APPENDIX A: FINAL TSPCK ASSESSMENT TOOL

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Electric Circuit TSPCK Tool

The purpose of this research is to find the difficulties teachers experience and the strategies teachers use when teaching Electric circuits at the Grade 10 level. The assessment instrument consists of two parts; (i) Electric circuit content tool and (ii) Electric circuit Topic Specific Pedagogical Content Knowledge tool

The information will be used for research purposes only: your responses will be treated confidentially. Codes will be used to protect your identity.

Demographic Information

		CODE:	
NAME:			
GENDER	Male	Female	
SUBJECTS YOU ARE CURRENTLY TEACHING			
NUMBER OF YEARS TEACHING SCIENCE			

QUALIFICATIONS

Degree / Diploma	Where Obtained	Main Subjects	Year

Have you taught electric circuits?	**YES**		**NO**

If yes, please indicate the grade and the number of years for each Grade.

Grade	Number of years	Years (e.g. 2008, 2009)

There are 5 categories of questions in this tool

CATEGORY A:

- Category A contains typical student responses. Please indicate how you would respond to learners in each case i.e. what feedback you would give learners. Provide as much detail as possible.

CATEGORY B:

- Category B relates to planning and sequencing of topics. Your responses will assist in developing a consensus on the main ideas. Main ideas are statements describing key understanding that must be learnt in a topic.

CATEGORY C:

- Category C asks you to reflect on which ideas about electric circuits are difficult to teach and get across to learners. This will help us generate a list of difficult ideas that we can use for future research.

CATEGORY D:

- Category D provides 2 groups of representation and analogies. Think about which ones you find more useful and then fill in the table relating to the effectiveness of these analogies in the classroom setting

CATEGORY E

- Category E gives you a student's exercise and asks you to think about how you would assist this learner develop her conceptual understanding of electric circuits.

Instructions

- Please type or write responses directly into the response boxes.
- Please be as detailed as possible as to how you respond in your teaching setting

Thank you for your valued input and assistance

Electric Circuit TSPCK Instrument

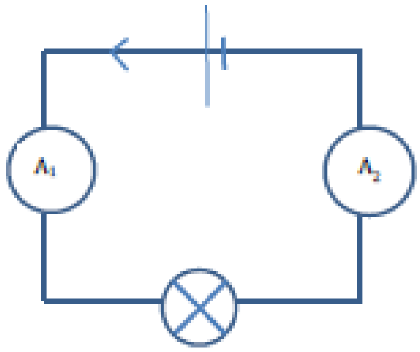
Category A – Typical Student Responses

The two questions below are typical multiple choice items that students have answered incorrectly. A selection of possible teacher responses are provided, <u>none of which are incorrect</u>. Select the response you would most likely use in your practice and explain the reason for your response

A1. How would you comment in writing to the student who **selects B** as the answer to the question below, where A_1 and A_2 are ammeters

Which one of the following options is correct for the circuit shown below?

A. $A_2 > A_1$
B. $A_1 > A_2$
C. $A_1 = A_2$



Response A: Keep in mind that this is a series circuit so current is not divided; therefore the correct answer is C. The current is the same throughout the circuit

Response B: Current is the rate of flow of charge. In this case the charge flowing is electrons. Electrons are particles that have mass and cannot disappear as they flow around the circuit. None of the electrons disappear through the circuit so the correct answer is C

Response C: Charged particles move under the influence of the electric field created by the battery, all the charged particles are in the same field, with the easiest path being in the single, undivided conductor. The flow of the charged particles is same throughout, so the correct answer is C

Response D: None of the above

Choose your response, and expand on the reason for your selection in the space provided

My choice is ________________________________
My reason is …….

A2. How would you respond verbally to a student who answers B to the following question?

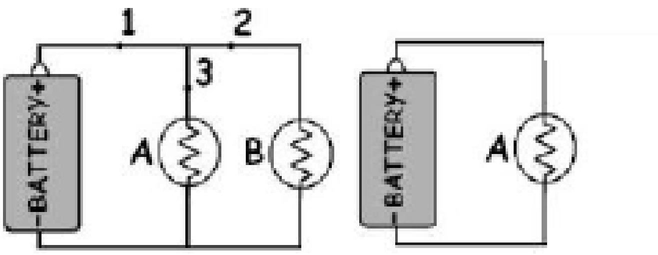


Figure 6 Figure 7

Compare the brightness of Bulb A in Figures 6 and 7.

A. Brighter in Figure 6
B. Brighter in Figure 7
C. The same in the both figures

Response A: Just because there are two light bulbs in figure 6, doesn't mean that A will burn brighter. The brightness is dependent on the amount of current moving through the bulb. In Figure 6 the current has been divided at the parallel connection. The presence of the parallel connection means resistance is halved so current is doubled so the amount of current through the parallel branches, in this case, is the same as through the single bulb so there is no difference in brightness.

Response B: All the bulbs are identical; their brightness is dependent on how efficiently they can transform energy, which is defined by the term power. In electric circuits power can be calculated by P = VI. In the parallel connection if we calculate the equivalent resistance of the parallel connection. If we assume a resistance of 2Ω then $\frac{1}{R_T} = \frac{1}{2} + \frac{1}{2}$ which is equal to 1Ω exactly half the overall resistance in Figure 7. Seeing that as voltage stays the same current would be doubled and then halved again at the parallel connection, so the same amount of current is available to be transformed.

Response C: You seem to have missed that the bulbs in figure 6 are connected in parallel. At the parallel connection the current divides. The bulbs have identical resistance so the current will divide equally through both branches. Two bulbs in parallel halves the resistance, which doubles the current, which is then halved again at the parallel connection, so the net effect is zero and bulbs will burn equally bright.

Response D: None of the above

Choose your response, and expand on the reason for your selection in the space provided

My choice is ______________________________
My reason is ______________

Category B – Planning and Sequencing

A selection of content and concepts relating to electric circuits is provided. The question below refers to how knowledge and concepts are ranked and how a teacher makes connections between content and concepts.

B1. Review the list of concepts relating to electric circuits below.

Select and rank three foundational concepts, that you regard, as both basic and central concepts in electric circuits.

1. To obtain an electric current there needs to be a continuous loop from one battery terminal to the other terminal
2. An electric current is the net flow of charge.
3. Parallel connection in a circuit are current dividers
4. The materials that make up the circuit provide the charged particles when there is an electric current
5. A battery provides the energy for an electric current
6. Voltage can be defined as $J.C^{-1}$
7. Ohm's law can be expressed as $V = \frac{R}{I}$
8. When there is a current, energy flows from the battery to the external circuit.
9. Resistance is the opposition to current flow
10. A battery creates an electric field within the materials that make up the circuit. The electric field is the cause of current flow.
11. The resistance of a parallel connection can be calculated by $\frac{1}{R_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$....
12. An electric circuit is a system in which changes in one part can affect other parts
13. Power is the rate at which energy is dissipated by the circuit component.
14. Current measured with an ammeter and voltage by a voltmeter

Write the number of the concepts you have selected, in order of importance.

Concepts
Concept 1.
Concept 2.
Concept 3.

B2. Using the three selected concepts from B1, give the sequence you would teach them in and your reasons for doing so

Concept	Reason for sequence

B3. Using the above three concepts as your main ideas, **draw a concept map** of how they inter-relate. In your concept map include other subordinate ideas, from the concepts provided in B1 and from your own practice that you would bring into your teaching of electric circuits.

Draw your concept map here

B3: Why do you think it is important for students to learn about electric circuits?

Write your response here:

Category C - What is difficult to teach?

C1. What **three** electric circuit concepts, in your experience, are the most difficult to present effectively to students and what do you think the reason for this is? Some **examples** are provided, which you may use as a basis for your response or **give your own ideas. (Only give reasons for 3 concepts, either using the ones given or your own)**

Fill in your response in the table below

Concept 1 – Energy in circuits	**Reason……**
Concept 2 – Ohm Law, the relationship between voltage and current	**Reason……**
Concept 3 – Electric circuits as a system	**Reason……**
Concept 4 – Resistors in a parallel connection reduced the total resistance	**Reason……**

Concept 5 – What is meant by voltage	
Concept 6 –	
Concept 7 –	
Concept 8 –	

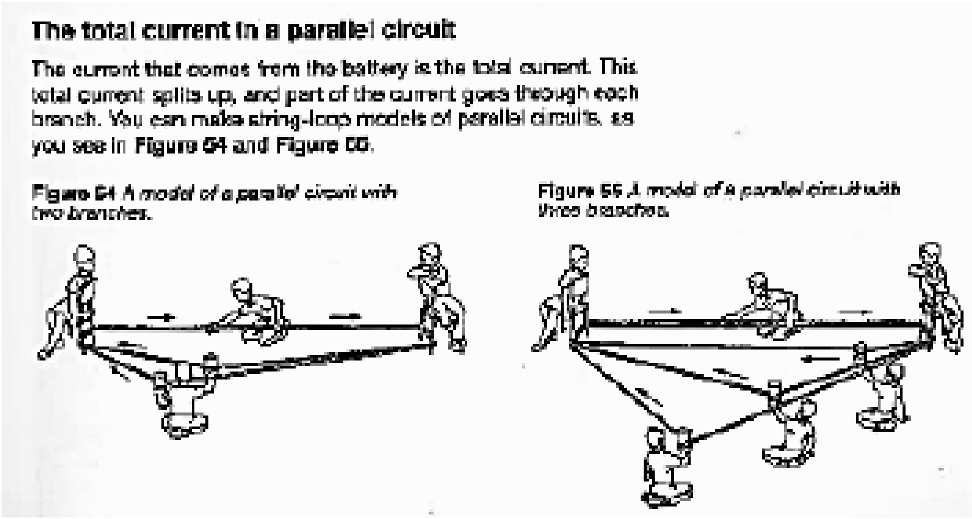
C2. Physics terminology is quite precise and presents difficulties for students. Which two terms in circuits pose the most difficulty for students and please give a reason for your selection

Term 1	Reason:
Term 2	Reason:

Category D – Representations

D1. Below are three possible representations for teaching the concept of current in a parallel connection are provided. Complete the table below by describing what you like and dislike about each representation and why one representation is better than another.

Representation 1


The total current in a parallel circuit

The current that comes from the battery is the total current. This total current splits up, and part of the current goes through each branch. You can make string-loop models of parallel circuits, as you see in **Figure 54** and **Figure 55**.

Figure 54 *A model of a parallel circuit with two branches.*

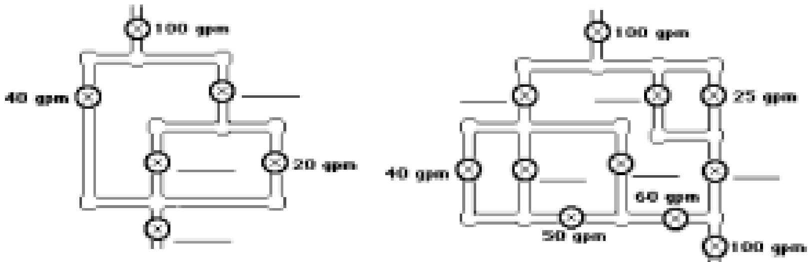
Figure 55 *A model of a parallel circuit with three branches.*

Science for All Grade 9 Learner's Book (Pg 35)

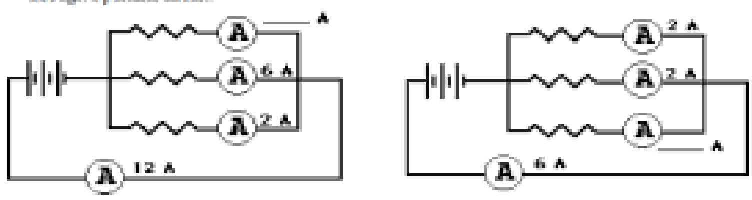
Representation 2

Water Analogy:

4. When the water flow (or charge flow) is divided into two or more separate pathways (as in a parallel circuit) the sum of the current in each individual pathway equals the total current. Utilize this principle to fill in the blanks in the following two diagrams. The meters in the diagram are measuring water flow rates in gallons per minute ("gpm").

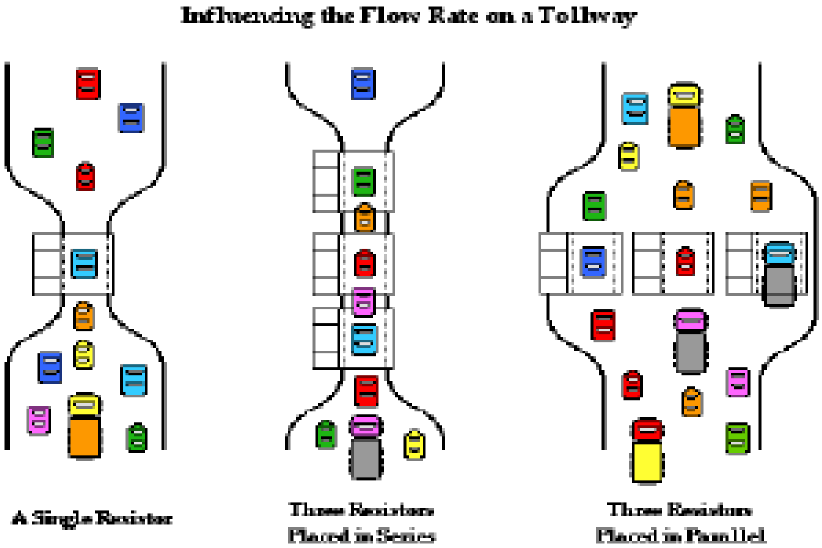


5. Apply the same principle to fill in the blanks in the following diagrams for charge flow (i.e., current) through a parallel circuit.



http://www.windows2universe.org/physical_science/physics/electricity/images/circuit_analogy_water_pipes_sm.jpg

Representation 3



	What I like and why	What I dislike and why
Representation 1		
Representation 2		
Representation 3		

D2. Which one of above three representations did you like the most and how would you use it in a lesson

Representation I liked the most	How would you use the representation selected in a lesson?

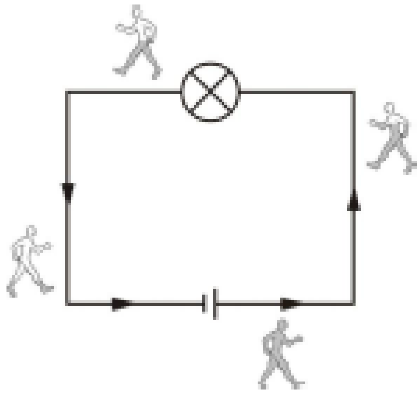
Category E - Conceptual Teaching strategies

E1. Study the student's answers to a classroom activity below. Read through her answers and describe what strategies you would employ to assist the student. The student has given a mix of incorrect and correct responses.

The student responses are given in *bold italic*

Activity

The following diagram represents Sparky who departs the cell full of energy. Answer the following questions with reference to the diagram.



(a) What is represented by Sparky?

Electricity

(b) What is represented by the shaded areas in his body?

Current

(c) Where does Sparky get the energy from?

Battery

(d) What happens while Sparky moves from the positive terminal to the negative terminal of the cell?

Sparky's charge gets used up

(e) Is it correct to say that the electric current is used up? Explain your answer.

Yes because as the current moves around the circuit, it gets used for things like heat and light and by the time it gets back to the battery all the current is finished.

a. What conceptual ideas does this student have in place?

Write your response here

b. What are the key conceptual gaps, in your opinion, that this student demonstrates?

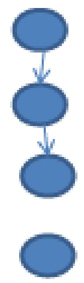
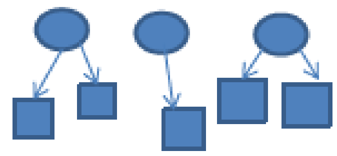
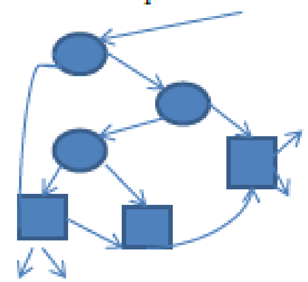
Write your response here

c. What specific strategies would you employ to bridge these gaps?

Write your response here

APPENDIX B: RUBRIC FOR TSPCK ASSESSMENT TOOL

		Limited	Basic	Developing	Exemplary
Category A: Learners prior knowledge and misconceptions	A1 – I is the same throughout the circuit A2 – R and I in a parallel circuit	• No identification/ No acknowledgement/No consideration of student prior knowledge or misconceptions • No explanation of concepts • Incorrect explanation given	• Teacher acknowledges misconception • Provide standardized knowledge as definition • Repeats standard definition with no expansion *E.g. Bulbs are series therefore current is constant throughout* • No indication of action that the teacher would take	• Teacher acknowledges misconception or prior knowledge and provides correct explanation to confront misconception • Provide standardized knowledge as definition and/or expands and re-phrase explanation with a single level explanation *E.g. I would explain that ……*	• Teacher acknowledges misconception and provides a correct explanation to confront misconception • Provide standardized knowledge as definition and/or Expands and re-phrases explanation with a multi-level approach. *Eg Makes use of conservation of particles or fields in explanation. Not just a single approach* • Explanation demonstrates conceptual understanding
Category B: Planning and Sequencing	B1/B2- Big Ideas and Sequencing	• Only subordinate ideas or 1 Big Idea Identified • Sequencing no value due to mixed concepts or no sequence provided at all ***Big Ideas (any 3 from list below)*** *1. To obtain an electric current there needs to be a continuous loop from one battery terminal to the other terminal* *2. An electric current is the net flow of charge.* *5. A battery provides the energy for an electric current* *8. When there is a current, energy flows from the battery to the external circuit.* *10. A battery creates an electric field within the materials that make up the circuit. The electric field is the cause of current flow.* *12. An electric circuit is a system in which changes in one part can affect other parts*	• Identifies 2 Big Idea Sequencing can be followed but has at least one illogical placing of key concepts (Big Ideas). • Reasons given for sequence unclear or lacks logic. *E.g. Need to know what resistance is before the rest can be taught*	• Identifies at least 2 or 3 Big Ideas • Provides a logical sequence for the concepts. • Reasons given for sequence are logical in terms of content or learner's level • Sequencing is linear: it follows only one concept through and makes no links to other concepts *E.g. For current to flow a 'closed' path is need from + battery to the – end of the battery*	• Identifies at least 3 Big Ideas • Provides logical sequence for all three Big Ideas with correct and logical reasons • Sequencing links the Big Ideas to multiple concepts. *E.g. Once learners see a circuit as a system you can then explain how charge 'flows' in the system and introduce concepts of rate of flow of charge and potential difference*

	B3 (a) –concept map	• Identified subordinate ideas mixed with those Big Ideas of other topics • Not all Big ideas have subordinate ideas • Identified subordinate ideas mainly incorrect or repetitions of Big Ideas • Response lacks logic No linking words	• Not all Big ideas have subordinate concepts identified. However those identified are correct • Some Subordinate concepts used as starting point • Some subordinate ideas relate to Big Ideas • Subordinate ideas are limited to algorithms or standard definitions • There are few connections between concepts and connections not always correct 	• Identifies subordinate ideas and shows links to Big ideas with no additional information • Uses 2 or 3 Big Ideas as a starting point • Subordinate ideas relate to Big ideas on map • Identified subordinate ideas include applications of equations and concepts • Evidence of linking of at least two concepts • Concept map has several connections to subordinate ideas, which are correct. 	• Identifies subordinate ideas and explains/shows Links • Uses only Big ideas as a starting points • Subordinate ideas relate to Big ideas on map includes pre-concepts • Identified subordinate ideas focus on understanding concepts underlying equations and concepts • Cross links shown where applicable • Differentiates clearly and correctly be main, subordinate ideas and minor concepts. Has a logical sequences and visually illustrates the 'circuit' nature of electrical concepts. 
	B3(b) – Why is it important?	• Reasons limited to a general statement One reasons given or gives a general statement such as " has important applications in …"	• Identifies the importance as a topic related to aspects, application and motivation/interest and gives a reason for one aspect *E.g. Electricity is a vital part of everyday life. It is important for students know how circuits works so that they can use electricity safely*	• Identifies the importance as a topic related to aspects, application and motivation/interest and gives reasons for both aspects *E.g. These are systems used in their everyday lives, so it is important to have a basic understanding of how they work and the effects of circuits and it is a key part of the final matric exam*	• Reasons given include three considerations, application, motivation and interest and conceptual considerations such as scaffolding/sequential development of understanding for other subsequent topics

Category E: Conceptual teaching strategies	**E1 – 'Sparky'**	• Incorrectly identifies of student prior knowledge and misconceptions • Strategy to confront misconceptions not included or limited E.g. *Differentiate between charge, energy and current*	• Identifies student prior knowledge and Misconceptions. • Strategy to confront misconceptions limited	• Considers confirmation/confrontation of student prior knowledge and/or common misconceptions • Strategy includes a clear plan for the explanation, which is correct yet basic *E.g. I would label all the parts and then talk through Sparky's journey with the student, from when sparky leaves the cell to when he returns to the cell. Use the correct terminology*	• Considers prior knowledge and/or common misconceptions • Strategy is multifaceted it includes more than one possible strategy e.g. an analogy, demonstration *E.g. Use of the traffic analogy (petrol as source of energy) cars as particles that move to show that the number of cars going from point A to B does not change. Then set up a simple circuit with an ammeter to measure current at different points in the circuit* • There is evidence of self-reflection in their description of their strategy

APPENDIX C: FINAL CONTENT KNOWLEDGE ASSESSMENT TOOL

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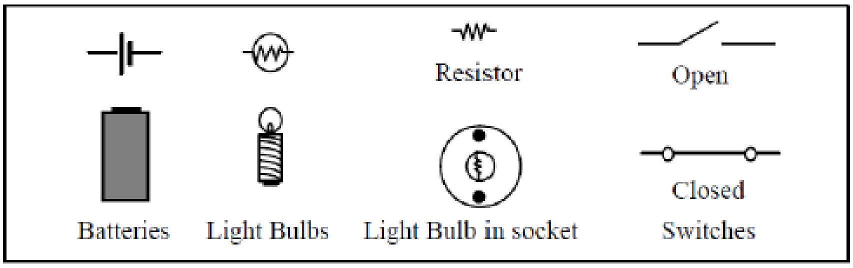
Electric Circuit Content Tool

The purpose of this research is to find the difficulties and strategies teachers' use when teaching Electric circuits at the Grade 10 level. The assessment instrument consists of two parts; (i) Electric circuit content tool and (ii) Electric circuit Topic Specific Pedagogical Content Knowledge tool

The information will be used for research purposes only: your responses will be treated confidentially. Codes will be used to protect your identity.

Instructions

1. Please fill in the demographic information on the TSPCK instrument
2. Answer all the question on the answer sheet provided.
3. The questions are in the form of multiple-choice items. Please indicate the option you feel is the most correct with a cross
4. Each item also has a confidence level where you indicate how sure you are of your answer.
5. All light bulbs, resistors, and batteries should be considered identical unless you are told otherwise.
6. The battery is to be assumed ideal, that is to say, the internal resistance of the battery is negligible.
7. In addition, assume the wires have negligible resistance.
8. Below is a key to the symbols used on this test.



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Answer Sheet

	MC Item Answer						*Confidence Level of Answer*		
1	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
2	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
3	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
4	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
5	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
6	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
7	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
8	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
9	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
10	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
11	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
12	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
13	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
14	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
15	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
16	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
17	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
18	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
19	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
20	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure

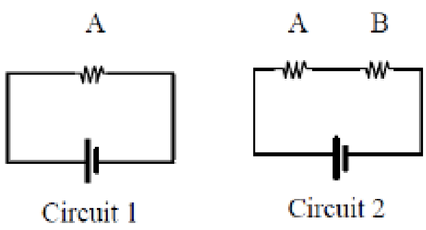
Questions

1. Are charges used up in a light bulb, being converted to light?

   A. Yes, charges moving through the filament produce "friction" which heats up the filament and produces light.
   B. Yes, charges are emitted.
   C. No, charge is conserved. It is simply converted to another form such as heat and light.
   D. No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

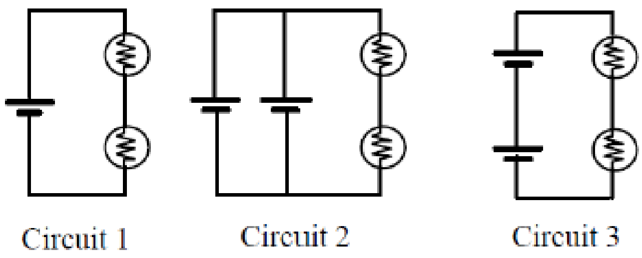
2. How does the power delivered to resistor A change when resistor B is added as shown in circuits 1 and 2 respectively

   A. Increases
   B. Decreases
   C. Stays the same



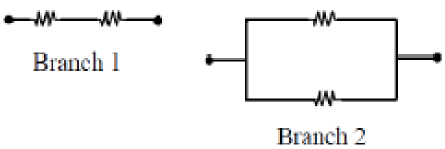
3. Consider the circuits shown below. Which circuit or circuits have the greatest energy delivered to it per second?

   A. Circuit 1
   B. Circuit 2
   C. Circuit 3
   D. Circuit 1 = Circuit 2
   E. Circuit 2 = Circuit 3

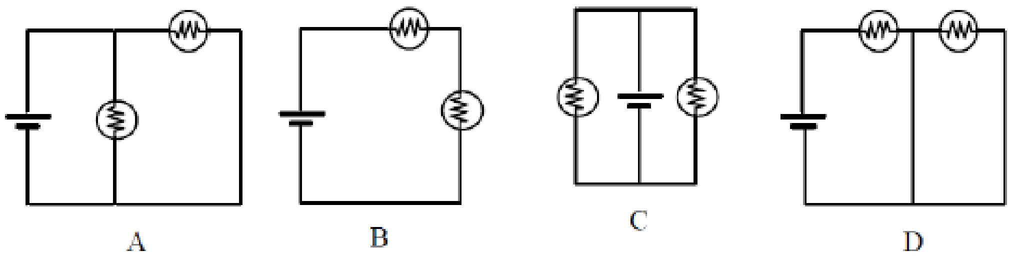


4. Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. Which has the least resistance?

   A. Branch 1
   B. Branch 2
   C. Neither, they are the same



5. Consider the following circuits

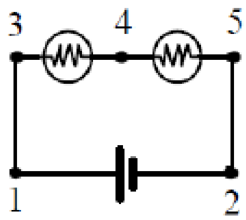


Which circuit/s above represent(s) a circuit consisting of two light bulbs in parallel with a battery?

A. A
B. B
C. C
D. A and C
E. A, C and D

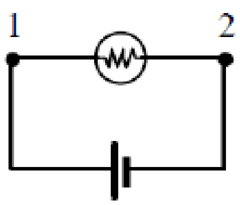
6. Rank the potential difference between points 1 and 2, points 3 and 4 and points 4 and 5 in the circuit shown below from highest to lowest

A. 1 and 2; 3 and 4; 4 and 5
B. 1 and 2; 4 and 5; 1 and 2
C. 3 and 4; 4 and 5; 1 and 2
D. 3 and 4 = 4 and 5; 1 and 2
E. 1 and 2; 3 and 4 = 4 and 5



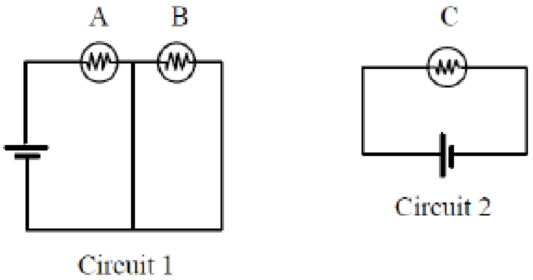
7. Compare the current at point 1 with the current at point 2. Which point has the larger current?

A. Point 1
B. Point 2
C. Neither, they are the same



8. Compare the brightness of bulbs A and B in circuit 1 with the brightness of bulb C in circuit 2. Which bulb or bulbs are the brightest?

   A. A
   B. B
   C. C
   D. A = B
   E. A = C

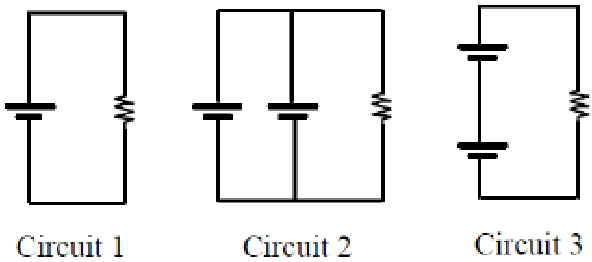


9. Why do the lights in your home come on almost instantaneously?

   A. Charges are already in the wire. When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.
   B. Charges store energy. When the circuit is completed, the energy is released.
   C. Charges in the wire travel very fast.
   D. The circuits in a home are wired in parallel. Thus, a current is already flowing.

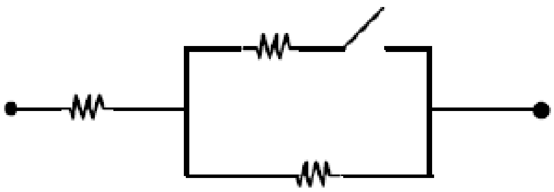
10. Consider the power delivered to each of the resistors shown in the circuits below. Which circuit or circuits have the least power delivered to it/them?

   A. Circuit 1
   B. Circuit 2
   C. Circuit 3
   D. Circuit 1 = Circuit 2
   E. Circuit 1 = Circuit 3



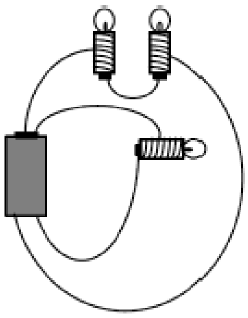
11. How does the resistance between the endpoints change when the switch is closed?

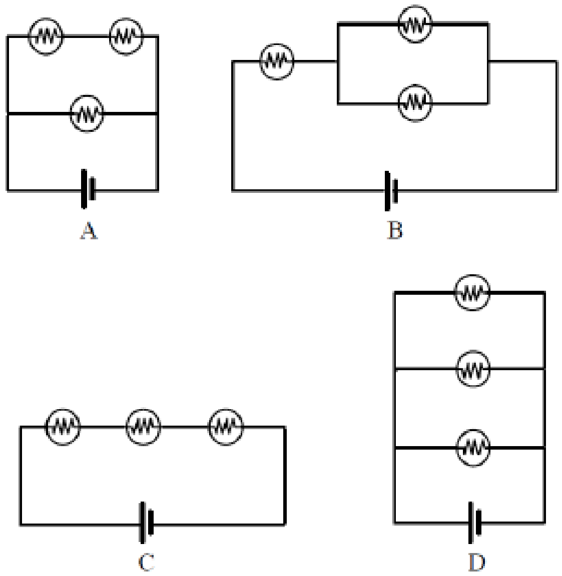
   A. Increases
   B. Decreases
   C. Stays the same



5

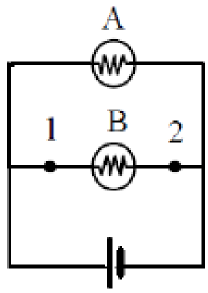
12. Which schematic diagram best represents the realistic circuit shown below?





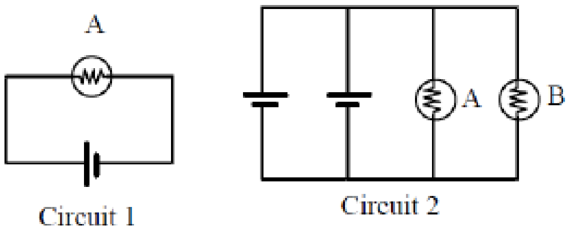
A. A
B. B
C. C
D. D
E. None of the above

13. What happens to the potential difference between points 1 and 2 if bulb A is removed?



A. Increases
B. Decreases
C. Stays the same

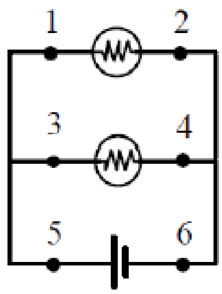
14. Compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. Which bulb is dimmer?



A. Bulb A in circuit 1
B. Bulb A in circuit 2
C. Neither, they are the same

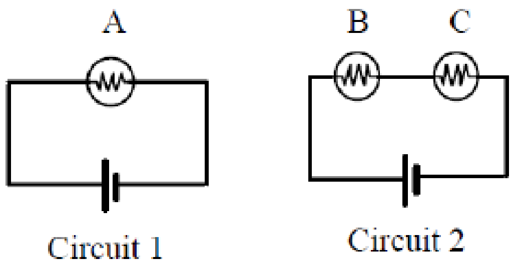
15. Rank the currents at points 1, 2, 3, 4, 5, and 6 from highest to lowest.

A. 5, 1, 3, 2, 4, 6
B. 5, 3, 1, 4, 2, 6
C. 5 =6, 3 = 4, 1 =2
D. 5 = 6, 1 = 2 = 3 = 4
E. 1 = 2 = 3 = 4 = 5 = 6



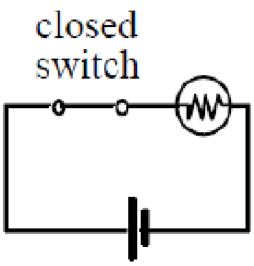
16. Compare the energy delivered per second to the light bulb in circuit 1 with the energy delivered per second to the light bulbs in circuit 2. Which bulb or bulbs have the least energy delivered to it/them per second?

A. A
B. B
C. C
D. B = C
E. A = B = C



17. Immediately after the switch is opened, what happens to the resistance of the bulb?

A. The resistance increases.
B. The resistance decreases.
C. The resistance stays the same.
D. The resistance goes to zero.



APPENDIX D: CONTENT TOOL MEMORANDUM

Masters research project – Protocol Number 2013ECE064M – Gwyneth Zimmerman

Answer Sheet

	MC Item Answer					*Confidence Level of Answer*			
1	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
2	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
3	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
4	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
5	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
6	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
7	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
8	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
9	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
10	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
11	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
12	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
13	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
14	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
15	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
16	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
17	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
18	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
19	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure
20	A	B	C	D	E	Blind guess	A bit unsure	Confident	Completely sure

APPENDIX E: PARTICIPANT INFORMATION AND CONSENT LETTER

INFORMATION SHEET: TEACHERS

DATE: 16th April 2014

Dear Colleague

My name is Gwyneth Zimmerman, I am a senior science teacher and part-time student in the School of Education at the University of the Witwatersrand, currently doing my Masters degree in Education, with a Science focus.

I am doing research on the 'Design and Validation of an Instrument to Measure Topic Specific Pedagogical Content Knowledge of Electric Circuits of Physical Sciences Teachers'. The purpose of this research is for the partial fulfilment of the Masters degree.

The research involves designing and validating a questionnaire to measure Topic Specific Pedagogical Content Knowledge (TSPCK) and Content Knowledge in electric circuits. Electric circuits are a component of most Physics curricula at multiple grade levels. The concepts and terminology involved in electric circuits are problematic for many students. Electricity is part of the everyday life of most students but this familiarity can lead to the reinforcing of misconceptions. The instruments is aimed at the concepts that would be covered at the Grade 10 level as this forms the conceptual framework for more complex topics at the higher grades. Experienced practicing teachers often have the ability to transform content knowledge in such a way when teaching electric circuits in order to help learners' understand the necessary concepts. Therefore, measuring topic specific PCK of experienced teachers can be used to support less experienced teachers through professional development programmes in developing PCK and ultimately assist learners to gain a better understanding of circuits.

I would really appreciate your expertise and input by completing the Topic Specific PCK questionnaire (TSPCK). Completing the questionnaires should take approximately an hour of your time. I am grateful for your willingness to give of your time and experience.

Your name and identity will be kept confidential at all times and in all academic writing, including my final research report, in conference proceedings and any journal articles about the study. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed within 3-5 years after completion of the project.

You will not be advantaged or disadvantaged in any way. You may however benefit by finding ways to incorporate the knowledge gained to improve your teaching practice or find ways to assist less experienced teachers that have to teaching stoichiometry in the new curriculum for the first time. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for this study.

Your completed form can either be emailed back to me, or I can come at collect it when it is convenient for you.

Please let me know if you require any further information.
Thank you very much for your help.

Yours sincerely,

SIGNATURE

NAME: Gwyneth Jean Zimmerman
ADDRESS: 897 Alverstoke Ave Strubensvalley
EMAIL: gwynethzimmerman1@gmail.com
TELEPHONE NUMBERS: 071 202 3468

Teacher's Consent Form: Questionnaire

Please fill in and return the reply slip below indicating your willingness to fill in the questionnaire for my voluntary research project called: 'The Design and Validation of an Instrument to Measure Topic Specific Pedagogical Content Knowledge in Electric Circuits of Physical Sciences Teachers'.

Permission for the use of questionnaires

I,____

Give/do not give * my consent to fill in these questionnaires.

[ ] I know that my participation is voluntary and that I may withdraw from the study at any time and that I will not be advantaged or disadvantaged in any way.

[ ] I know that I can decline to answer a specific question and that I understand I have the right to review the questionnaires I complete before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks.

[ ] I am aware that the researcher will keep all information confidential in all academic writing and that results will be reported so that my identity is anonymous.

[ ] I understand that the results of the study may be published, but my identity will be anonymous.

[ ] I am aware that my questionnaires will be destroyed between 3—5 years after the completion of the project.

Teacher Signature: Date:

I would like to thank you in advance for your time and your voluntary participation.

Contact person:

NAME: Gwyneth Jean Zimmerman
ADDRESS: 897 Alverstoke Ave, Strubensvalley
EMAIL: gwynethzimmerman1@gmail.com
TELEPHONE NUMBERS: 071 202 3468

APPENDIX F: INFORMATION AND MEMORANDUM GIVEN TO TEACHERS AFTER COMPLETION OF ASSESSMENT TOOLS

Misconceptions in Electric Circuits

Hammer defined a misconception as *stable cognitive structures to be changed that affect students' understanding of scientific concepts and must be overcome so that students learn scientific concepts effectively*. (Hammer, 1996)

Below is a summary of some the common misconceptions found in the process of learning electric circuits

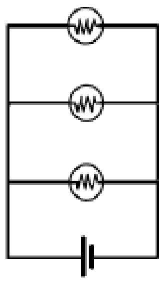
Misconception	Description
'attenuation model' - Current is used up	It is intuitive for students to think that current is consumed because charge is 'used up'. After all, they commonly hear that a 'dead' battery must be 're-charged'; therefore it must have become 'empty'. (Wainwright, 2007)
'power supply as constant current source' or **'voltage in Closed Circuits** - Batteries deliver a fixed amount of current regardless of cell components	Even after instruction students use the voltage concept as having approximately the same properties as the current concept. They tend to think of a battery as a source of constant current rather than a source of constant voltage. (Wainwright, 2007)
'sequential model' - A change in a circuit only affects the components after the component.	Assuming that what occurs 'downstream' in the circuit cannot affect 'upstream' components of the circuit, again failing to recognize the circuit as a system. (Wainwright, 2007)
'empirical rule model' - The further away a bulb is away from the battery the dimmer it will be	
'short circuit' - Wires with no circuit components can be ignored when analysing a circuit	
'parallel circuit misconceptions' - Increase of resistors in parallel increases the overall resistance	Most students have difficulty with the inverse/non-additive effect of resistors in parallel. (Wainwright, 2007)
'local reasoning' - Circuit not viewed as a system. Any change only affects the component being changed and not the whole circuit	This phenomenon occurs when students focus on what is occurring at only one point within the circuit without considering the circuit as an interrelated system. A student may assume, for example, that once current reaches a junction, it must divide equally into each branch. (Wainwright, 2007)
'battery origin' - Battery a source of charges that are pumped out rather than being recycled	Many students assume that the battery is the source of mobile charge (current) in a circuit – that charges are pumped out of a supply within the battery rather than recycled. (Wainwright, 2007)
'inter-changeability of terms' - Voltage, current, power charges, energy, used as one property	Some students have difficulty understanding the effect of changing resistance in a circuit, considering the battery to be a constant current source. (Wainwright, 2007)
'clashing model' - Current from the positive and negative terminal meet at the circuit component	An assumption that current must be released from both ends of a battery, and that bulbs light when current moves through them in both directions. For example, many students believe a single bulb will light if connected to a cell with one wire; adding a second wire just supplies it with more current. (Note: this model was not included in the Content Tool because it is uncommon)

'shared current model' - Current is shared equally with all circuit components	
'current as water flow' - Current strongest in a straight path. A bend in the wire decreases current strength	

Memo

Question	Answer	Misconception	Comment – if the student answers incorrectly
1.	D	i. Attenuation model	• Charges are seen as particles that have energy. There is connection between this concept and the material covered in 'Particle Model' in the earlier grades
2	B	i. Power supply as a constant current source ii. Local Reasoning iii. Shared current model	• The student presumes that because the battery is the same, the same current is delivered • The impact of the second resistance viewed as not having an impact because it is placed after the resistor A (using conventional current). The student doesn't view the circuit as a whole system and doesn't see that a change anywhere in the circuit impacts the entire circuit. • Students will also need to know that P =VI and that increased resistance means decreased current
3.	C	i. Inter-changeability of terms ii. Parallel circuit misconceptions iii. Power supply as a constant current source	• Students will need to know that the question is asking for voltage (J/s) and that the resistance in all the circuits is the same • Students will need to see the cells connected in parallel will produce the same voltage as the single cell • Students may be confused with the way the two cells in series are drawn
4	B	i. Parallel circuit misconceptions	• Student who don't understand the impact of resistors in series would most likely answer C
5.	D	i. Parallel circuit misconceptions	• Most students would be able to select A but miss that C is also parallel because the current has two possible pathways
6.	E	i. Local Reasoning ii. Power supply as a constant current source	• Between points 1 and 2 the total V is being measured and across the light bulbs this will be less than the total V but equal to each other. Students need to understand the circuit as a whole system
7.	C	i. Sequential Model ii. Local Reasoning iii. Current as water flow	• This a common misconception, where students think current gets 'used up' as it moves through a light bulb. They don't see current as constant through a series circuit. They muddling up concepts of current flow and energy transformation • If students think about current as water flow, the idea is

			the 'water' somehow 'dams' up behind the light bulb and that is why the current drops the light bulb
8.	E	i. Short circuit	• The connecting wire between A and B provides a much lower resistance pathway so current wouldn't flow through B – effectively cutting it out of the circuit. Students will overlook the impact of the connecting wire and just focus on the bulbs
9.	A	i. Battery origin ii. Attenuation iii. Local Reasoning	• Charges are not seen as the same particles that make up material. Some external sources is seen as the 'producer' of charges. The explanation is given that when the battery 'runs out' of charges the battery is flat. • Connecting wires are seen as empty channels and not part of the whole system that makes up the circuit
10.	D	i. Inter-changeability of terms ii. Parallel circuit misconceptions iii. Power supply as a constant current source	• Similar to Question 3. Student will need to know that the voltage delivered in Circuits 1 and 2 are the same but less than 3, so using P = VI Circuits 1 and 2 will have the lower power rating
11.	B	i. Parallel circuit misconceptions	• Students struggle with the idea that adding a resistor can have the effect of dropping the overall resistor, if it is added in parallel
12.	A	i. Parallel circuit misconceptions	• It is sometime difficult for students to see the two possible pathways in the realistic circuit. • Students often struggle when there is a mix of parallel and series. • Being able to translate the realistic from to the schematic shows an understanding of how a circuit is constructed
13.	C	i. Local reasoning ii. Inter-changeability of terms	• Students need to recognise that because there are no other cell components in the circuit the voltage of the battery is the same as the voltage across the resistors, regardless of how the resistors are arranged. • Students who answer B (decreases) are most likely interchanging concepts of voltage and current
14.	C	i. Parallel circuit misconceptions	• Students will first need to see voltage delivered is the same for both circuits • The addition light bulb in parallel, in Circuit 2, will have the effect of halving the total resistance and therefore doubling the total current but when the current splits at the parallel connects it halves again so the net effect on current in the parallel branches is the same as Circuit 1
15.	D.	i. Parallel circuit misconceptions ii. Sequential model iii. Attenuation	• Current at 5 and 6 represents the total current and they are equal – current isn't 'used up' • Current in the parallel branches is equal and the same after the light bulbs

16.	D	i. Local Reasoning ii. Inter-changeability of terms	• The total V delivered is the same for both circuits but the available energy has to be split between two bulb equally
17.	C	i. Inter-changeability of terms. ii. Local reasoning	• Resistance is a property of the materials used • Current changes as a result of resistance and not the other way round
18.	D	i. Local reasoning ii. Inter-changeability of terms	• The components and how they inter-relate is key to understanding circuits. The batter delivers and creates a fields. • How energy is converted is a function of the components in the circuit.
19.	D	i. Local ii. reasoning	• Students sometimes battle to see that even if no current is flowing the battery still has a voltage reading. This forms the basis for understanding emf and internal resistance that is covered in the higher grades
20.	B	i. Parallel circuit misconceptions	• The connecting wires have negligible resistance – Question 20 diagram is the same as the diagram below and then it is easy to see that the current would divide evenly three ways. 

References

Engelhardt, P., & Beichner, R. (2004, January). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics, 72*, 98 -115.

Hammer, D. (1996). More than misconceptions. Multiple perspectives on student knowledge and reasoning and an appropriate role for education research. *American Journal of Physics, 64*, 1316 - 1325.

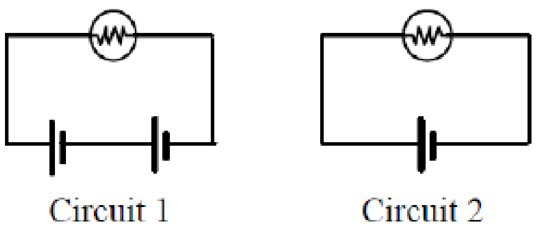
Pesman, H., & Eryilmaz, A. (2010). Development of a three-tier test to assess misconceptions about simple electric circuits. *The Journal of Educational Research, 103*, 208 -222.

Wainwright, C. (2007). *Toward Learning and Understanding Electricity: Challenging Persistent Misconceptions.* Retrieved 2013, from Pacific University: http://fg.ed.pacificu.edu/wainwright/index.html

Some Additional Questions

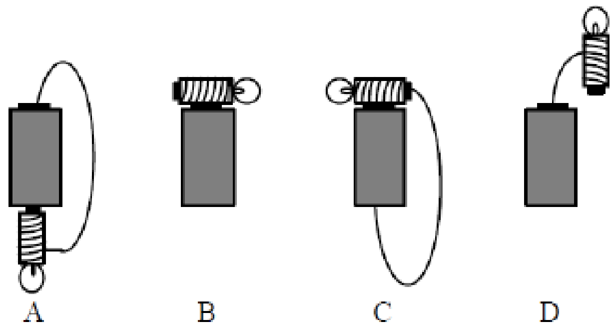
1. Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is brighter?

   A. Bulb in circuit 1
   B. Bulb in circuit 2
   C. Neither, they are the same



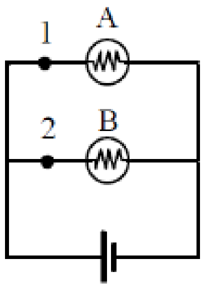
2. Which circuit(s) will light the bulb?

   A. A
   B. C
   C. D
   D. A and C
   E. B and D

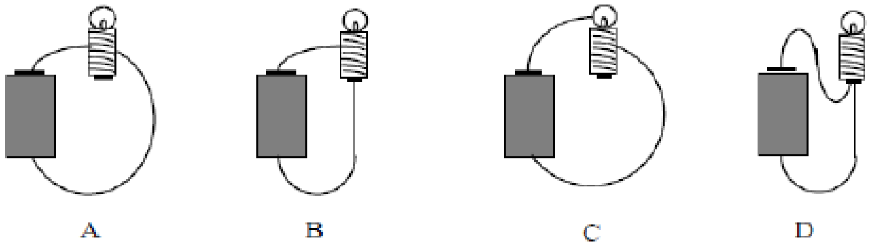


3. What happens to the brightness of bulbs A and B when a wire is connected between points 1 and 2?

   A. Increases
   B. Decreases
   C. Stays the same
   D. A becomes brighter than B
   E. Neither bulb will light



6. Will all the bulbs be the same brightness?



A. Yes, because they all have the same type of circuit wiring.

B. No, because only B will light. The connections to A, C, and D, are not correct.

C. No, because only D will light. D is the only complete circuit.

D. No, C will not light but A, B, and D will.

7. What happens to the brightness of bulbs A and B when the switch is closed?

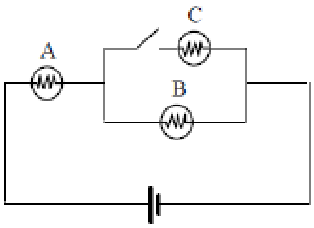
A. A stays the same, B dims

B. A brighter, B dims

C. A and B increase

D. A and B decrease

E. A and B remain the same



8. Which circuit(s) will light the bulb?

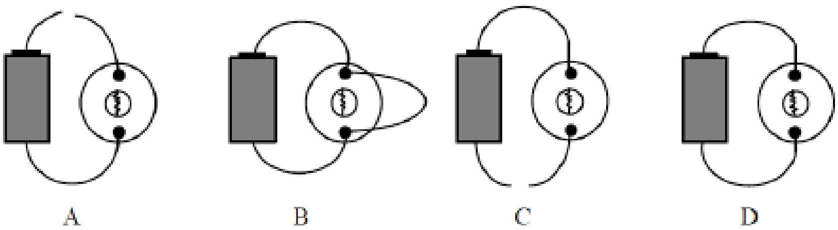
A. A

B. B

C. D

D. B and D

E. A and C



APPENDIX G: ETHICS PERMISION LETTER

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Student Number:
8807461V
Protocol Number:
2013ECE064M

Date: 04-Jun-2013

Dear Gwyneth Zimmerman

Application for Ethics Clearance: Master of Education

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has considered your application for ethics clearance for your proposal entitled:

The Design of an Instrument to Measure the Topic Specific Pedagogical Content Knowledge of Physical Science Teachers in Electric Circuits

The committee recently met and I am pleased to inform you that clearance was granted.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely

Matsie Mabeta
Wits School of Education

011 717 3416

CC Supervisor: Prof M Rollnick and Ms. C Steinberg

APPENDIX H: COMPLETED TSPCK ASSESSMENT TOOL

Electric Circuit TSPCK Instrument

Category A – Typical Student Responses

The two questions below are typical multiple choice items that students have answered incorrectly. A selection of possible teacher responses are provided, none of which are incorrect. Select the response you would most likely use in your practice and explain the reason for your response

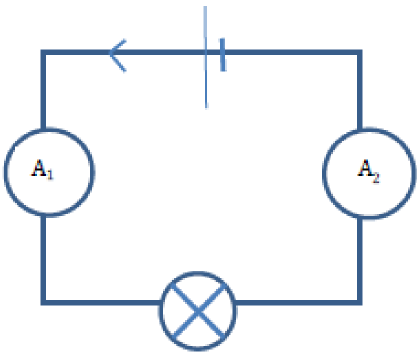
A1. How would you comment in writing to the student who selects B as the answer to the question below, where A_1 and A_2 are ammeters

Which one of the following options is correct for the circuit shown below?

A. $A_2 > A_1$

B. $A_1 > A_2$

C. $A_1 = A_2$



Response A: Keep in mind that this is a series circuit so current is not divided; therefore the correct answer is C. The current is the same throughout the circuit

Response B: Current is the rate of flow of charge. In this case the charge flowing is electrons. Electrons are particles that have mass and cannot disappear as they flow around the circuit. None of the electrons disappear through the circuit so the correct answer is C

Response C: Charged particles move under the influence of the electric field created by the battery, all the charged particles are in the same field, with the easiest path being in the single, undivided conductor. The flow of the charged particles is same throughout, so the correct answer is C

Response D: None of the above

Choose your response, and expand on the reason for your selection in the space provided

My choice is C

My reason is …….

Answer C provides the best conceptual explanation since the movement of electrons are as a result of an electric field that is established by the battery.
A just states the facts again, and B works with the definition as a starting point.
The reason learners get this wrong is because they don't understand why charge move in a circuit in the first place, and C provides a part explanation for that.

A2. How would you respond verbally to a student who answers B to the following question?

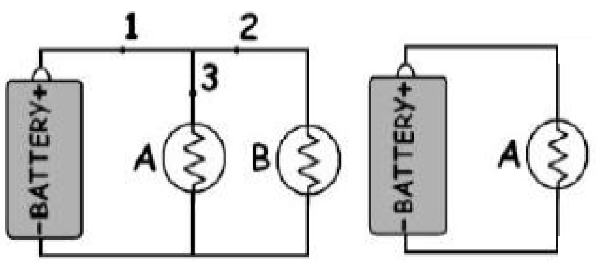


Figure 6 Figure 7

Compare the brightness of Bulb A in Figures 6 and 7.

A. Brighter in Figure 6
B. Brighter in Figure 7
C. The same in the both figures

Response A: Just because there are two light bulbs in figure 6, doesn't mean that A will burn brighter. The brightness is dependent on the amount of current moving through the bulb. In Figure 6 the current has been divided at the parallel connection. The presence of the parallel connection means resistance is halved so current is doubled so the amount of current through the parallel branches, in this case, is the same as through the single bulb so there is no difference in brightness.

Response B: All the bulbs are identical; their brightness is dependent on how efficiently they can transform energy, which is defined by the term power. In electric circuits power can be calculated by P = VI. In the parallel connection if we calculate the equivalent resistance of the parallel connection. If we assume a resistance of 2Ω then $\frac{1}{R_T} = \frac{1}{2} + \frac{1}{2}$ which is equal to 1Ω exactly half the overall resistance in Figure 7. Seeing that as voltage stays the same current would be doubled and then halved again at the parallel connection, so the same amount of current is available to be transformed.

Response C: You seem to have missed that the bulbs in figure 6 are connected in parallel. At the parallel connection the current divides. The bulbs have identical resistance so the current will divide equally through both branches. Two bulbs in parallel halves the resistance, which doubles the current, which is then halved again at the parallel connection, so the net effect is zero and bulbs will burn equally bright.

Response D: None of the above

Choose your response, and expand on the reason for your selection in the space provided

My choice is B
My reason is ______ Learners really struggle with questions like these. In an answer like C about halving and doubling and halving again, many learners do not follow your explanation. I think the switch between words and symbols and diagrams all the time is really difficult. In my experience, working with numbers, by putting real values into the circuit, helps learners make it more concrete. Possibly also because one is only working with symbols, so it is easier. I have therefore chosen B. It also brings in power, which is needed to explain brightness. A and C does not talk about power, only R and I.

Category B – Planning and Sequencing

A selection of content and concepts relating to electric circuits is provided. The question below refers to how knowledge and concepts are ranked and how a teacher makes connections between content and concepts.

B1. Review the list of concepts relating to electric circuits below.

Select and rank three foundational concepts, that you regard, as both basic and central concepts in electric circuits.

1. To obtain an electric current there needs to be a continuous loop from one battery terminal to the other terminal
2. An electric current is the net flow of charge.
3. Parallel connection in a circuit are current dividers
4. The materials that make up the circuit provide the charged particles when there is an electric current
5. A battery provides the energy for an electric current
6. Voltage can be defined as $J.C^{-1}$
7. Ohm's law can be expressed as $V = \frac{R}{I}$
8. When there is a current, energy flows from the battery to the external circuit.
9. Resistance is the opposition to current flow
10. A battery creates an electric field within the materials that make up the circuit. The electric field is the cause of current flow.
11. The resistance of a parallel connection can be calculated by $\frac{1}{R_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$....
12. An electric circuit is a system in which changes in one part can affect other parts
13. Power is the rate at which energy is dissipated by the circuit component.
14. Current measured with an ammeter and voltage by a voltmeter

Write the number of the concepts you have selected, in order of importance.

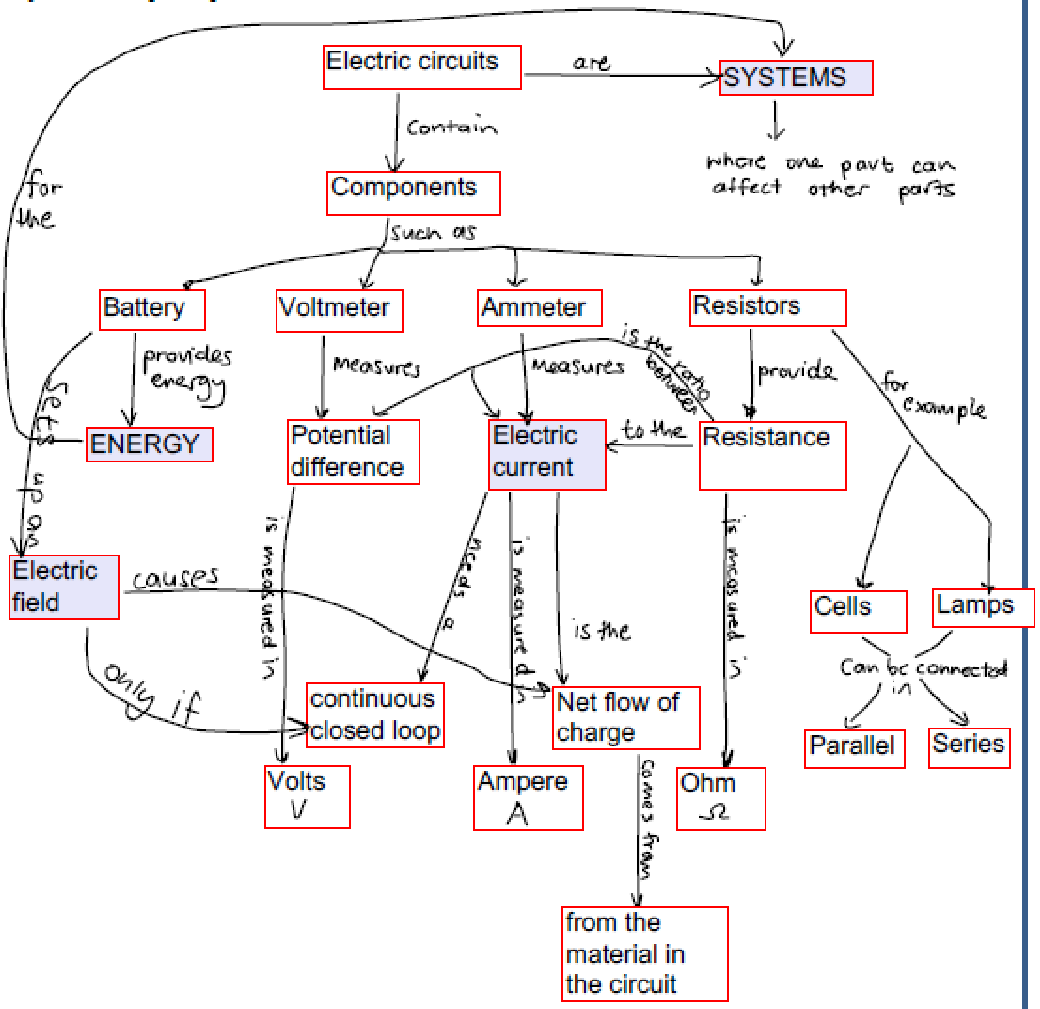
Concepts	
Concept 1.	An electric circuit is a system in which changes in one part can affect other parts
Concept 2.	An electric current is the net flow of charge
Concept 3.	A battery creates and electric field within the materials that make up the circuit. The electric field is the case of current flow.

B2. Using the three selected concepts from B1, give the sequence you would teach them in and your reasons for doing so

Concept	Reason for sequence
An electric circuit is a system in which changes in one part can affect other parts	I would teach the section with the following three questions in mind What is an electric circuit? What is an electric current? What makes a circuit work?/Where does it get its energy from?
An electric current is the net flow of charge	I would therefore start by introducing an electric circuit as a system, a concept which they are familiar with from primary school, and also grade 8 and 9. I would then talk about the different
A battery creates and electric field within the materials that make up the circuit. The electric field is the case of current flow.	components of a circuit, and the purpose of each. That would lead me to what an electric current is - one of the big ideas in circuits. And then where do the electrons in a current get their energy from.

B3. Using the above three concepts as your main ideas, **draw a concept map** of how they inter-relate. In your concept map include other subordinate ideas, from the concepts provided in B1 and from your own practice that you would bring into your teaching of electric circuits.

Draw your concept map here



B3: Why do you think it is important for students to learn about electric circuits?

Write your response here:

Electric circuits play an important role in modern life. They supply us with energy in our homes, cars, etc. Learners need to understand that energy is the driving force for life, with no energy, no life is possible. Electric circuits is one way of how we have been able to capture the energy in the universe so that it is useful for us (keep us warm, let us cook food, have light, communicate with others, etc.

Knowledge of electric circuits are also needed for further study at school level, e.g in electric motors or generators, and beyond school e.g electrical engineering.

I also think this is general knowledge that the public should have bacis scientific literacy for everyone, especially usefulness and importance/need to have electricity, and the dangers of electricity.

Category C - What is difficult to teach?

C1. What **three** electric circuit concepts, in your experience, are the most difficult to present effectively to students and what do you think the reason for this is? Some **examples** are provided, which you may use as a basis for your response or **give your own ideas. (Only give reasons for 3 concepts, either using the ones given or your own)**

Fill in your response in the table below

Concept 1 – Energy in circuits	**Reason…….** Energy is a really difficult concept, it is, in my opinion, the most difficult in science. It is not tangible, there is no really good definition for it, yet it is the driving force for life. I am not even sure that I always understand it well, so that makes it very difficult to bring across, especially to learners who want to know more than just 'the facts'.
Concept 2 – Ohm Law, the relationship between voltage and current	**Reason…….**
Concept 3 – Electric circuits as a system	**Reason…….** Learners sometimes struggle to see the bigger picture and with systems one needs to be able to see all the bits as a unit, with an input and an output, parts working together. Often circuits are just presented as a bunch of calculations and learners don't understand how the parts fit together.
Concept 4 – Resistors in a parallel connection reduced the total resistance	**Reason…….**

Concept 5 – What is meant by voltage	This is a concept that is not well understood, like with energy, I am not sure I always understand it well enough to be able to explain it to others. Often just a definition is given, and shown how to use it in an equation, or to solve a circuit, and that is usually sufficient for most students, but for those who really want to understand, it is not enough. I realised my own uncertainty when I had to explain it to a 10 year old, and I struggled. :-)
Concept 6 –	
Concept 7 –	
Concept 8 –	

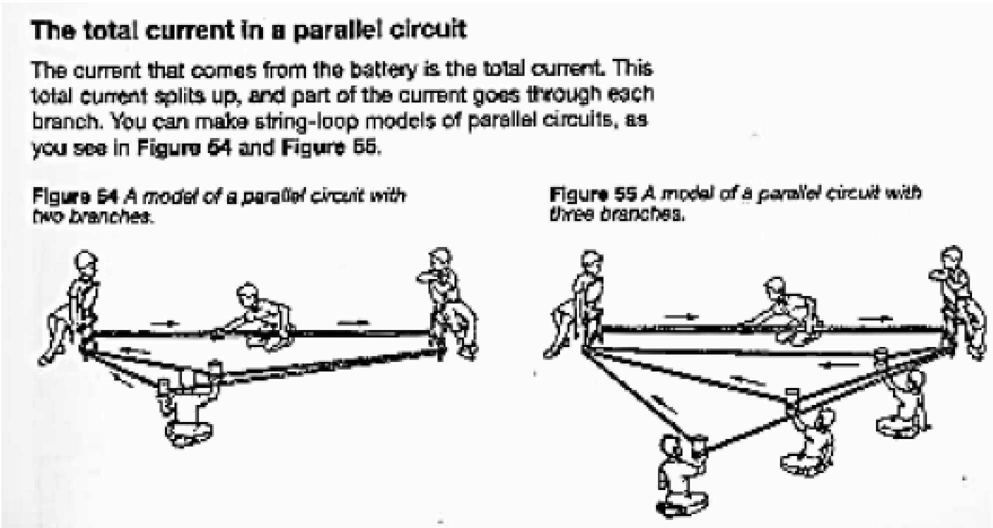
C2. Physics terminology is quite precise and presents difficulties for students. Which two terms in circuits pose the most difficulty for students and please give a reason for your selection

Term 1 Energy	Reason: I don't think a 'good' definition which captures the nature of energy is available. Energy cannot be created or destroyed is what is often used, and this still does not tell me what it is.
Term 2 potential difference or voltage	Reason: As explained in the previous section, this is also not well defined, and needs the understanding of other difficult concepts, like field, energy, or joules.

Category D – Representations

D1. Below are three possible representations for teaching the concept of current in a parallel connection are provided. Complete the table below by describing what you like and dislike about each representation and why one representation is better than another.

Representation 1


The total current in a parallel circuit

The current that comes from the battery is the total current. This total current splits up, and part of the current goes through each branch. You can make string-loop models of parallel circuits, as you see in Figure 54 and Figure 55.

Figure 54 *A model of a parallel circuit with two branches.*

Figure 55 *A model of a parallel circuit with three branches.*

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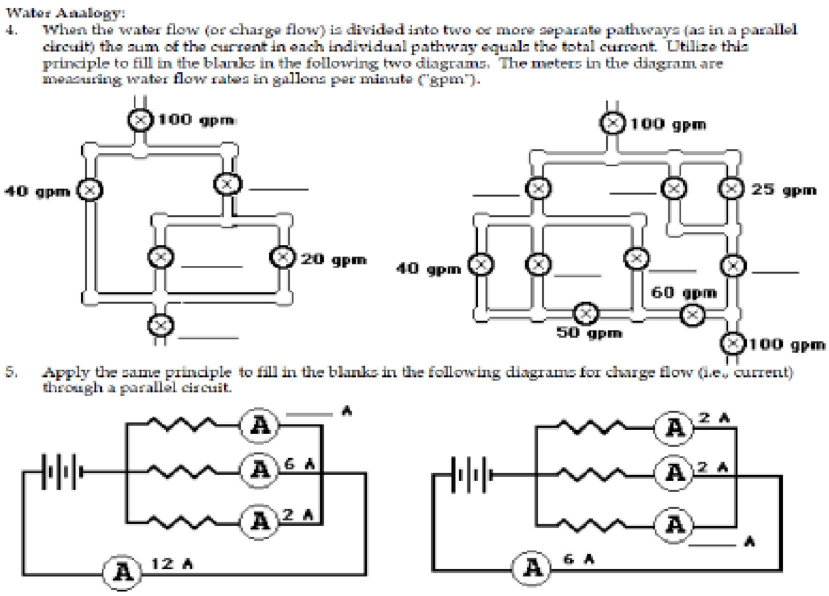
Representation 2

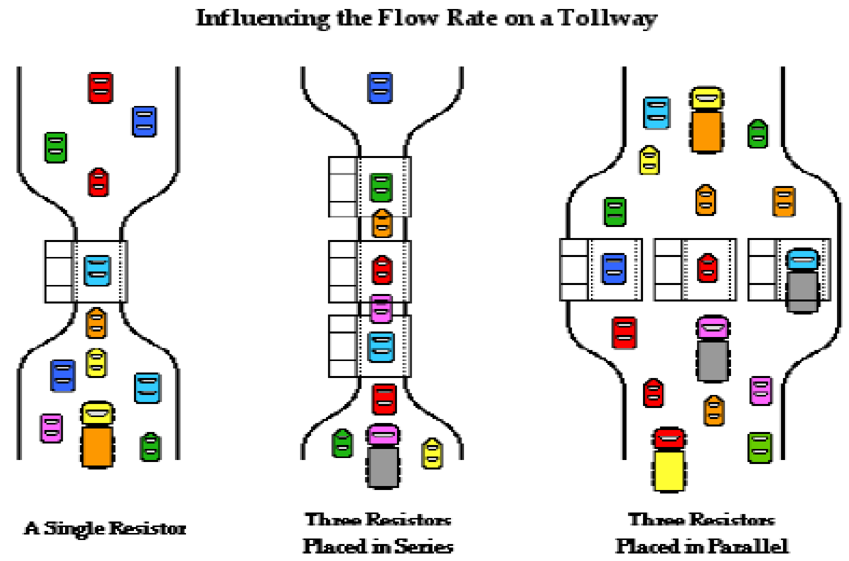

Water Analogy:

4. When the water flow (or charge flow) is divided into two or more separate pathways (as in a parallel circuit) the sum of the current in each individual pathway equals the total current. Utilize this principle to fill in the blanks in the following two diagrams. The meters in the diagram are measuring water flow rates in gallons per minute ("gpm").

5. Apply the same principle to fill in the blanks in the following diagrams for charge flow (i.e., current) through a parallel circuit.

http://www.windows2universe.org/physical_science/physics/electricity/images/circuit_analogy_water_pipes_sm.jpg

Representation 3



	What I like and why	What I dislike and why
Representation 1	It can help learners follow the path of electrons and 'see' the different options so it makes the abstract a bit more tangible.	Learners might think that charge can 'choose' like people, which way to go.
Representation 2	This is not a bad analogy as it links the water example to a circuit and lets the learners apply their understanding in a new situation. One can also use water to help learners understand if the water pump is switched on in the one side, the water immediately comes out on the other side, just like electrons which are available throughout the circuit.	The water is a bit better than the one above as it does not create the impression that charge can 'choose' which way to go.
Representation 3	This can be useful to explain the flow of charge is like the flow of cars, to get the rate principle across.	Again, electrons, or charge, are not like cars which can choose where to drive, nor do electrons flow in lanes in a circuit, so these might cause further misconceptions.

D2. Which one of above three representations did you like the most and how would you use it in a lesson

Representation I liked the most	How would you use the representation selected in a lesson?
Possible nr 2	I don't really think any analogy in circuits are great, as most of them could introduce further misconceptions, but I have found that the water analogy does work well to help learners understand that charge will flow in the path where there is the least resistance, also flow in all paths but not necessarily in equal amounts, and also split where there are junctions, and come together after the split. It is also useful to get the idea across that when a switch is closed, charge is available everywhere in the circuit at the same time, like water in a pipe, it comes out the one end immediately when the tap is opened.

So in a lesson I might use this in a number of places, as I teach different concepts, and also come back to it at various points in time. I will however also point out that charge is NOT water, and that it is only a useful example to help us understand.

The cars analogy I would rather use to link current with resistance, where a higher current (more cars) flows in a conductor with a lower resistance (wide road).

I have not really used, or seen, the analogy with the children, so I am not sure how learners will understand, of misunderstand it, so I don't know if and how I will use that.

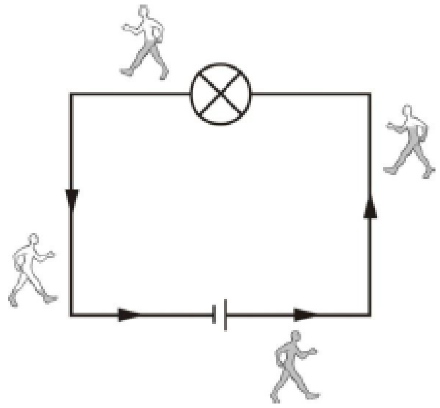
Category E - Conceptual Teaching strategies

E1. Study the student's answers to a classroom activity below. Read through her answers and describe what strategies you would employ to assist the student. The student has given a mix of incorrect and correct responses.

The student responses are given in *bold italic*

Activity

The following diagram represents Sparky who departs the cell full of energy. Answer the following questions with reference to the diagram.



(a) What is represented by Sparky?

Electricity Electron

(b) What is represented by the shaded areas in his body?

Current Energy

(c) Where does Sparky get the energy from?

Battery From the chemical reactions in the cell/battery

(d) What happens while Sparky moves from the positive terminal to the negative terminal of the cell?

Sparky's charge gets used up Sparky loses energy to the components in the circuit.

(e) Is it correct to say that the electric current is used up? Explain your answer.

Yes because as the current moves around the circuit, it gets used for things like heat and light and by the time it gets back to the battery all the current is finished.

No, electrical energy is converted to other forms like light (in a lamp) or heat (in a resistor) causing Sparky to lose energy.

a. What conceptual ideas does this student have in place?

Write your response here

Electricity is what is moving through a circuit.
The battery supplies current to sparky, so the battery produces current which is carried through the circuit.
Like a person who needs energy to move, the electricity also needs energy to go around the circuit and this energy is used up, like people 'use up' energy every day.
The student is confusing electricity, charge and energy. No mention is made of electrons, or energy conversions.

b. What are the key conceptual gaps, in your opinion, that this student demonstrates?

Write your response here

Fundamentally the learner does not understand what current is and how it is able to flow through a circuit.

The battery has chemical compounds in it which provides electrons with energy (converted from chemical pot energy to electrical pot energy).
This is where redox chemistry comes in, and can be referenced, if learners have done this before.
The electrons move from a high energy (high potential) on the positive terminal) to a low potential (negative terminal) through the circuit.
The potential difference is set up by the chemical reactions in the battery.
Electrical energy, which is carried by the electrons, is converted in the circuit components to other forms of energy, e.g. to light in a light bulb, or heat/radiation in a resistor. Potential energy is converted to kinetic energy as the electrons move in the conductor.

c. What specific strategies would you employ to bridge these gaps?

Write your response here

Reteach the section!!

I think here one will have to start from the beginning because the learner has fundamental issues.
I guess I would start with What a circuit is? Talk about the components first, and let the learners play on some circuit boards to see what happens if different components are added and removed.
Maybe just work with the effect of more cells in a circuit at first.
I would also open up a battery and show the learners what is inside.
Then link this with the function of a battery, and what current it.
Then link with energy and how this is carried in a circuit, and how and why electrons flow.
And then talk about potential difference, again bringing it back to the cell and what is inside. (And I wouldn't use an analogy with a person in it as I think it creates misconceptions :-).