4.4 Case study 4 (CS4 Poland)

Concept focus	Simple electric circuits Electrical conductivity of everyday materials
Activities implemented	Activities A-C
Inquiry skills	Planning investigations
Scientific reasoning and literacy	Scientific reasoning (identifying connections) Scientific literacy (explaining the principles of electricity scientifically)
Assessment methods	Classroom dialogue Teacher observation Peer-assessment Self-assessment Worksheets Student devised materials (mind maps)
Student group	**Grade:** lower second level **Age:** 14 years **Group composition:** mixed gender and ability; groups of 4 (20 students) **Prior experience with inquiry:** None

In this case study, students' *scientific reasoning* and *scientific literacy* were assessed, in particular their ability to form connections between scientific concepts and prior knowledge or experiences, and their ability to explain the principles of electricity in a scientific way. Teacher observation and a frequency chart were used to record students' contributions during brainstorming, while student artefacts were evaluated using rubrics. In addition, peer- and self-assessment were used to assess skill in *planning investigations*.

(i) How was the learning sequence adapted?

The **Electricity** SAILS inquiry and assessment unit was implemented during two lessons (45 minutes each) in a group of students of 14 years old (students from city and countryside with different abilities). Students were divided into 5 groups, 4 students in each group. The unit was carried out as per the original unit, which was completed in the classroom up to question 10 in Activity C. Students were asked to do question C.11 as a homework exercise.

(ii) Which skills were to be assessed?

The teacher identified several opportunities to assess development of inquiry skills:

- Brainstorm – *scientific reasoning* and *scientific literacy*
- Mind map – *scientific reasoning* and *scientific literacy*
- Evaluation of representations of electrical circuits – *scientific reasoning* and *scientific literacy*
- Evaluation of planning the experiment (*planning investigations*)

Teacher observation, frequency charts and rubrics were used to evaluate student work and to assess development of selected skills during particular activities. The teacher developed 6-point rubrics, which are consistent with grading in traditional context in Poland.

(iii) Criteria for judging assessment data

Assessment based on brainstorming activity

Teacher observation was used for assessment of *scientific literacy* (using prior knowledge of electricity in a new context) and *scientific reasoning* during the brainstorming exercise. The teacher used a participation frequency chart, on which she marked a plus (+) beside the student name each

time they contributed to the class discussion (Table 1). Evaluation criteria were used to determine a mark on a 6-point scale (Table 2), which was entered in the final column (Mark) in Table 1.

Table 1: Participation frequency chart

Assessed Skill	Prior knowledge	Engagement	Mark
Student 1	+ +	+ + +	6
Student 2	+	+ +	4
Student 3	+	+ + +	5
Student 4		+ +	3

Table 2: Evaluation criteria

No. of pluses (+)	0	1	2	3	4	5-6
Mark	1	2	3	4	5	6

Assessment of mind maps

The teacher used a modified rubric (Table 3) to evaluate student artefacts and to assess development of selected skills during the mind map activity.

Table 3: Rubric for assessment of student mind maps

Task	1	2	3	4	5	6
Drawing a mind map	Student doesn't draw mind map or draws it putting words not connected to topic (can't explain the connection to the topic).	Student can draw a mind map containing 5 words connected to the topic, but there is a lack of connections and relations between them.	Student can draw a mind map containing more than 5 words connected to the topic and the majority of the words are from common language. There is a lack of connections and relations between words.	Student can draw a mind map with more than 8 words connected to the topic (majority of words are from common language). Student draws the connections between some words.	Student can draw a mind map with more than 10 words connected to the topic (most of words are from common language). Student draws connections between words but the structure is not very much expanded.	Student can draw a mind map with more than 10 words connected to the topic and most of words are scientific. Student draws proper relations and connections between words.

Evaluation of representation of electrical circuits

The teacher used a modified rubric to evaluate student artefacts and to assess student skill in drawing electrical circuits (Table 4). The teacher looked at

- Selection of materials (Activity B.1)
- Drawings of one scheme of electrical circuits with bulb (Activity B.3)
- Drawing of one circuit to check conductivity of different materials (Activity C.2).
- Drawings of schemes of circuits (Activity C.5)

Table 4: Rubric for assessment of representing circuits

Task	1	2	3	4	5	6
Drawing circuits	Student can choose proper components of circuit to light a bulb (B.1) but can't draw the scheme or draws it incorrectly (B.3). S/he can't draw proper circuit (C.2) and schemes of circuits (C.5)	Student can choose proper components of circuit to light a bulb (B.1) and can draw this circuit (B.3). S/he can't draw circuit or do it incorrectly (C.2). S/he can't draw schemes of circuits (C.5)	Student can choose proper components of circuit to light a bulb (B.1) and can draw this circuit (B.3). Student can draw circuit (C.2) but can't draw properly the schemes of circuits (C.5).	Student can choose proper component of circuits to light a bulb (B.1) and draws one of the circuits (B.3) or (C.2), but can't draw properly the scheme of circuits (C.5).	Student can choose proper component of circuit to light a bulb (B.1) and draw circuits (B.3) and (C.2). Student makes mistakes in drawing one of the schemes of circuits (C.5).	Student can choose proper component of circuit to light a bulb (B.1) and draws circuits (B.3) and (C.2). Student can draw schemes of circuits (C.5).

Evaluation of planning investigations

The teacher used a modified rubric (Table 5) to evaluate student artefacts and to assess student skill *planning investigations* (Activity C, 1). In addition, this was used as an opportunity for self-assessment (Table 6) and peer-assessment (Table 7).

Table 5: Rubric for assessment of planning investigations

Task	1	2	3	4	5	6
Planning investigations	Student can't list things made of different materials for measurement and can't write down an experiment plan.	Student can list 2-3 things made of different materials for measurement but can't write down an experiment plan.	Student can list 4-5 things made of different materials for measurement and writes down an incorrect experiment plan.	Student can list 4-5 things made of different materials for measurement and writes down an almost correct experiment plan.	Student can list 6-7 things made of different materials for measurement and writes down an almost correct experiment plan.	Student can list more than 7 things made of different materials for measurement and writes down a correct experiment plan.

Table 6: Self-assessment tool for assessing planning investigations

Self-assessment card	0 (not at all)	1	2	3	4	5	6 (very much)
1. I was involved in planning the experiment							
2. I carried out the tasks							
3. I helped colleagues in my group							
4. I was involved in filling in the data collection table							
5. I was active in performing the experiment							
6. I communicated properly with the others							

Table 7: Peer-assessment card for assessment of planning investigations (grade from 1-6)

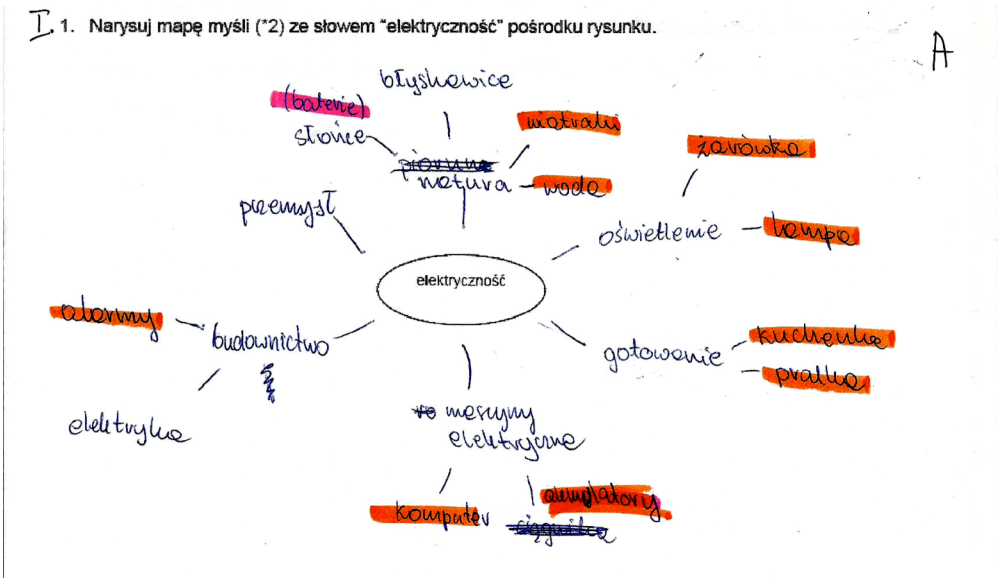
Peer-assessment card	Peer 1	Peer 2	Peer 3
1. Did your colleague take part in planning the experiment?			
2. Did your colleague take part in carrying out the given tasks?			
3. Was your colleague helping the group?			
4. Was your colleague engaged in data collection?			
5. Did your colleague take part in performing the experiment?			
6. Did your colleague communicate properly in the group?			

(iv) Evidence collected

During the lesson, the teacher evaluated different students for different skills. The teacher focused on one group for assessment of planning and performing the main experiment (conductivity of different materials).

Assessment of mind maps

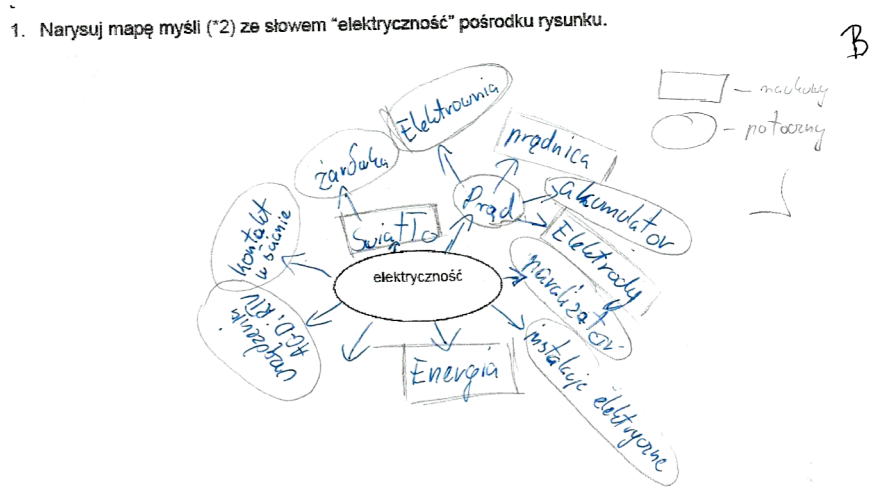
Students prepared mind maps during question A.1 (draw a mind map with the word "electricity" in the centre), which teacher evaluated to assess *scientific literacy* and *scientific reasoning*. Examples of student work, and corresponding teacher feedback are shown in Figure 1, Figure 2, Figure 3, and Figure 4.



Words include (*clockwise from bottom left*): ***electricity, alarms, building construction, industry, the Sun (batteries), lightning, nature, windmills, water, lighting, bulb, lamp, cooking, stove, washing machine, electric machines, computers, accumulators***

Assessment mark: ***3; mind map with more than 10 words. Mind map was about usage of electricity and only a few words from scientific language.***

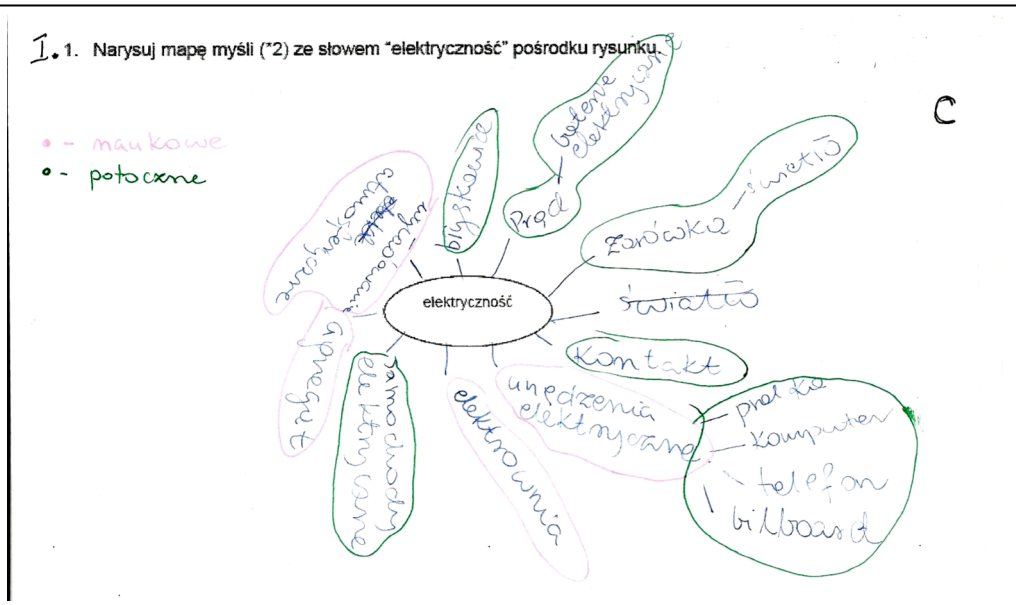
Figure 1: Example of mind map by student A



Words include (*clockwise from bottom left*): ***household appliance, electrical socket, light, bulb, current, power station, generator, accumulator, electrodes, taser, electrical installation, energy***

Assessment mark: ***4; mind map with more than 10 words. Mind map was not complex. Student used a few scientific words.***

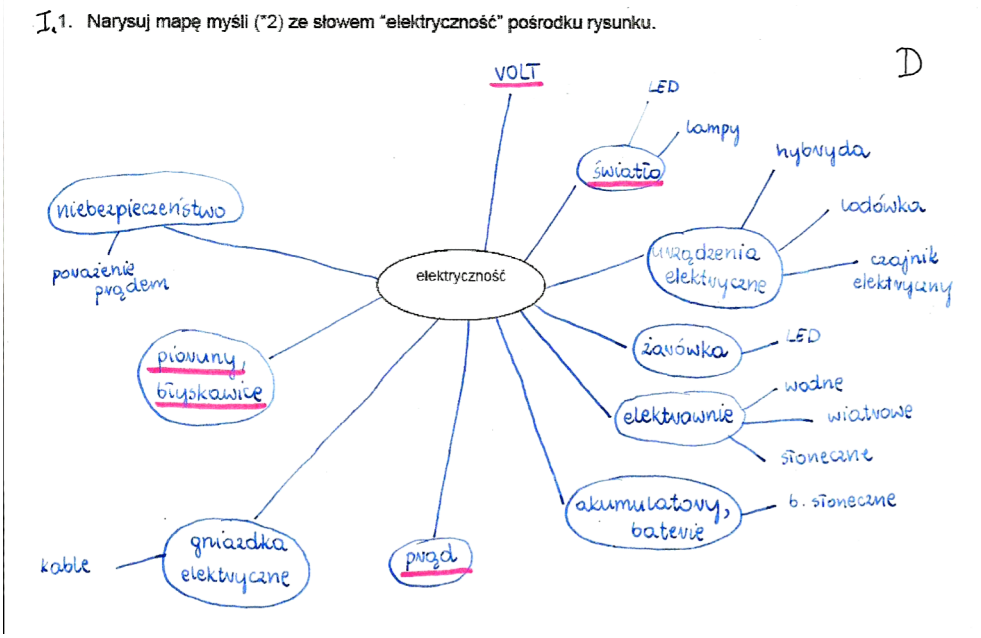
Figure 2: Example of mind map by student B



Words include (*clockwise from bottom left*): ***electric cars, aggregator, thunderbolt, lightning, current, electric batteries, bulb-light, contact, electric devices, washing machine, computer, telephone, billboard***

Assessment mark: ***4; mind map with more than 10 words. Mind map was not complex. Student used a few scientific words.***

Figure 3: Example of mind map by student C



Words include (*clockwise from bottom left*): ***electrical sockets, wires, thunderbolt, lightning, danger, electrocution, volt, light, LED, lamps, electric devices, hybrid, fridge, electric kettle, bulb, LED, power station, water, wind, sun, accumulators, batteries, sun batteries, current***

Assessment mark: ***6; mind map with more than 10 words with a lot of core words. Mind map wasn't only about the usage of electricity. Student used a lot of words from scientific language and showed the relationships between them.***

Figure 4: Example of mind map by student D

Representation of electrical circuits

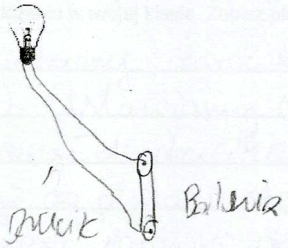
To assess students' ability to represent electrical circuits in different ways (*scientific literacy*), teacher looked at

- selection of materials (question B.1)
- drawings of one scheme of electrical circuits with bulb (question B.3)
- drawing of one circuit to check conductivity of different materials (question C.2).
- drawings of schemes of circuits (question C.5)

Examples of student work are shown in Figure 5, Figure 6, Figure 7 and Figure 8.

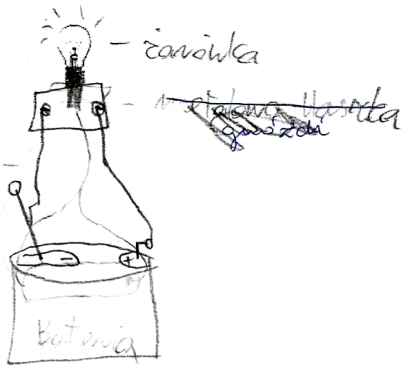
II. 3. Narysuj najprostszy obwód elektryczny (*3), w którym żaróweczka będzie się świecić.

E



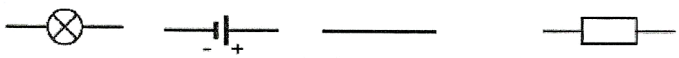
III. 2. Narysuj (*3) najprostszy działający obwód elektryczny, pozwalający na zbadanie własności elektrycznych (przewodnictwa) przedmiotu z twojego otoczenia.

E



III. 5. W naukach ścisłych i inżynierii, podczas dokumentowania wyników eksperymentów zamiast rysunków realistycznych używa się rysunków schematycznych. Na przykład obwód elektryczny przedstawia się za pomocą schematu obwodu elektrycznego. Żeby wykonać taki rysunek, trzeba znać symbole poszczególnych elementów elektrycznych. Zwykle używa się następujących znaków:

E



żarówka bateria przewód elektryczny przedmiot włączony do obwodu

Używając powyższych symboli, narysuj poniżej schematy elektryczne reprezentujące obwody elektryczne z części II.3 i III.2 tego arkusza.

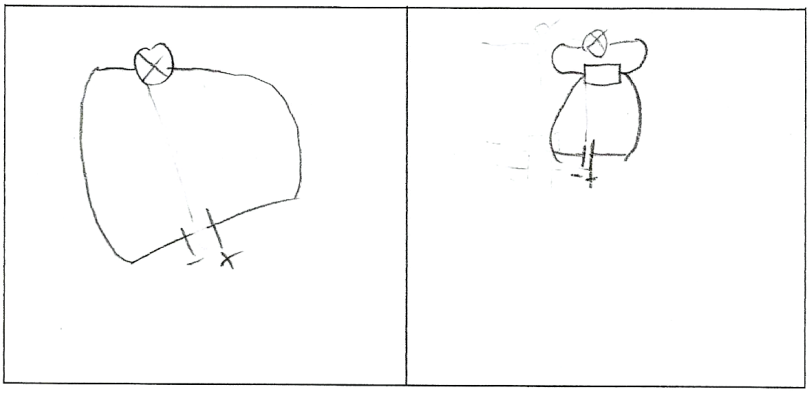
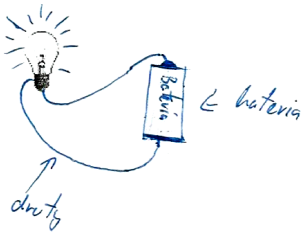
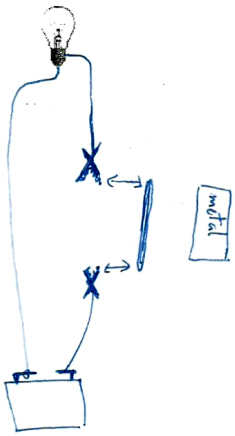


Figure 5: Example of representation of a circuit, by Student E. Mark: 2; student properly chose the components of circuit B.1, drew proper circuit B.3, but drew incorrect image and scheme of circuit for C.5

II, 3. Narysuj najprostszy obwód elektryczny (*3), w którym żaróweczka będzie się świecić.



2. Narysuj (*3) najprostszy działający obwód elektryczny, pozwalający na zbadanie własności elektrycznych (przewodnictwa) przedmiotu z twojego otoczenia.



III, 5. W naukach ścisłych i inżynierii, podczas dokumentowania wyników eksperymentów zamiast rysunków realistycznych używa się rysunków schematycznych. Na przykład obwód elektryczny przedstawia się za pomocą schematu obwodu elektrycznego. Żeby wykonać taki rysunek, trzeba znać symbole poszczególnych elementów elektrycznych. Zwykle używa się następujących znaków:

żarówka bateria przewód elektryczny przedmiot włączony do obwodu

Używając powyższych symboli, narysuj poniżej schematy elektryczne reprezentujące obwody elektryczne z części II.3 i III.2 tego arkusza.

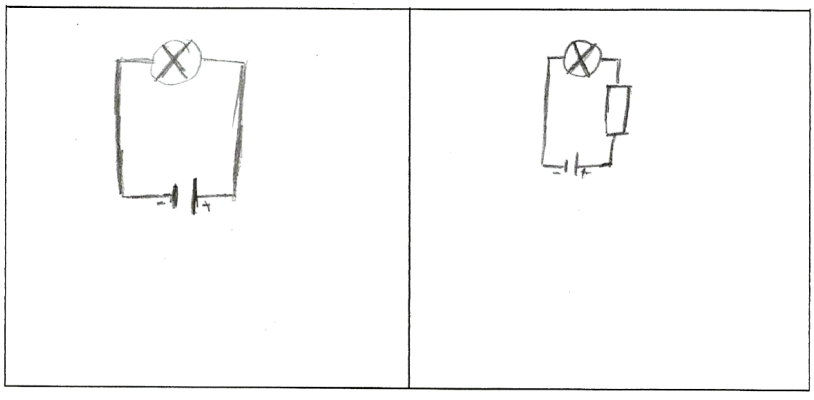
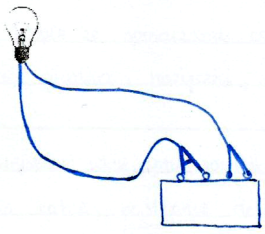


Figure 6: Example of representation of a circuit, by Student F. Mark: 6; student properly chose the components of circuit B.1, drew proper circuits in B.3 and C.3, and correct scheme of circuit for C.5

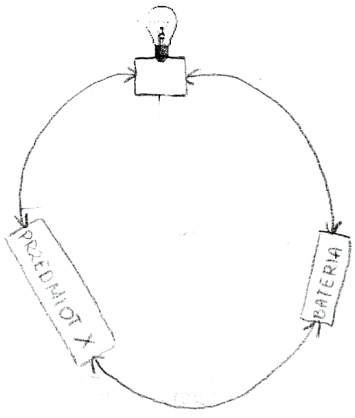
II. 3. Narysuj najprostszy obwód elektryczny (*3), w którym żaróweczka będzie się świecić.

G



III. 2. Narysuj (*3) najprostszy działający obwód elektryczny, pozwalający na zbadanie własności elektrycznych (przewodnictwa) przedmiotu z twojego otoczenia.

G



IV. 5. W naukach ścisłych i inżynierii, podczas dokumentowania wyników eksperymentów zamiast rysunków realistycznych używa się rysunków schematycznych. Na przykład obwód elektryczny przedstawia się za pomocą schematu obwodu elektrycznego. Żeby wykonać taki rysunek, trzeba znać symbole poszczególnych elementów elektrycznych. Zwykle używa się następujących znaków:

G

żarówka bateria przewód elektryczny przedmiot włączony do obwodu

Używając powyższych symboli, narysuj poniżej schematy elektryczne reprezentujące obwody elektryczne z części II.3 i III.2 tego arkusza.

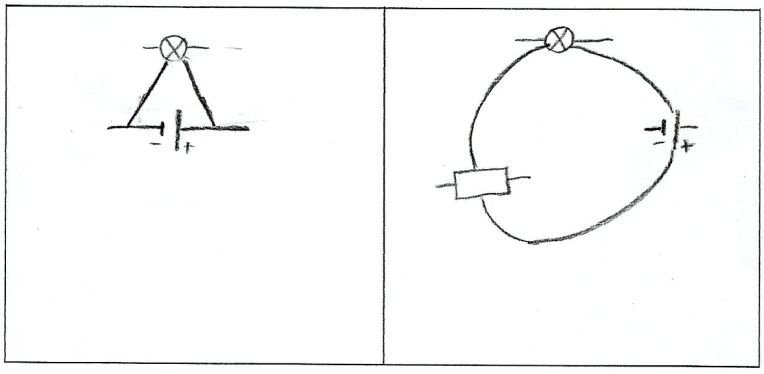
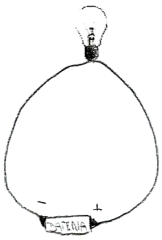
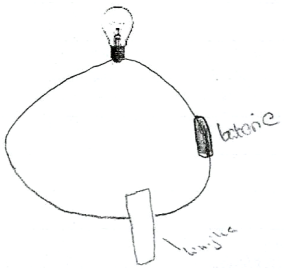


Figure 7: Example of representation of a circuit, by Student G. Mark: 4; student properly chose the components of circuit B.1, drew proper circuit B.3 and C.2, but made some mistakes in schemes of circuit for C.5

II, 3. Narysuj najprostszy obwód elektryczny (*3), w którym żaróweczka będzie się świecić. H



III. 2. Narysuj (*3) najprostszy działający obwód elektryczny, pozwalający na zbadanie własności elektrycznych (przewodnictwa) przedmiotu z twojego otoczenia. H



III .5. W naukach ścisłych i inżynierii, podczas dokumentowania wyników eksperymentów zamiast rysunków realistycznych używa się rysunków schematycznych. Na przykład obwód elektryczny przedstawia się za pomocą schematu obwodu elektrycznego. Żeby wykonać taki rysunek, trzeba znać symbole poszczególnych elementów elektrycznych. Zwykle używa się następujących znaków: T H

żarówka bateria przewód elektryczny przedmiot włączony do obwodu

Używając powyższych symboli, narysuj poniżej schematy elektryczne reprezentujące obwody elektryczne z części II.3 i III.2 tego arkusza.

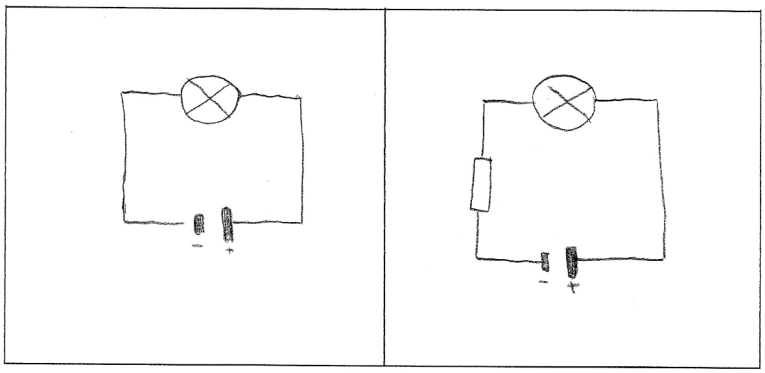
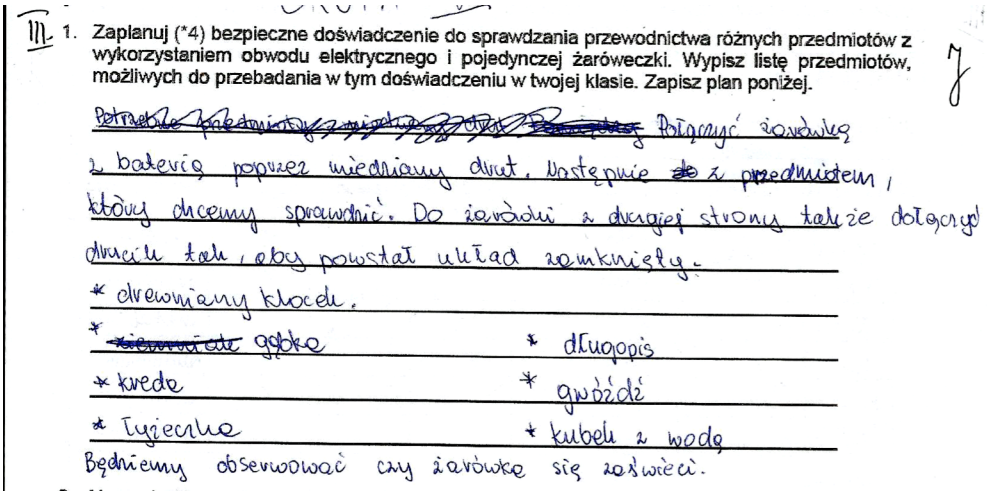


Figure 8: Example of representation of a circuit, by Student H. Mark: 6; student properly chose the components of circuit B.1, drew proper circuits in B.3 and C.3, and correct scheme of circuit for C.5

Planning investigations

To assess student skills in *planning investigations*, the teacher looked at responses to Activity C – question C.1 and question C.3. Figure 9 and Figure 10 show the answers provided by Group J. The teacher assigned an assessment mark of 5, stating, "students listed a few materials for conductance measurements, while planning the experiment they wrote how to connect necessary items in a

circuit and how to perform the experiment." Figure 11 and Figure 12 show the work submitted by Group K, who were also assigned an assessment mark of 5. The teacher explained, "students listed a few materials for conductance measurements, while planning the experiment they wrote how to connect necessary items in a circuit and how to perform the experiment."



1. Zaplanuj (*4) bezpieczne doświadczenie do sprawdzania przewodnictwa różnych przedmiotów z wykorzystaniem obwodu elektrycznego i pojedynczej żaróweczki. Wypisz listę przedmiotów, możliwych do przebadania w tym doświadczeniu w twojej klasie. Zapisz plan poniżej.

Połączyć żarówkę z baterią poprzez miedziany drut. Następnie ~~do~~ z przedmiotem, który chcemy sprawdzić. Do żarówki z drugiej strony tak że dotykał drucik tak, aby powstał układ zamknięty.

* drewniany klocek.
* ~~ziemniak~~ gąbka
* kreda
* łyżeczka
* długopis
* gwóźdź
* kubek z wodą

Będziemy obserwować czy żarówka się zaświeci.

1. Plan the experiment to check conductivity of different objects, using the electric circuit with a single electric bulb. Include the list of possible objects you could investigate in the classroom. Write down the plan below.

Connect the bulb and a battery with a wire. Next connect with an object you would like to check. Link a wire from the other side to the bulb as to make a closed electric circuit.

**** wooden block***	**** pen***
****sponge***	****nail***
****teaspoon***	**** mug with water***

We are going to observe if the bulb lights

Figure 9: Response to question C.1 by Group J.

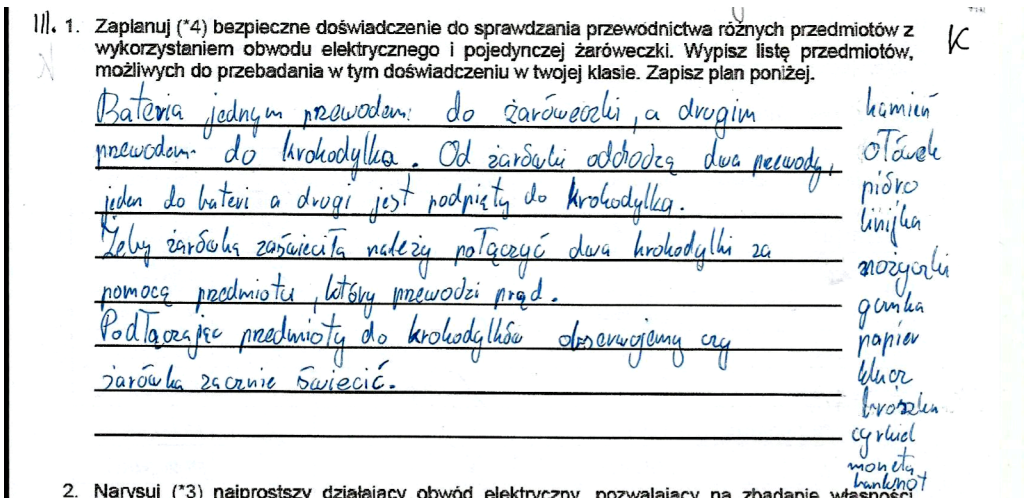
Tabela przewodnictwa.

przedmiot / materiał	hipoteza	Wynik doświadczalny – Przedmiot przewodzi prąd ...			typ materiału
		dobrze	słabo	wcale	
gąbka (sucha)	wcale			X	izolator
kreda	wcale			X	izolator
łyżeczka	słabo	X			przewodnik
gwóźdź	dobrze	X			przewodnik
kubek z (z kranu) wodą	dobrze			X	izolator
długopis metalowy	wcale	X			przewodnik
gumka	wcale			X	izolator
klucz	~~dobrze~~ słabo	X			przewodnik
linijka	wcale			X	izolator
moneta	słabo	X			przewodnik
spinka	dobrze	X			przewodnik
drewno (klocek)	wcale			X	izolator

Conductivity table:

Object/material	Hypothesis	Experimental result			General type
		Well	Poorly	Not at all	
sponge (dry)	not at all			X	Insulator
chalk	not at all			X	Insulator
teaspoon	poorly	X			Conductor
nail	well	X			Conductor
mug with tap water	well			X	Insulator
Metal pen	not at all	X			Conductor
eraser	not at all			X	Insulator
key	well	X			Conductor
ruler	not at all			X	Insulator
coin	poorly	X			Conductor
fastener	well	X			Conductor
wood (block)	not at all			X	Insulator

Figure 10: Response to question C.3 by Group J.


III. 1. Zaplanuj (*4) bezpieczne doświadczenie do sprawdzania przewodnictwa różnych przedmiotów z wykorzystaniem obwodu elektrycznego i pojedynczej żaróweczki. Wypisz listę przedmiotów, możliwych do przebadania w tym doświadczeniu w twojej klasie. Zapisz plan poniżej.

K

Bateria jednym przewodem do żaróweczki, a drugim przewodem do krokodylka. Od żarówki odchodzą dwa przewody, jeden do baterii a drugi jest podpięty do krokodylka. Żeby żarówka zaświeciła należy połączyć dwa krokodylki za pomocą przedmiotu, który przewodzi prąd. Podłączając przedmioty do krokodylków obserwujemy czy żarówka zaczyna świecić.

kamień
ołówek
piórko
linijka
nożyczki
gumka
papier
kleszcz
drzewo
cyrkiel
monety
banknot

2. Narysuj (*3) najprostszy działający obwód elektryczny, pozwalający na zbadanie własności

1. Plan the experiment to check conductivity of different objects, using the electric circuit with a single electric bulb. Include the list of possible objects you could investigate in the classroom. Write down the plan below.

One wire from the battery to the bulb, another wire from the battery to the crocodile clip. Two wires hanging from the bulb – one to the battery, another one to the crocodile clip. In order to make the bulb light, it is necessary to connect two crocodile clips with a conducting object. While connecting objects to the crocodile clips we observe if the bulb lights or not.

Figure 11: Response to question C.1 by Group K

Tabela przewodnictwa.

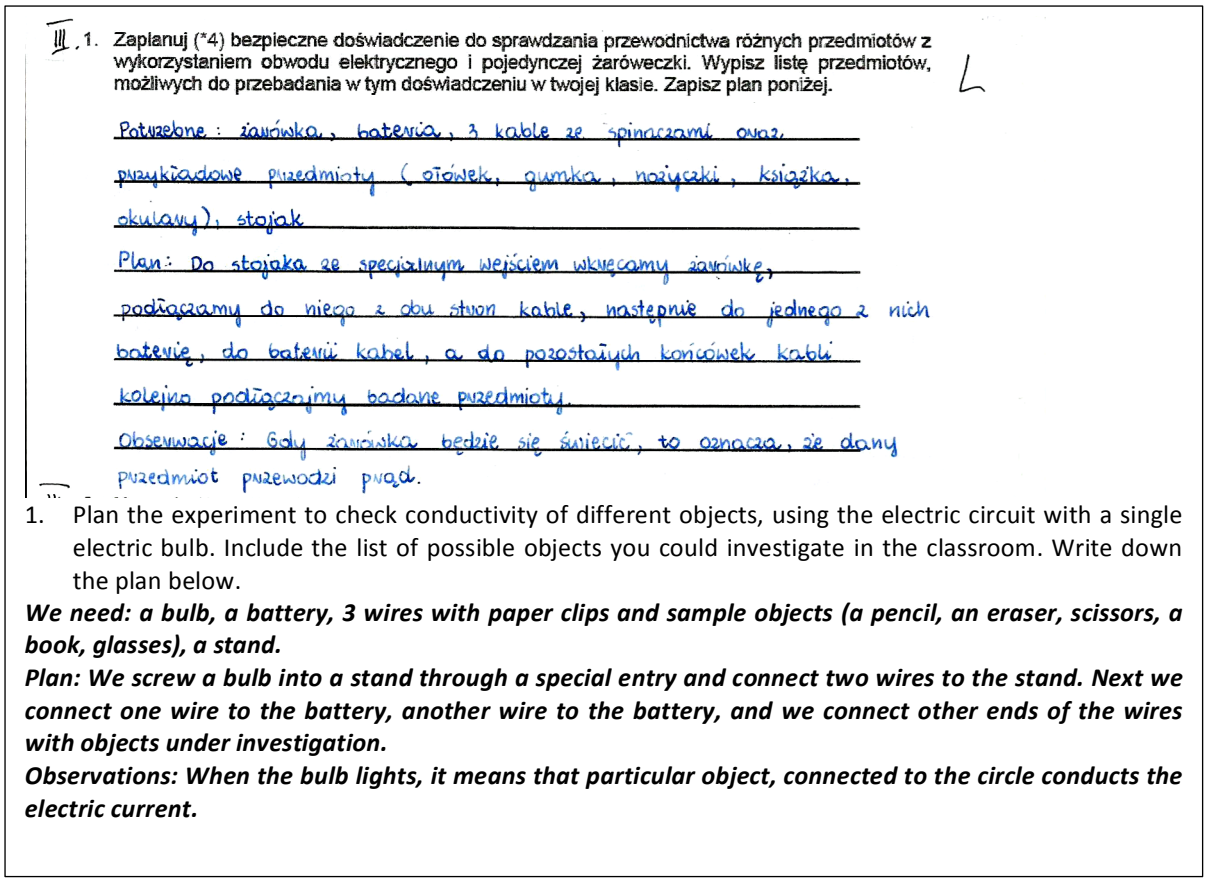
przedmiot / materiał	hipoteza	Wynik doświadczalny – Przedmiot przewodzi prąd ...			typ materiału
		dobrze	słabo	wcale	
linijka	wcale			X	izolator
pióro	wcale			X	izolator
cyrkiel	dobrze	X			przewodnik
ołówek	wcale			X	izolator
nożyczki	dobrze	X			przewodnik
gumka do mazania	wcale			X	izolator
klucz	dobrze	X			przewodnik
kredka	dobrze	X			przewodnik
papier	wcale			X	izolator
kamień				X	izolator
dowód osobisty				X	izolator
banknot				X	izolator
moneta		X			przewodnik

Conductivity table:

Object/material	Hypothesis	Experimental result			General type
		Well	Poorly	Not at all	
ruler	not at all			X	Insulator
pen	not at all			X	Insulator
calipers	well	X			Conductor
pencil	not at all			X	Insulator
scissors	well	X			Conductor
eraser	not at all			X	Insulator
key	well	X			Conductor
pin	well	X			Conductor
paper	not at all			X	Insulator
stone				X	Insulator
ID card				X	Insulator
bill				X	Insulator
coin		X			Conductor

Figure 12: Response to question C.3 by Group K

Group L were assigned an assessment mark of 6 for the work shown in Figure 13 and Figure 14. The teacher stated that, "students listed a few materials for conductance measurements and necessary elements of an electrical circuit. They wrote down how connect the circuit, how to perform the experiment and what they expected."



1. Plan the experiment to check conductivity of different objects, using the electric circuit with a single electric bulb. Include the list of possible objects you could investigate in the classroom. Write down the plan below.

We need: a bulb, a battery, 3 wires with paper clips and sample objects (a pencil, an eraser, scissors, a book, glasses), a stand.

Plan: We screw a bulb into a stand through a special entry and connect two wires to the stand. Next we connect one wire to the battery, another wire to the battery, and we connect other ends of the wires with objects under investigation.

Observations: When the bulb lights, it means that particular object, connected to the circle conducts the electric current.

Figure 13: Response to question C.1 by Group L

Tabela przewodnictwa.

przedmiot / materiał	hipoteza	Wynik doświadczalny – Przedmiot przewodzi prąd ...			typ materiału
		dobrze	słabo	wcale	
gumka do mazania	wcale			X	izolator
taśma klejące	wcale			X	izolator
okulary	wcale			X	izolator
mundurek	wcale			X	izolator
nożyczki	dobrze	X			przewodnik
kartka papieru	wcale			X	izolator
gąbka	wcale			X	izolator
kreda	słabo			X	izolator
ołówek	wcale			X	izolator
zamek	dobrze	X			przewodnik
pierścionek	dobrze	X			przewodnik
klucz	dobrze	X			przewodnik
złotówka	dobrze	X			przewodnik

Conductivity table:

Object/material	Hypothesis	Experimental result			General type
		Well	Poorly	Not at all	
eraser	not at all			X	Insulator
tape	not at all			X	Insulator
glasses	not at all			X	Conductor
school uniform	not at all			X	Insulator
scissors	well	X			Conductor
paper card	not at all			X	Insulator
sponge	not at all			X	Conductor
chalk	poorly			X	Conductor
pencil	not at all			X	Insulator
lock	well	X			Insulator
ring	well	X			Insulator
Key	well	X			Insulator
1 zloty coin	well	X			Conductor

Figure 14: Response to question C.3 by Group L

Group M were assigned an assessment mark of 3 for the responses shown in Figure 15 and Figure 16. The teacher explained that "students listed a few materials for conductance measurements; during planning the experiments they wrote how to connect necessary items of circuit."

III. 1. Zaplanuj (*4) bezpieczne doświadczenie do sprawdzania przewodnictwa różnych przedmiotów z wykorzystaniem obwodu elektrycznego i pojedynczej żaróweczki. Wypisz listę przedmiotów, możliwych do przebadania w tym doświadczeniu w twojej klasie. Zapisz plan poniżej.

potrzebne rzeczy: żaróweczka, dwa kable, bateria

badane przedmioty: klucz, nożyczki, linijka, kredka, kredka, kapsel

1. Połączyć żaróweczkę z baterią i obwód z kluczami, nożyczkami, linijką, kredką i kredą, kapsel

1. Plan the experiment to check conductivity of different objects, using the electric circuit with a single electric bulb. Include the list of possible objects you could investigate in the classroom. Write down the plan below.

We need: a bulb, 2 wires, battery

Objects under investigation: the key, scissors, a ruler, a crayon, chalk

1. ***Connect the bulb into electric circuit together with the key, scissors, ruler, fishing rod, rod, cap.***

Figure 15: Response to question C.1 by Group M

abela przewodnictwa.

przedmiot / materiał	hipoteza	Wynik doświadczalny – Przedmiot przewodzi prąd ...			typ materiału
		dobrze	słabo	wcale	
linijka	wcale			+	izolator
klucz	dobrze	+			przewodnik
nożyczki	dobrze		+		przewodnik
kreda	wcale			+	izolator
kredka	wcale			+	izolator
kapsel	słabo			+	izolator
kolczyki	słabo	+			przewodnik
okulary	wcale			+	izolator

Conductivity table:

Object/material	Hypothesis	Experimental result			General type
		Well	Poorly	Not at all	
ruler				X	Insulator
key		X			Conductor
scissors			X		Conductor
chalk				X	Insulator
crayon				X	Insulator
metal cap				X	Insulator
earrings		X			Conductor
glasses				X	Insulator

Figure 16: Response to question C.3 by Group M