Appendix A

Contents of information tab

Page title	Category	Summary of content
Static electricity		
1. Static electricity	d. Peripheral concepts	**Static electricity**: electricity produced by friction. **Electrification**: the process of giving an object an electric charge.
2. Coulomb force	d. Peripheral concepts	**Electrostatic force**: the force of attraction or repulsion between two objects that have an electric charge.
3. Electron	c. Fundamental concepts	**Electrons**: negatively charged particles. **Electric quantity**: amount of electric charge.
4. Principle of conservation of charge	d. Peripheral concepts	**Law of conservation of electric charge**: the total amount of electric charge is conserved.
5. Conductor	d. Peripheral concepts	**Conductor**: a substance that allows electricity to flow easily. **Insulator**: a substance that does not allow electricity to flow easily.
6. Free electron	c. Fundamental concepts	**Free electrons**: electrons that can move freely, and current flows as these free electrons move.
Electric Potential/Voltage		
7. Electric Potential	c. Fundamental concepts	**Electric potential**: the potential energy due to the coulomb force at a certain position.
8. Voltage	a. Terms	**Voltage**: the potential difference between two points, and it represents the magnitude of the driving force that is exerted to make the electric current flow.
Electric circuit		
9. Current	a. Terms	**Current**: the flow of free electrons in a conductor from the negative to the positive terminal of a battery. The direction of current is defined as the direction of positive charge flow.
10. Electric circuit	a. Terms	**Electric circuit**: a path for electric current to flow. Series connection: a circuit where the components are connected along a single path.

11. Resistance	a. Terms	**Resistance:** a measure of how much a material impedes the flow of electric current. The unit of resistance is the ohm (symbol: Ω). Resistors and light bulbs are devices that have resistance.
12. Voltage drop	a. Terms	**Voltage drop**: a decrease in electric potential caused by resistance. When an current flows through a conductor with resistance, the potential at the entry point is higher than at the exit point. This can be measured using a voltmeter.
13. Terminal voltage	a. Terms	**Terminal voltage**: voltage that appears between the two terminals of a battery, which refers to the voltage of the battery. **Electromotive force**: the action of raising the potential of a battery.
14*. Ohm's law	e. Laws and models	Ohm's law: a proportional relationship between the voltage [V] and the current [A] that flows through conductor. The law states that this relationship is shown in the following equation: $V = RI$ (V[V]: voltage, R[Ω]: resistance, I[A]: current
15*. Hydraulic analogy	e. Laws and models	Hydraulic analogy: analogy that compare electric circuits to water flowing through pipes, where voltage corresponds to water level difference, current to amount of water flow, and electricity to total water amount. The battery acts as a pump that creates electric current by moving electric charges from low to high potential side. Resistance causes a voltage drop, like a drop in water level in a pipe.
16*. Combined resistance	e. Laws and models	**Combined resistance**: the total resistance of a circuit. When multiple resistors are connected in series, the combined resistance is the sum of the individual resistor values, since connecting resistors in series is analogous to increasing the length of the conductor. The formula for calculating equivalent resistance in a series circuit is $R = R_1 + R_2$.
Measurement tools		
17. Voltmeter	b. Measurement tools	**Voltmeter:** a tool used to measure voltage (voltage drop) in a specific part of a circuit. By connecting the voltmeter's positive and negative terminals to the two ends of the component being measured, the voltage value can be determined. The voltmeter's handles can be swapped to reverse the polarity of the voltage.
18. Ammeter	b. Measurement tools	**Ammeter**: a tool to measure the current flowing through a specific part of a circuit. An ammeter is connected to the part of the circuit being measured.

Appendix B

Prompts list

Inquiry phase	Category	ID	Variable	Prompt
Conceptualization	Identifying variables	1-1-1	V & C	Please identify which of the terminal voltage and current is the independent variable and which is the dependent variable.
		1-1-2	R & C	Please identify which of resistance and current is the independent variable and which is the dependent variable.
		1-1-3	R & V	Please identify which of resistance and voltage drop is the independent variable and which is the dependent variable.
	Predicting	1-2-1	V & C	Before the experiment, please predict the relationship between terminal voltage and current.
		1-2-2	R & C	Before the experiment, please predict the relationship between resistance and current.
		1-2-3	R & V	Before the experiment, please predict the relationship between resistance and voltage drop.
Investigation	Planning	2-1-1	V & C	How do you investigate the relationship between terminal voltage and current? Please plan an experiment.
		2-1-2	R & C	How do you investigate the relationship between resistance and current? Please plan an experiment.
		2-1-3	R & V	How do you investigate the relationship between resistance and voltage drop? Please plan an experiment.
	Designing	2-2-1	-	First, please start with a simple circuit consisting of only one battery and one resistor or light bulb.
		2-2-2*	-	First, please start with a simple circuit consisting of only one battery and two resistors or light bulbs.
		2-3-1*	R & V	Please investigate what happens to the voltage drop when different resistance values are set for each resistor (light bulb).
		2-3-2*	R & V	Please investigate what happens to the voltage drop when the same resistance values are set for each resistor (light bulb).
	Controlling	2-4	-	Please perform the experiment according to your plan.
		2-5-1	V	Please manipulate the terminal voltage value.

	2-5-2	R	Please manipulate the resistance value.
	2-6*	R	Please start by manipulating only one resistor value.
	2-7-1	V	Please set a round voltage value that ends in 0.
	2-7-2	R	Please set a round resistance value that ends in 0.
Observing	2-8-1	C	Please measure the value of current.
	2-8-2	V	Please measure the value of voltage drop.
	2-8-3*	R & V	Please measure only the voltage drop occurring in the resistor (light bulb) whose value you are manipulating.
	2-10-1*	C	Please measure the current at various points in the circuit.
	2-10-2*	R & V	Please measure the voltage drop occurring in the other resistor (light bulb) in the circuit.
	2-11*	R & V	When one resistance value is manipulated, how does the voltage drop in the other resistor (light bulb) change?
	2-12	-	Please record the obtained data in a table.
Generating rules	3-1-1	V & C	What is the relationship between terminal voltage and current?
	3-1-2	R & C	What is the relationship between resistance and current?
	3-1-3	R & V	What is the relationship between resistance and voltage drop?
Comparing	3-2	-	Please compare the prediction with the experimental results.
Evaluating	3-3-1*	C	What values does the current take at various points in the circuit?
	3-3-2*	V	What values does the voltage drop take in each resistor or light bulb in the circuit?
	3-4*	V	Based on the measured data, please consider if there are any laws between the terminal voltage value and the voltage drop value for each resistor (light bulb).
Applicating	3-5-1*	R & C	How do the individual resistance values affect the overall current in the circuit?
	3-5-2*	R & V	How do the individual resistance values affect the overall voltage drop in the circuit?

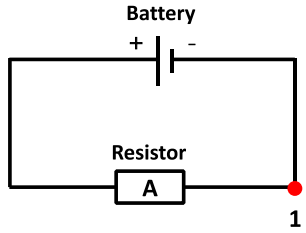
Note. Due to the different nature of tasks 2 and 3, prompts with * on their IDs were provided in task 3.

Appendix C

Pre and posttests items.

The estimated time to answer this section is 15 minutes.

For the following 9 questions, choose the correct option that follows the statement provided.



Q5-1. If the resistance of resistor A is increased, the value of the voltage drop across resistor A

- Increase
- Decrease
- Does not change
- Decreases to 0

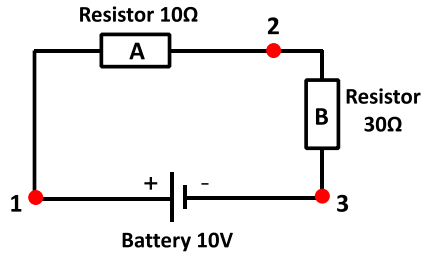
- Please explain the reason why that answer is correct.

Q5-2. If the resistance of resistor A is increased, the value of current at point 1

- Increase
- Decrease
- Does not change
- Decreases to 0

- Please explain the reason why that answer is correct.

6. There is a series circuit containing a 10 V battery and two resistors (resistor A: 10 Ω, resistor B: 30 Ω).



Q6-1. Between the voltage drops across resistor A and resistor B,

- The voltage drop across resistor A is greater
- The voltage drop across resistor B is greater

- The voltage drops across resistors A and B are equal
- No voltage drop across resistor B

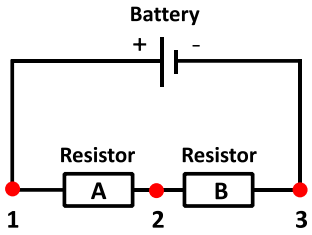
- Please explain the reason why that answer is correct.

Q6-2. For the currents at the three points,

- The current at point 1 is the largest and decreases in the order of points 2 and 3
- The current at point 3 is the largest, followed by points 2 and point 1
- The currents at points 1 and 3 are equal, and the current at point 2 is smaller
- The currents at points 1, 2, and 3 are all equal

- Please explain the reason why that answer is correct.

7. There is a series circuit containing one battery and two resistors A and B. The resistance values of resistors A and B are equal at the beginning.



Q7-1. If the resistance of resistor A is increased without changing the resistance of resistor B, the voltage drop

- Increases across both resistors A and B
- Increases across resistor B and decreases across resistor A
- Increases across resistor A and does not change across resistor B
- The value does not change across either resistor

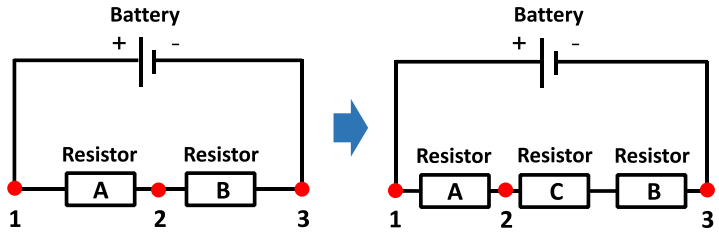
- Please explain the reason why that answer is correct.

Q7-2. If the resistance of resistor A is increased without changing the resistance of resistor B, the current

- Increases in all points from 1 to 3
- Decreases at all points from 1 to 3
- No change at point 1, but decrease at points 2 and 3
- No change at all points from 1 to 3

- Please explain the reason why that answer is correct.

8. There is a series circuit containing a battery and two resistors A and B. The resistance values of resistors A, B, and C are all equal.



Q8-1. If resistor C is added between resistors A and B, the voltage drop

- increases across both resistors A and B
- Decreases across both resistors A and B
- Unchanged across resistor A and decreased across resistor B
- No change in value for either resistor

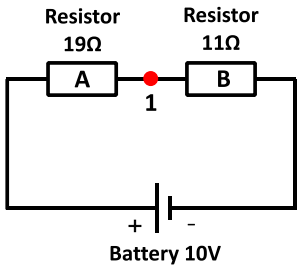
- Please explain the reason why that answer is correct.

Q8-2. If resistor C is added between resistors A and B, the current

- Increases at all points
- Decreases at all points
- Unchanged at point 1, decreased at points 2 and 3
- No change in value at all points

- Please explain the reason why that answer is correct.

9. There is a series circuit containing a 10 V battery and two resistors (resistor A: 19 Ω, resistor B: 11 Ω). The voltage drop across resistor A is 6.33 V and the value of the current at point 1 is 0.33 A.



Q9. The voltage drop across resistor B is

- 2.33 V
- 3.67 V
- 6.33 V
- 10 V

- Please explain the reason why that answer is correct.

Appendix D

Rule application (reason for the answer)

Grade	Description	Example
2 points	An explanation that describes the reason for the answer by referring to the principle or law behind the rule.	"Because the current in a series circuit is determined by the terminal voltage divided by the combined resistance."
1 point	An explanation that relies solely on observed rules or facts to explain the reason for the answer and does not refer to the laws operating in the system behind the rule.	"Because the current is constant in a series circuit."
0 point	Incorrect/incomplete explanation.	"Because the current decreases after passing through the resistor."

Appendix E

Descriptions of inquiry strategies in the orientation

Strategy		Description
1.	Identifying variables	Before conducting an experiment, identify what the independent and dependent variables are. *Independent variables are variables that can be directly manipulated in the experiment and are not affected by other values or variables. A dependent variable is a variable whose value is determined by the independent variable.
2.	Predicting	Before starting an experiment, predict what results you will get for the relationship you want to examine. By conducting an experiment with a forecast in mind, you will be able to conduct the experiment in a more purposeful and systematic.
3.	Planning	When the task is complex, it is easy to get lost. It is important to set a goal and plan the experimental steps to achieve it. Modify your plan along the way if necessary.
4.	Designing	When conducting an experiment, keep it simple. Start with a simple experimental setup and gradually increase the number of variables to be investigated or change the conditions. Doing so will make it easier and more accurate to observe patterns in your results.
5.	Controlling	When manipulating the value of a variable, change only one variable at a time and keep the others constant. Changing only one at a time allows you to observe patterns more clearly.
6.	Observing	During the experiment, you should not only observe with your eyes but also use instruments to measure. By doing so, you will be able to understand exactly what relationships, laws, and patterns are present.
7.	Generating rules	After collecting the data, derive what relationships and laws exist based on the observed patterns. This is a strategy for connecting the dots and integrating knowledge.
8.	Comparing	When testing your prediction in an experiment, compare your results with the prediction you made. If you obtain results that differ from your prediction, consider the reasons why.
9.	Evaluating	Before concluding the experiment, evaluate whether there is anything else to be investigated or any laws that have been overlooked.
10.	Applicating	Consider whether the relationships and laws you have derived can be applied to a broader relationship or overall system. It is important to look at the relationships and laws from a bird's eye view.

11.	Explaining	For each relationship or law derived, explain the rationale or background for why you see such a relationship. Providing explanations is an important key to deepening your understanding of science learning.

Appendix F

Means and SDs of frequency of prompts per group

	Inq		Inq+SE	
	Mean	*SD*	*Mean*	*SD*
Task B	11.10	(4.13)	10.65	(3.60)
Task C	6.90	(4.40)	8.00	(3.03)
Total	18.00	(6.84)	18.65	(5.22)