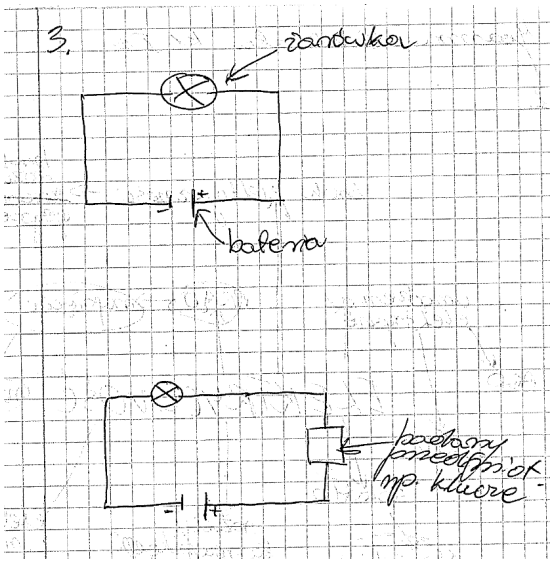
Conclusions: the key and the cables conduct electric current

Score in accordance with rubric: ***3***

<u>Representation of electrical circuits</u>

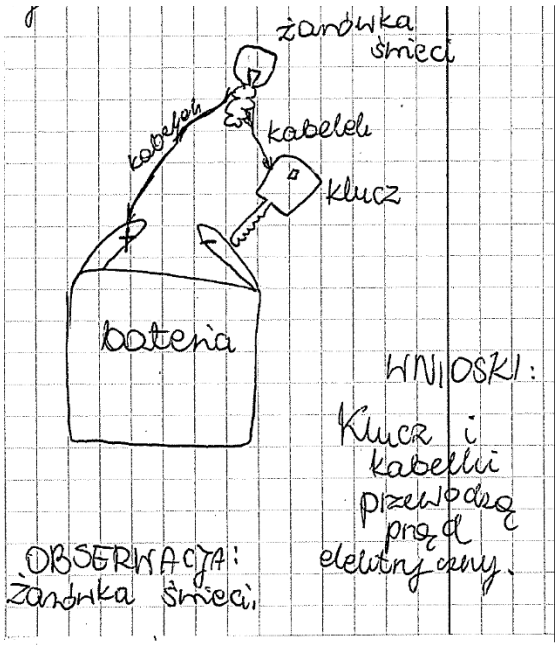
To assess students' ability to draw representations of working electric circuits, responses to activities B.3 and C.2 were evaluated. Both student 13 (female) and student 16 (male) drew two circuits. However the second circuit of student 16 is not totally correct/readable (inclusion of scissors). As the lesson was supposed to end at point C.4, the teacher did not introduce electric symbols (C.5). Considering the above, drawings done by students 14, 15 and 16 had been accepted as correct ones. Students 14 and 15 (both female) drew only one circuit each. However in student 15's drawing the circuit is not closed.

Student 13



Assessment score: 4

Student 14



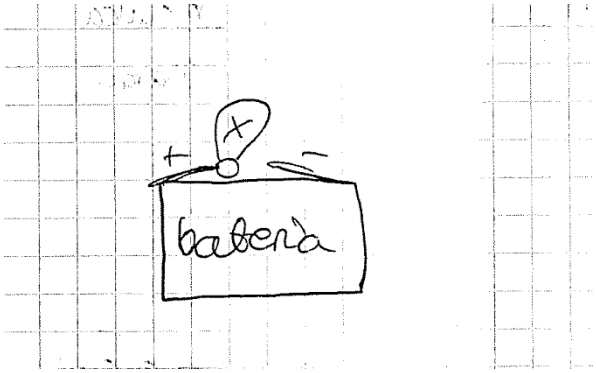
Observation: the bulb lights on

Conclusions: the key and the cables conduct electric current

Score in accordance with rubric: ***3***

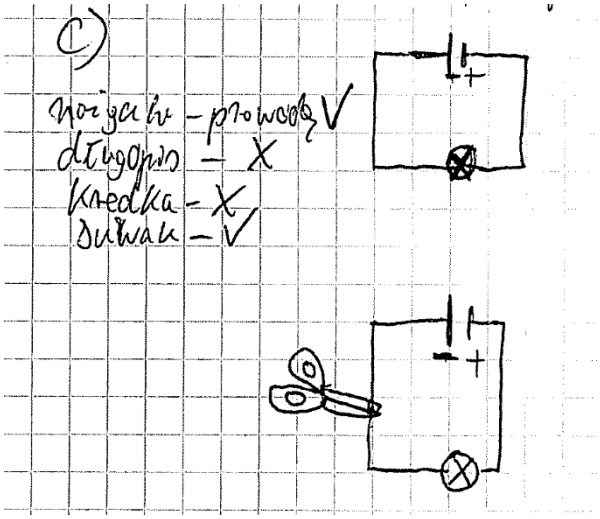
Assessment score: 2

Student W



Assessment score: 1

Student 16



Assessment score: 3