Alternative Conceptions about Simple Electric Circuits amongst High School FET Band Learners

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Abstract
The aim of the study is to reveal high school FET band learners alternative conceptions about simple electric circuits and to establish whether specific alternative conceptions are peculiar to South African learners. A conceptual understanding test containing simple electric circuits' questions was used to collect data from high school learners in grade 10, 11 and 12. A random sample of three learners per grade took part in an interview where a semi-structured interview technique was used. Learners who participated in the interview were probed to explain their responses in the conceptual understanding test. Findings show that alternative conceptions reported in the literature are found within South Africa. However there are alternative conceptions that are peculiar to South African learners.

Keywords: alternative conceptions; simple electric circuit; FET band; conceptual understanding;

Motivation and research questions

The learners alternative conceptions of science have aroused science educators interest for more than 30 years because of the principle idea of constructivist learning theory, which was stated as " learners come to the learning environment with the preconceptions, which were formed during their interactions within physical and social environment and those preconceptions affect learning " (Pfundt and Duit, 2006). The main interest of studies focus on those alternative conceptions of which contradict with scientific knowledge and create problems in learning. Research carried out resulted with some findings about main feature of alternative conceptions. These finding are listed below (Tytler, 2002).

- Alternative conceptions of learners who have different culture, religion and language are frequently similar to each other.
- Alternative conceptions may deeply penetrate into learner's minds and resist change.
- Everyday language, culture and religion can cause the formation of alternative conceptions.
- Alternative conceptions can be parallel to the explanations made by earlier scientists in interpreting science phenomena.
- Alternative conceptions may develop after formal teaching.

Learners may sometimes have alternative conceptions stemming from the use of everyday language (Gilbert et al.1982) summarize this situation as follows.

> Many words in science are used in an alternative way in everyday language. Often a student can listen to, or read a statement in science and *make sense* of it by using the everyday interpretation of the word. The interpretation is not the one intended by the teacher or textbook writer. For example: The air is made up of small particles (is

anything else made up of small particles?) glass. They are made out of small particles of sand which have been turned hot. ... Turned clear and then sort of take them out. ... And put them between two pieces of metal when they have been hardened and when they take it off they find that they have a clear surface called glass. (Step 7; age 11) The word 'particle' is commonly used in science classes to mean atom, molecule or ion. In everyday use it refers to a small, but visible, piece of solid substance. The everyday [p626 starts] meaning has been applied to air. The interviewee has apparently presumed that the 'particle' size in sand is retained in glass.

Learners' acquisition of new alternative conceptions during teaching is one of the possible situations (Sherry et al., 2001). The existence of alternative conceptions in learners 'minds during teaching sometimes depends on the extent to which teachers hold the same alternative conceptions (Pardhan and Bano, 2001; Küçüközer and Demirci, 2005).
In light of the studies and ideas outlined above, this study aims to reveal FET band learners alternative conceptions about simple electric circuits. Therefore, questions to be sought for the responses are:

1. What are FET band learner alternative conceptions about the simple electric circuits?
2. Are there specific alternative conceptions that are peculiar to South African learners?

Theoretical framework
In science teaching according to the National Curriculum Statements (NCS) on Physical Science Curriculum (Department of Education, 2005) it is advisable to use a spiral approach. In a spiral approach, concepts are first introduced in a simple way. Later in the year, or in later years, the concepts are revisited and studied in greater depth. This approach allows learners to gradually build up an understanding of the concepts over a period of time without getting bogged down by too much detail all at once. It also takes into account that learners mature and develop cognitively over time. This means that their ability to cope with greater complexity and cognitive demand also increase.
In Grade 10 learners get a qualitative introduction to electric circuits. They learn that there must be a closed circuit for charges to flow, and that the rate of flow of charge is called the current. Which circuit elements are placed in the circuit and in which arrangement determines the resistance of the circuit, which can be thought of as the obstacle to the flow of charge. In order for charges to flow in a circuit there must be a difference in electrical potential energy across the circuit (Department of Education, 2005).
A battery is a device that provides potential difference, which is the difference in electrical potential energy per unit charge, also called voltage. The voltage across the battery when it is not in a circuit is called its emf. (Note that in the past the word "battery" was used to mean a combination of cells; nowadays the word "battery" is used in physics, regardless of how many cells there are and "cell" is seldom used.)
Learners learn that the voltage across a circuit element is proportional to its resistance, and the current through it is inversely proportional to its resistance, but they do not do detailed calculations. They learn that, in general, the current that flows through a battery depends on how many resistors there are in a circuit and how they are arranged. More resistors in series create a greater obstacle to flow so there is less current; more resistors in parallel create more pathways for the flow of charge so there is more current.

Learners also learn how to measure the voltage across a circuit element and the current through it using a voltmeter and an ammeter, respectively.
In Grade 11 learners study Ohm's Law, and use it to solve problems involving the resistance, voltage and current of circuits of different configurations. They learn how to calculate the equivalent resistance for parallel and series circuits. They also learn about series-parallel circuits, which are neither purely series nor purely parallel. They study the Wheatstone Bridge as an important example of another type of circuit, namely a bridge circuit (Department of Education, 2005).
In grade 12 learners do not study electric circuits as a core concept but are expected to study electrodynamics. The themes there will be:

- electrical machines (generators, motors)
- alternating current
- capacitance and inductance

Conceptual level at different grades
In the Physical Sciences curriculum progression is reflected by the increase in the quantity and depth of the understanding of concepts used, together with an increasing understanding of the connections between different concepts in order to develop a well organised knowledge base (Department of Education, 2005).
In grade 10 a learner is expected to recall and state basic prescribed scientific knowledge (Department of Education, 2005).
In grade 11 attainment is evident when a learner is able to: define and discuss the prescribed scientific knowledge. While in grade 12 attainment will be evident when the learner is able to define, discuss and explain prescribed scientific knowledge (Department of Education, 2005).

Literature review framework
Electricity is one of the basic areas in the school curriculum Physical Sciences and it starts as a component of Natural Sciences in the lower grades. While its basic application encompasses many areas in our everyday lives it remains a fertile ground for alternative conceptions, in which learners develop views and imagery that are very different from scientific ones. A lot of research has been conducted in electricity in general and an electrical circuit is particular. The results indicate that learners hold alternative conceptions about current, voltage, resistor and other electricity related concepts. According to these studies in the literature the learners alternative conceptions about simple circuits are summarised as follows:

1. Sink model: learners think that wire connection allows electricity to sink from power source to device, thereby powering the device (Cambers and Andre, 1997; McDermott & Shaffer, 1992).
2. Clashing Model: learners think positive electricity moves from the positive terminal and negative electricity moves from the negative terminal and they meet at a device and clash (Heller & Finley, 1992; Chambers and Andre, 1997).
3. Weakening current model: learners think that current flows in one direction and gradually weakens because each device gradually uses up some of the current (Heller & Finley, 1992; Chambers and Andre, 1997).

4. Shared current model: learners think that devices share current equally but less current turns to power supply (Heller & Finley, 1992; Chambers and Andre, 1997).
5. Local reasoning: when change is made up in a circuit, leaners often focus at the point where change occurs, they do not recognise that change made at one point result in changes at other points(Cohen, Eylon & Ganiel, 1983; Heller & Finley,1983)
6. Empirical rule: learners think that the further away the bulb is from the battery the dimmer the bulb (Heller and Finley, 1992).
7. Learners regard the battery as a constant current source rather than a constant voltage source (Cohen, Eylon & Ganiel, 1983; Heller &Finley,1992; Psillos & Koumaras,1988).
8. Potential and potential difference: learners did not realise that brightness of identical bulbs depend on how they are connected in a circuit not on where they are connected (Shipstone, Jung & Dupin, 1988)
9. Sequential reasoning: if a circuit element changed in a circuit, learners analyse the circuit in terms of before and after current passes that place (Heller & Finley, 1992).
10. Short Circuit preconception: learners believe that in a circuit, wire connection without devices attached to the wire can be ignored (Shipstone, Jung & Dupin, 1988)

Methodology

This research is a qualitative study in which conceptual understandings test involving open-ended questions was used and interviews were conducted to find out the learners pre-knowledge. The conceptual understanding test was administered to 123 learners in the FET band secondary school learners in the East Rand in Gauteng province. The participants were drawn from various schools through a Saturday school initiative that is meant to improve the learners performance in mathematics, life sciences and physical sciences. These learners come from 17 high schools in the areas of Benoni, Brakpan, Springs and Nigel. They are from former Model C schools and from township schools in areas otherwise known as formerly disadvantaged areas. These learners are from different schools but meet every Saturday for four hours of tuition.

Conceptual understanding test (CAT) and interviews as data collection tools are explained below.

Conceptual understanding Test

In the pilot phase the designed conceptual understanding test consisted of 8 questions. These questions are influenced by ideas from studies investigating simple electric circuits literature from ((Shipstone, 1985; Shipstone et al., 1988; Mc Dermott and Shaffer, 1992; Lee and Law, 2001)

The content validity was done and the results of the pilot indicated that this test will be more effective if I concentrate on the first five questions (for the conceptual understanding test). The pilot results showed that participants did not attempt questions 6 to 8, I then attributed this to the 45 minute time allocation and concentrated on the first five questions for CAT.

Interviews

A semi-structured interview technique was used in the study. Interviews were used to probe learners deeply about the ideas in the conceptual understanding test (CAT). In the interviews even questions six to eight were asked where time allowed because the interviews were up to a maximum of 40 minutes per learner, the interviews were video and audio recorded and all this was explained to the learners and they were made to feel at ease in these sessions. Maximum attention was paid not to lead participants but to strive to develop interaction in a natural and comfortable atmosphere

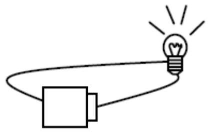
Findings and discussion

Results

This section looks at a summary of responses by learners in grades 10, 11 and 12.a total of 123 learners participated in the CAT and the actual number as well as a percentage of learners who articulated similar responses is indicated in the tables below. The responses were categorised in terms of the similarity and the frequency of responses to a particular question. The responses are indicated as stated by learners and a discussion follows at a later section.

Question 1

1.



A bulb is connected to a battery and gives light as shown in the figure. Explain why the bulb gives light?

Because,

Table 1

Responses	Frequency	
	No of responses	Percentage
The battery acts as a source of energy, so when a bulb is connected to a cell it will light up	59	48%
Because there's current that flows from the battery to the bulb, which therefore produces light. The bulb gives light because it is connected to a power source which gives the circuit current.	19	15%
The electron which are positive and negative collide with each other at the bulb and this brings light to the bulb	24	19%
The bulb gives light because the two conducting wires have been connected to the battery on the negative side and on the positive side this makes the electrons move which ends up producing light,	10	11%
Uncodable	11	12%

Question 2

2.

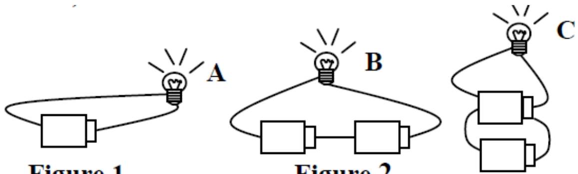


Figure 1 Figure 2 Figure 3

Batteries and bulbs are identical in three figures. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❑ A>B>C	❑ B>A>C	❑ B>A=C
❑ A=B=C	❑ B=C>A	❑ ....

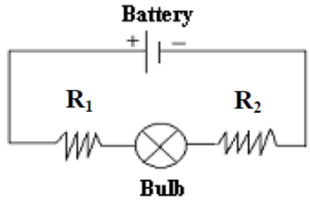
Your explanation:

Table 2

Options	Explanations	Frequency	
		No of responses	Percentage
B = C > A	Circuit B and C have the same amount of current flowing through the, regardless of the connection type. Circuit A has less current hence bulbs C and B are brighter that bulb A. Figure 2 and 3 have the same number of cells/batteries the difference is just that one is in parallel and the other in series but provide the same amount of power for light while figure1 has one cell making the brightness become much less.	60	49%
	The electrons take much lesser time to get to the bulb with much lesser cells. The charge moves at a slower pace when there is one cell and at a faster pace when two cells are connected and this a brighter bulb than with one cell. Two cells make the current move more quickly and the bulb more brighter		
A = B = C	All three bulbs will have the same brightness because the bulb can only withstand a certain amount of watts , voltage, current regardless of how many cells have been connected to the bulbs	22	18%
B > A = C	B has two cells which will supply more current that A and C, plus the cells are in series connection. hence the more cells connected in se brighter	19	15%
Uncodable	No response and irrelevant	22	18%

Question 3

3.



This question involves the changes made in a sample electric circuit. Please put a X for each situation into the box next to the response you chose and explain why you choose that alternative.

a) If R_1 decreased, brightness of bulb;

❑ INCREASES ❑ DECREASES ❑ STAYS THE SAME

Your explanation:

b) If R_2 decreased, brightness of bulb;

❑ INCREASES ❑ DECREASES ❑ STAYS THE SAME

Your explanation:

c) If R_1 increased, brightness of bulb;

❑ INCREASES ❑ DECREASES ❑ STAYS THE SAME

Your explanation:

d) If R_2 increased, brightness of bulb;

❑ INCREASES ❑ DECREASES ❑ STAYS THE SAME

Your explanation:

Table 3

Options	**Explanations**	**Frequency**	
		No of responses	**Percentage**
increase	There is lower resistance therefore the current increases. Resistance is decreased therefore the energy entering the bulb increases. The current will increase that will make the bulb brighter.	20	16%
Stays the same	The battery produces current from the negative side; therefore R1 does not affect the brightness of the bulb.	65	53%
uncodable	The resistor is there so that not much power is released which will make the bulb blow up, so a resistor allows the power to be enough for the bulb to light up bright enough.	38	31%

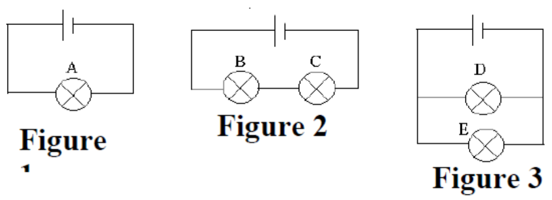
Question 3b Table 4

Options	**Explanations**	**Frequency**	
		No of responses	**Percentage**
Decrease	The bright of the bulb will decrease it will have less power.	6	5%
Stay the same	The electrical energy would have already	76	63%

	passed the bulb Resistor R2 is put after the bulb which will have no effect at all. The brightness will stay the same because R2 is connected after the bulb and current travels in one direction.		
Increase	the brightness of the bulb will increase because a lot of energy is resisted from flowing through the cell	22	17%
Uncodable		19	15%

Question 4

4. **Bulbs and batteries are identical in the figures given below.**



Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❑ A>B=C=D=E
❑ A=D=E>B=C
❑ A=B=C>D=E
❑ A=B>C>D>E
❑ A>B=C>D=E
❑ ....

Your explanation:

Table 5

Options	Explanations	Frequency	
		No of responses	Percentage
A=B=C>D=E	A,B,C Will have the same amount current but D and E has less because it is in parallel Every time that the current reaches a 'T' junction point in a circuit, it splits the amount of current into equal parts.	10	8%
A > B=C=D=E	A is the only bulb in the circuit making it brighter than B,C,D,E More current will flow through and less energy will be needed, whereas the others are equal	48	39%
A = B > C = D= E	A and B are equal because the current pass through them 1st and D and E are equal because they are parallel B is greater than C because current passes through it first	47	38%
A=B=C > C=D	ABC are in series so the current moves quickly whereas because D & E is parallel it moves slowly.	4	3%
uncodeable	A can't carry the same light or brightness as compared to B,C and D because I believe the more the bulbs the greater the	14	12%

	brightness. Bulb B and C will be brighter than bulb A		

Question 5 (i)

5. All bulbs are identical in the circuit shown in Figure 1. Use this information answers the questions below.

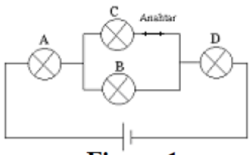


Figure 1

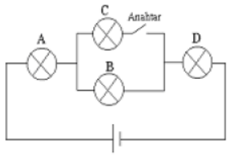


Figure 2

I) Switch is closed in Figure 1. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❑ A=D>B=C ❑ A>B=C>D ❑ C>A=D>B ❑ A=B=C=D
❑ None of bulbs are lit when the switch is closed ❑ ....

Your explanation:

II) Switch is opened in Figure 2. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❑ A>B=C>D ❑ A>B=D, C isn't lit ❑ A=D>B=C ❑ A=B= C=D ❑ A>B>D, C isn't lit ❑ None of bulbs are lit when the switch is opened ❑ ....

Your explanation:

Table 6

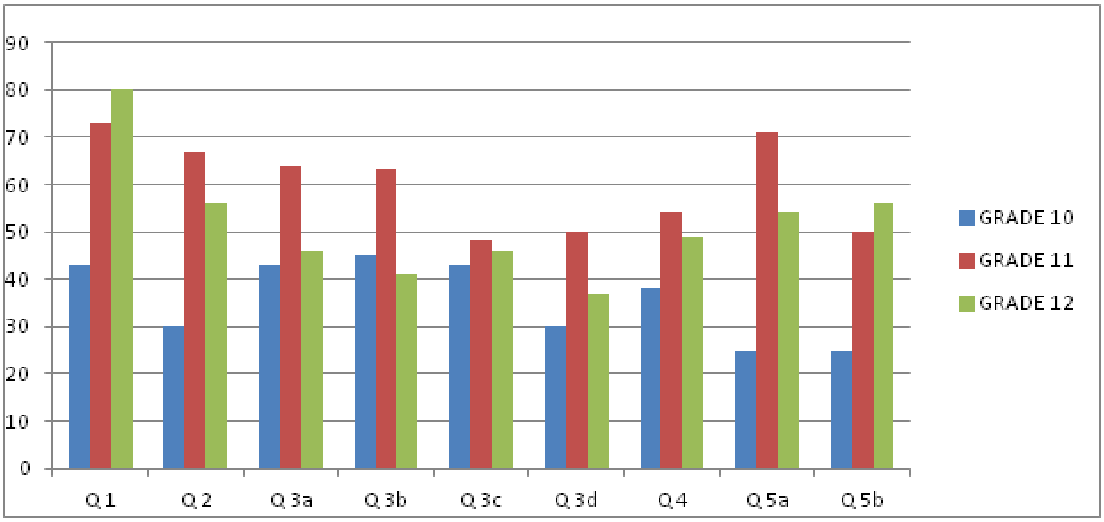
Options	Explanations	Frequency	
		No of responses	Percentage
A =D > C =B	The brightness of B and C is the same because they are connected in parallel, while the brightness of A and C is the same because they are connected in series.	43	35%
None of the bulbs are lit when the switch is closed.	In a closed switch, there isn't any flow of the current as it is unable to do so because the brightness of the bulb is dependent on the flow to be present so that it can light.	27	22%
A = B = C = D	The brightness will be equal throughout the circuit because the current is distributed equally because of the parallel connection	20	16%
No response		33	27%

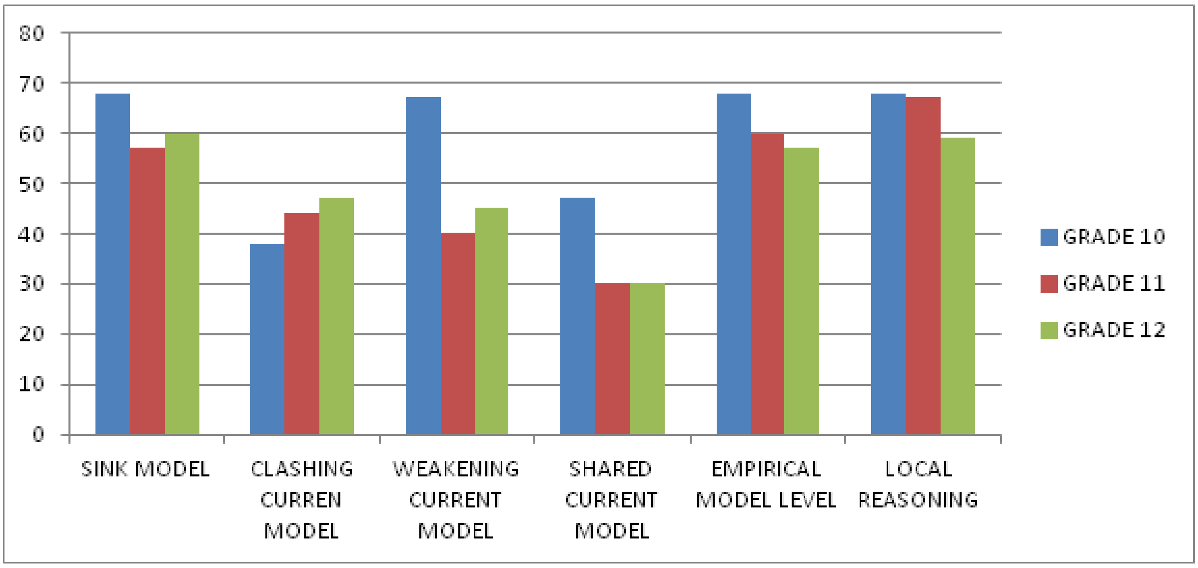
Question 5 (ii)
Table 7

Options	Explanations	Frequency	
		No of responses	Percentage
None of the bulbs are lit when the switch is open	It is because there is no current flowing Energy cannot flow through an open switch.	73	59%
	Although the switch is open it is away from the battery which means there will be current passing through bulb A, B and C not D because the switch is just before D its open stopping current.	37	30%
No response		13	11%

Performance per grade **Table 8**

		Grade 10		Grade 11		Grade 12	
Question 1		17	42.5%	31	73%	33	
Question 2		12	30%	28	67%	23	
Question 3	a	17	42.5%	27	64%	19	
	b	18	45%	25	62.5%	17	
	c	17	42.5%	20	47.6%	19	
	d	12	30%	21		15	
Question 4		15	37.5%	23		20	
Question 5		10	25%	30		22	
		10	25%	21		24	





Discussion

Findings show that alternative conceptions reported in the literature are also found within South African learners. For example, learners conceptualise a cell as producing current; rather than viewing it as an energy source: source of pd – out of which follow of charges arises. In addition some learners see the cell as a source of constant current, irrespective of the external resistance.

Conceptual errors identified in the study that are similar to those in (Osborne, 1983; Cohen at al.., 1982; Shipstone at al.., 1984; Lee and Law, 2001; Küçüközer, 2003)

- Inability to conceive that a change in one part of the circuit will cause change in other parts.
- Learners see a cell or battery as a source of constant current rather than emf
- Learners' perceive that current gets used up
- Learners misunderstand the role of resistance in circuits. Resistance is seen as an obstacle rather than a conducting path.
- Parallel resistors are not understood.

Questions 1

Concept of potential difference, current and energy were used interchangeably as if they all are the same . The same finding was also reported by Kärrqvist (1985), Shipstone et al. (1988) and Borges and Gilbert (1999).

Question 2

In this question the type of alternative conceptions that arise are similar to those that are found in the literature in particular those that were found by Lee and Law (2001) "Bulb gives more light when the number of batteries increases (independent from the type of connection)" and "Bulb becomes brighter when batteries are connected in parallel compared to batteries connected in series". These alternative conceptions were also found in the study of Lee and Law (2001).

Question 3

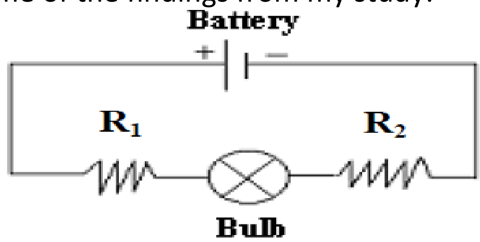
A configuration change in front of a bulb is regarded as having an effect upon the brightness of the bulb but that change after the bulb is thought to have no effect on the bulb's brightness in a serial circuit (sequential reasoning) . This alternative conception was also reported in the studies by McDermott and Shaffer (1992), Shipstone et al. (1988).

Question 4

Batteries are constant current sources. This type of alternative conception was also documented in the studies of Cohen et al. (1983), Shipstone et al. (1988), Kärrqvist (1985), McDermott and Shaffer (1992), Lee and Law (2001).

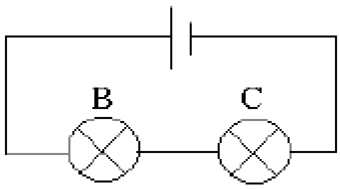
However there are alternative conceptions that are peculiar to South African learners

1. These are some of the findings from my study:



When asked what will happen to the brightness of the bulb when R1 is increased most learners responded:

- the current will travel slower through the resister and thus the bulb will be dimmer



2. When two identical bulbs are connected in series the bulb that is closer to the positive terminal of the cell will be brighter than the bulb that is further away from the positive terminal because the first bulb shall have consumed most of the current. Similar results were recorded by McDermont and Shaffer,1992 where they classified it as the *attenuation model*, whereby the current leaving a battery from one end is 'used up' by the elements in the circuit and the used portion returns back to the other terminal of the battery.

3. A number of alternative conceptions emerged from this question in particular. I have not encountered any alternative conceptions that are similar to these in the literature and this leads to the conclusion that these are peculiar to South African learners.

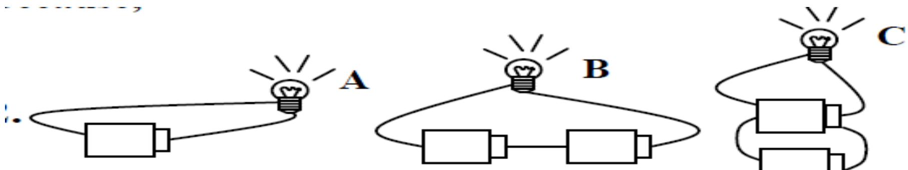


Figure 1 Figure 2 Figure 3

3.1 Learners (*see table 2*) believe bulbs A, B and C will have the same brightness irrespective of the number of cells or the type of connection because it can withstand a certain number of watts. *"All three bulbs will have the same brightness because the bulb can only withstand a certain amount of watts , voltage, current regardless of how many cells have been connected to the bulbs"*

3.2 Learners believe the number of cells determines the speed of the current and this in turn determines the brightness of the bulb. These are some of the frequent responses:

3.2.1 the electrons take much lesser time to get to the bulb with much lesser cells

3.2.2 the charge moves at a slower pace when there is one cell and at a faster pace when two cells are connected and thus a brighter bulb than with one cell.

3.2.3 Two cells make the current move quickly and the bulb brighter.

4. In question 4 learners indicated that bulbs in series will have the same brightness irrespective of the number of bulbs in each instance.

5.

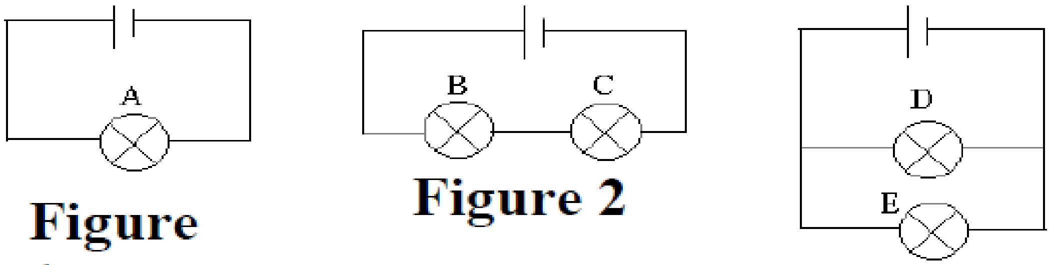


Figure 1 Figure 2 Figure 3

5.1 About eight percent of the learners were of the opinion that bulb A, B and C will have the same magnitude of current and therefore the same brightness. " *A,B,C Will have the same amount current but D and E has less because it is in parallel"*

5.2 About 3% of the learners had the same opinion, but for a different reason, they stated that in bulb A, B and C the current moves faster while in D and E the current moves slower.

6. In question 5 about 59% of learners had a language problem probably from the literal meaning of the word closed. They understood the word closed circuit out of context and because of the direct translation from the indigenous languages to the language of science. The word closed simply meant there is no current flow and closed meant just that closed and nothing will happen there. This lead to learners confusing the closed circuit and an open circuit. While they concluded that a closed

circuit means nothing flows there, they even failed to realise that even in their understanding of open and closed there was still a complete circuit there.

Conclusion

Learning is a process of personal construction and that learners, given an opportunity, will construct a scientifically orthodox conception of the physical phenomena if they see that the scientific conception is superior pre instruction conception (Postner, Strike,Hewson and Gertzog, 1982). In most studies it has emerged that common misconception or rather alternative conceptions were not confined to one country or to one educational system, but were common to various countries with different educational systems (Shipstone et al., 1988). Findings revealed that (Driver and Bell, 1986; Driver, 1989; Mitimuciuo, 1998)

- Alternative conceptions of learners who have different culture, religion and language are frequently similar to each other.
- Misconception may deeply penetrate into learners minds and resist to change
- Everyday culture, language and religion can cause the formation of alternative conceptions
- Alternative conceptions can be parallel to the explanations made by earlier scientists in interesting scientific phenomena.
- Alternative conceptions may develop after formal teaching.

There is a need to develop intervention strategies in order to remediate the alternative conceptions that arose from my study.

References

Chambers, S.K. and Andre, T. (1995) "Are Conceptual Change Approaches to Learning Science Effective for Everyone? Gender, Prior Subject Matter Interest and Learning about Electricity". *Contemporary Educational Psychology. 20(4): 377-391.*

Chambers. S.K., and Andre, T. (1997) "Gender. Prior Knowledge, Interest and Experience and Conceptual Change text Manipulations in Learning about Direct Current?". *Journal of Research in Science Teaching,34(2): 107-23,*

Cohen, R., Eylon, B. & Ganiel, U. (1983). Potential Difference and Current in Simple Electric Circuits: A Study of Learners's Concepts. *American Journal of Physics*, 51(5),

Department Of Education. (2005) *National Curriculum Statement* (NCS)

Helier, M.P. and Finley, N.F. (1992)"Variable Uses of Alternative Conceptions, A Case Study in Current EIectricity". *Journal of Research in Science Education, 29(3): 259-276*.

Küçüközer, H. & Demirci, N. (2005). High School Physics Teachers' Forms of Thought about Simple Electric Circuits. *23th International Physics Congress*, Muğla University 13-16 September.

Lee, Y. & Law, N. (2001). Explorations in Promoting Conceptual Change in Electrical Concepts via Ontological Category Shift. *International Journal of Science Education*, 23 (2), 111-149.

McDermott, L.C. & Shaffer, P.S. (1992) "Research as a Guide for Curriculum Development: An Example from Introductory Electricity. Part i: Investigation of Student Understanding". *American Journal of physics, 60(11): 994-1003.*

Osborne, R. (1983). Towards Modifying Children's Ideas about Electric Current. *Research in*

Science and Technological Education, 1 (1), 73-83.
Pfundt, H., & Duit, R. (2006). Bibliography: Students' and teachers' conceptions and science education. Kiel: IPN.
Psillos, D. and Koumaras, P. (1988) "Voltage Presented as a Primary Concept in an Introductory Teaching Sequence on DC Circuits". *International Journal of Science Education, 10(1): 29-43,*
Shipstone, D. M., Rhöneck, C.v., Kärrqvist, C., Dupin, J., Johsua, S. & Licht, P. (1988) A Study of Student' Understanding of Electricity in Five European Countries. *International Journal of Science Education*, 10 (3), 303-316.
Shipstone,D. (1988) "Pupils' Understanding of Simp1e Electrical Circuits: Some Implications for Instruction". *Physics Education*, *23(2): 92-96*,
Tytler, R. (2002). Teaching For Understanding In Science: Student Conceptions Research, And Changing Views Of Learning. *Australian Science Teachers Journal,* 48(3), 14-21.