# Chapter Four

## Analyses and presentation of the integrated data of Phase I design-based research

### 4.1 Introduction

Chapter Three deliberated on the research design and methodology of this research. It also explicated the four phases of the DBR. This chapter discusses phase I of the DBR in terms of the analyses and exploration of the research problem (Figure 3.4). The results therefore include the analyses of both quantitative and qualitative data. The quantitative analyses of the DIRECT concept test contributed to the descriptive statistics (frequencies, percentages and cross tabulations) (Cohen et al., 2007) of the biographical information (§4.2), as well as the identified misconceptions in order to interpret and determine the significant differences between the biographical information and the identified misconceptions (§ 4.3) relating to electric circuits. The qualitative analysis comprised an integrated dataset of interview data (McMillan & Schumacher, 2001) which resulted in the classification of the misconceptions.

### 4.2 Descriptive statistics of biographical information

Section A of the DIRECT concept test (Addendum 3.1) included eleven questions to collect biographical information of the respondents groups 1 and 2 (N=81) who completed the test. Table 4.1 provides the frequencies and percentages (rounded off to the nearest whole number) of the biographical data: age, gender, cultural background, home language, language of instruction, province of birth, residing province, mining company apprenticeship, level of education, access to devices, and access to Internet (Addendum 3.3). Table 4.1 provides a summary of the frequencies and percentages of the biological information of the respondents in trimesters 1 and 2.

**Table 4.1: Frequencies and percentages of the biographical information (N=81)**

| Question | Biographical information | | Frequencies | Percentages |
|---|---|---|---|---|
| 2.1 | Age | 19-22 | 62 | 77 |
| | | 23-28 | 17 | 21 |
| | | $30^+$ | 2 | 2 |
| 2.2 | Gender | Male | 50 | 62 |
| | | Female | 31 | 38 |
| 2.3 | Cultural background | Black | 34 | 43 |
| | | Coloured | 24 | 31 |
| | | White | 23 | 26 |
| 2.4 | Home language | Afrikaans | 44 | 54 |
| | | Sesotho | 5 | 6 |
| | | Setswana | 13 | 16 |
| | | Other | 19 | 23 |
| 2.5 | Language of instruction | Afrikaans | 51 | 63 |

| Question | Biographical information | | Frequencies | Percentages |
|---|---|---|---|---|
| | | Other | 30 | 37 |
| 2.6 | Province of birth | Eastern Cape | 1 | 1 |
| | | Free State | 2 | 2 |
| | | Gauteng | 7 | 9 |
| | | Limpopo | 1 | 1 |
| | | North West | 6 | 7 |
| | | Northern Cape | 51 | 63 |
| | | Western Cape | 4 | 5 |
| | | Other | 2 | 2 |
| 2.7 | Residing province | Gauteng | 4 | 5 |
| | | Limpopo | 2 | 2 |
| | | North West | 8 | 10 |
| | | Northern Cape | 60 | 74 |
| | | Western Cape | 3 | 4 |
| | | Other | 4 | 5 |
| 2.8 | Mining apprenticeship | Yes | 19 | 23 |
| | | No | 62 | 77 |
| 2.9 | Level of education | 1st year university | 3 | 4 |
| | | 2nd year university | 1 | 1 |
| | | BSc | 1 | 1 |
| | | Grade 12 | 48 | 59 |
| | | NQF Level 4 | 16 | 20 |
| | | N1 | 1 | 1 |
| | | N2 | 4 | 5 |
| | | N3 | 4 | 5 |
| | | N4 | 3 | 4 |
| 2.10 | Access to devices | Mobile | 63 | 78 |
| | | Tablet with Internet | 14 | 17 |
| | | Laptop without Internet | 15 | 18 |
| | | Laptop with Internet | 9 | 11 |

### 4.2.1 Age

Most of the respondents (77%) were between the ages of 19-22 years. A smaller percentage of the respondents (21%) were between the ages of 23-28, and only two per cent of the respondents were over thirty years old (Table 4.1).

### 4.2.2 Gender

The male respondents (62%) were more than their female counterparts (38%) enrolled for the course (Table 4.2). According to Statistics South Africa (2013) just over 51% of South Africa's population are female and the same percentage applies to the Northern Cape. In the Gamagara District the female population is at 51%, and the NCRFET College the female population is 51% (SAinfo reporter, 2012; SouthAfrica.info, 2012).

### 4.2.3 Cultural background

The cultural groups represented in this study were Black (43%), Coloured (31%), and White (26%) (Table 4.1). If we look at the country as a whole the Black population is at eighty per cent, the Coloured population at nine per cent, and the White population is also at nine per cent

(SouthAfrica.info, 2012). In the Northern Cape the Black population is 33%, the Coloured population is 52% and the White population is thirteen per cent (Statistics South Africa, 2011). The NCRFET College population distribution is as: Black 47%, Coloured 46% and White at seven per cent (SAinfo reporter, 2012).

#### 4.2.4 Home language

The Northern Cape Province is a predominantly Afrikaans-speaking (54%) region (SouthAfrica.info, 2012). The majority of the respondents (54%) spoke Afrikaans at home, even though most of the respondents came from the black community (Table 4.1). According to Statistics South Africa (2011) fourteen per cent of the population's home language is Afrikaans, ten per cent of the population's home language is English.

#### 4.2.5 Language of instruction

In South Africa either Afrikaans or English is used as medium of instruction. Most of the respondents (63%) receive their education in Afrikaans (Table 4.1). The NCRFET College uses both Afrikaans and English as medium of instruction (SAinfo reporter, 2012). The students attending the College, especially the Kathu Campus, come from a diverse background and to accommodate everybody, both languages are used simultaneously in class (dual medium).

#### 4.2.6 Province of birth

The majority of the respondents (63%) were born in the Northern Cape Province; few of the respondents were born in other provinces (Table 4.1).

#### 4.2.7 Residing province

Most of the respondents (74%) lived in the Northern Cape Province. Only ten per cent of the respondents resided in the neighbouring province (the North West province) of the Northern Cape (Table 4.1).

#### 4.2.8 Mining apprenticeship

Some of the respondents (23%) received apprenticeships from mining companies in the region (§ 3.4); however the majority of the respondents (77%) attended the course without external financial support.

### 4.2.9 Level of education

As explained in § 3.4, the course required the respondents to adhere to certain prerequisites to enrol for either the Electrical N2 or Millwright N2-trade. The majority of the respondents (59%) had grade 12, which meant they complied with the requirements for these courses (Table 4.1).

### 4.2.10 Access to devices

Although the majority of the respondents had access to a mobile device (78%), a few had access to either a tablet with (17%), or without (18%) access to the Internet (Table 4.1).

## 4.3 Identification of misconceptions

The analyses of phase I of the DBR are presented in this chapter according to an integrated discussion—explaining the results from both quantitative and qualitative analyses to provide an assimilated understanding. The following section presents the results of the quantitative (descriptive statistics of the misconceptions and with frequencies, percentages and cross tabulations) analyses and the concatenation of the qualitative analysis as a combined unit. While an effect size $V \leq 0.2$ was considered a small effect with no or very little significance, an effect size $0.3 \leq V \leq 0.4$ was considered a medium effect that tended towards a practically significant correlation. For the purpose of this investigation, an effect size $V \geq 0.5$, was considered a large effect which indicated a practically significant correlation. A $p \leq 0.05$ of the model indicated that the means of the groups differed significantly. The Statistical Consultation Service of the North-West University assisted in the cross tabulation analysis using SPSS (2012).

The DIRECT concept test determined the misconceptions of the respondents. The respondents answered the test, and on the base of their responses, the researcher identified the most common misconceptions in DC resistive circuits. Consequently, the four most common misconceptions were compiled in an open-ended interview test. Ten respondents were chosen to participate in the interview based on the criteria of the four misconceptions. This chapter discusses the results of the DIRECT concept test questions as well as the inductive analysis from the interview data (Addendum 3.1). As explained in Chapter Three, the misconceptions selected for these analyses were chosen based on the most frequently demonstrated misconceptions. The quantitative and qualitative analyses identified four prominent misconceptions which related to industrial electronics were: (i) understanding of concepts, (ii) short circuit, (iii) battery as a constant current source (misconception), and (iv) application of rules. The misconceptions from the 81 respondents are shown in Table 4.2 (Addendum 3.4).

**Table 4.2: Four misconceptions in direct current resistive circuits**

| Misconception | Frequency | Percentage |
|---|---|---|
| Understanding concepts | 77 | 95 |
| Understanding short circuits | 49 | 60 |
| Battery as a constant current source | 39 | 48 |
| Applications of rules | 58 | 72 |

Most of the respondents (95%) did not understand concepts of electric circuits. Sixty per cent of the respondents encountered difficulties to grasp theory of short circuits, 48% had the misconception that a battery will always produce the same amount of current no matter the load, and 72% could not apply Ohm’s law in cases (Table 4.2).

Figure 4.1 provides an overview of the themes and codes detected during the inductive analysis with Atlas.ti™. During the qualitative coding with Atlas.ti™ according to a deductive process relating to the four misconceptions, four qualitative themes emerged: (i) understanding concepts, (ii) understanding short circuit, (iii) seeing a battery as a constant current source, and (iv) rule application error (Figure 4.1). Table 4.3 provides a summary of the four themes and the code density of the qualitative analysis.

**Table 4.3: Summary of themes and code density of qualitative analysis of interview responses**

| Theme | Understanding of concepts | Understanding of short circuits | Battery as a constant current source | Application of rules |
|---|---|---|---|---|
| Code density | 11 | 5 | 2 | 7 |
| Quotation density | 23 | 10 | 7 | 10 |

The theme understanding of concepts had a code density of 11 and quotation density of 23; the theme understanding of short circuits had a code density of five and quotation density of ten; the theme battery as a constant current source had a code density of two and quotation density of seven, and the theme application of rules had a code density of seven and quotation density of ten.

The following sections (§4.3.1-4.3.4) discuss the four prominent misconceptions identified from the DIRECT concept test (Addendum 3.4) and the qualitative analysis as presented in Figure 4.1.

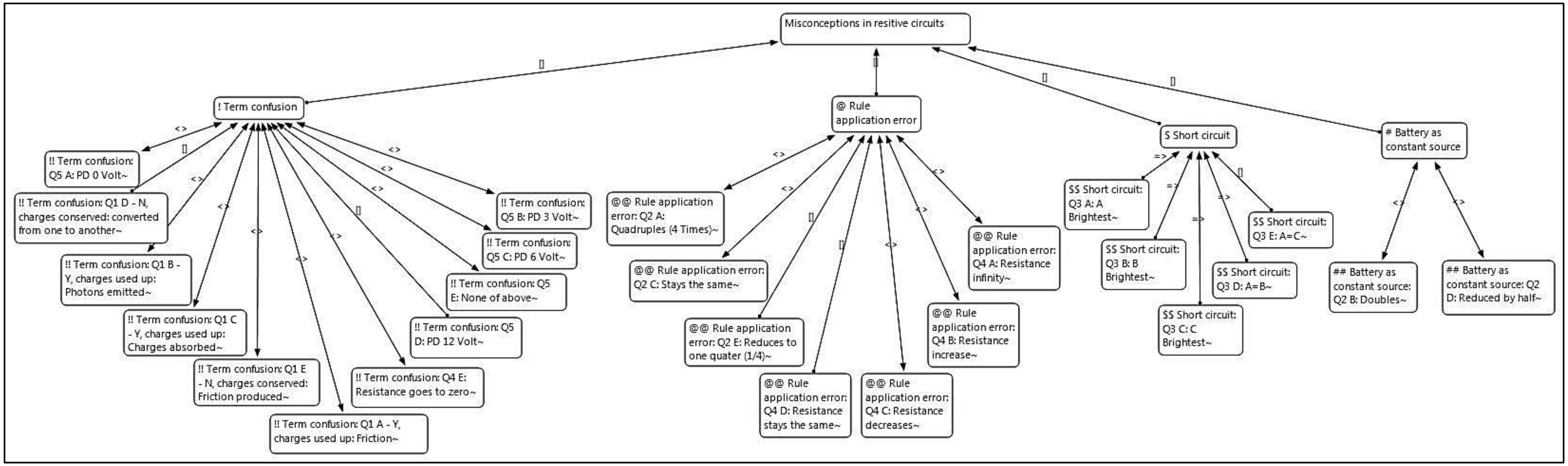


**Figure 4.1: Four prominent misconceptions in electric circuits**

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### 4.3.1 Misconception 1: Understanding of concepts

Eleven codes emerged during the qualitative analysis relating to the understanding of concepts. Respondents were not able to provide a description of the basic concepts of electric circuits. They were confused regarding certain terminology, particularly the concept of *current*. They allocated the properties of current to voltage, energy and/or resistance. Results showed that respondents had no clear understanding of the fundamental theory of the electric circuits and grappled with concurrent changes of variables. Current was the foremost concept used in resolving the problems. Two main misconceptions concerning Direct Current (DC) resistive electrical circuits: (i) current is consumed, and (ii) the battery is a source of constant current. The atomic characteristics of current were addressed by question 1, and were not offered in an introductory course.

1) Are charges used up in the production of light in a light bulb?

(A) Yes, charge is used up. Charges moving through the filament produce "friction" which heats up the filament and produces light.

(B) Yes, charge is used up. Charges are emitted as photons and are lost.

(C) Yes, charge is used up. Charges are absorbed by the filament and are lost.

(D) No, charge is conserved. Charges are simply converted to another form such as heat and light.

(E) No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

**Figure 4.2: Question 1 of the DIRECT concept test**

Question 1 (Figure 4.2) shows that 41.6% of the respondents chose option A as the correct answer. Properties of energy were assigned to current and respondents attributed the effect of electrical charge in the bulb's filament to current—which is incorrect. The electric field delivers the force which causes the charges to increase speed, resulting in a current. Table 4.4 displays the frequency and percentages of the respondents' understanding of the concepts.

**Table 4.4: Frequencies and percentages of Understanding Concepts**

| Question 1 (DIRECT) | | |
|---|---|---|
| **Option** | **Frequency** | **Percentage** |
| A | 32 | 41.6 |
| B | 4 | 5.2 |
| C | 5 | 6.5 |
| D | 27 | 35.1 |
| E | 9 | 11.7 |
| Missing | 3 | 3.7 |
| **Total** | **81** | **100** |

Question 28 (Addendum 3.1) investigated respondents' skills to identify a battery as a source of constant potential difference. For this question (Table 4.4) 56.3% of the respondents selected option A which revealed that respondents accepted the misconception that current and voltage always happened together, current was the cause for voltage, and if one increased, the other would also increase. This illustrates the issues relating to current/voltage term confusion. Tables 4.5 and 4.7 provide the cross tabulations of the biographical information (gender, and cultural background) with the *misconception 1: understanding concepts* using cross tabulation (Chi-square $X^2$) and effect size (Cramér V).

28) What is the potential difference between points A and B?

(A) 0 V

(B) 3 V

(C) 6 V

(D) 12 V

(E) None of the above

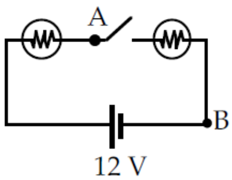



**Figure 4.3: Question 28 of the DIRECT concept test**

Table 4.5 provides the descriptive statistics of the cross tabulations between *gender* and *misconception 1* (understanding concepts).

**Table 4.5: Cross tabulations between Gender, and Understanding Concepts**

| | | Gender | | |
|---|---|---|---|---|
| | | **Male** | **Female** | **Row total** |
| **Misconception 1: Understanding Concepts** | **Yes** | 57 | 20 | 77 |
| | | 74 | 75 | 75 |
| | **No** | 3 | 1 | 4 |
| | | 26 | 25 | 25 |
| **Column total** | | **100** | **100** | **100** |

Phi coefficient=0.01
Cramer's effect sizes=0.01
Pearson's Chi-square (p value)=0.965

There was not a significant effect (V=0.01) between gender and understanding concepts (p=0.965). Most of the male (74%) and the female (75%) respondents did not understand concepts of current and voltage (Table 4.5).

**Table 4.6: Cross tabulations between Culture, and Understanding Concepts**

| | | Culture | | | |
|---|---|---|---|---|---|
| | | **Black** | **Coloured** | **White** | **Row total** |
| **Misconception 1: Understanding Concepts** | **Yes** | 32 | 24 | 21 | 77 |
| | | 94 | 100 | 91 | 95 |
| | **No** | 2 | 0 | 2 | 4 |
| | | 6 | 0 | 9 | 5 |
| **Column total** | | **100** | **100** | **100** | **100** |

Phi coefficient=0.16
Cramer's effect sizes=0.16
Pearson's Chi-square (p value)=0.367

There was not a significant effect (V=0.16) between culture and understanding concepts (p=0.367). The black (94%), coloured (100%), and white (91%) respondents encountered difficulties to understand concepts of current and voltage (Table 4.6).

**Table 4.7: Frequencies and percentages relating to question 28**

| Question 28 (DIRECT test) | | |
|---|---|---|
| **Option** | **Frequency** | **Percentage** |
| A | 45 | 56.3 |
| B | 1 | 1.3 |
| C | 10 | 12.5 |
| D | 16 | 20 |
| E | 8 | 10 |
| Missing | 1 | 2 |
| **Total** | **81** | **100** |

Ten respondents with the highest number of misconceptions were chosen to take part in a voluntary interview (Figure 3.4). During the interview the respondents were given similar questions regarding the four most common misconceptions. Regarding the misconception of term confusion, Question 1 (options A-E), Question 5 (options A-E), and Question 4 (option E) relate to this misconception (Figure 4.4).

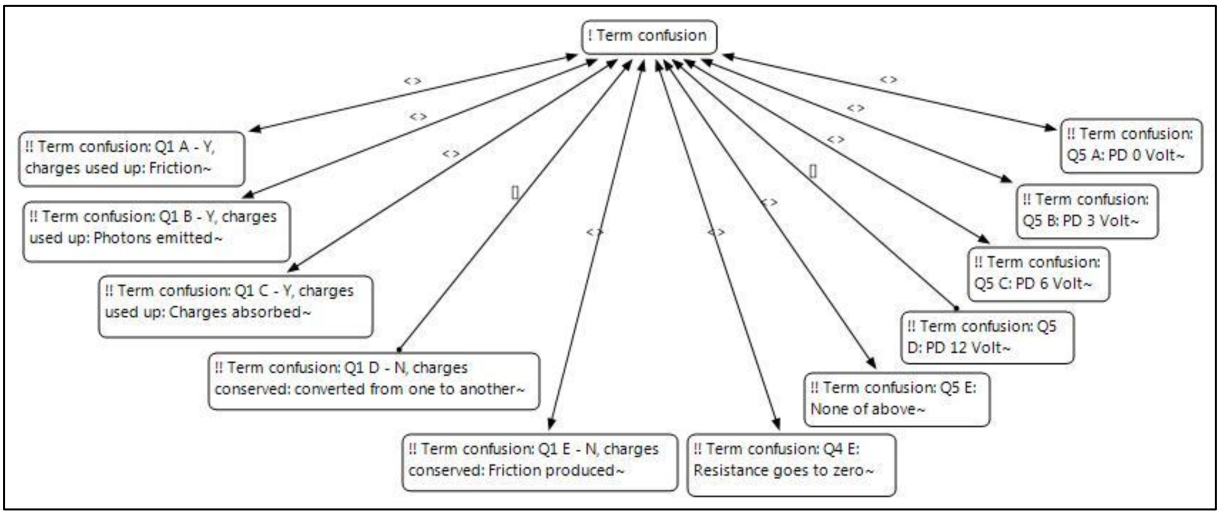



**Figure 4.4: Misconceptions about term confusion**

The problem comprised two questions that had four possible answers and each question could be considered as result of a misconception about term confusion (Figure 4.4). Relating to Question 1 of the interview questions, six of the respondents selected option A as correct. This indicated that the respondents did not demonstrate understanding of the conservation of energy. One respondent selected option B as correct, and one selected option C as correct, which also confirms that the respondents did not grasp the concept of energy and the transfer of energy. The following section provides comments from the respondents relating to answer options A, B and C:

> A. First of all sir I'm not sure like charges like what they are referring to as charges but if ever I want to think in a positive way I'll say maybe it's like a positive charger or maybe a negative. I'll say that yes they are used up the charges are moving through the filament produce a friction when they do they say which heats up the filament and it will produce light. I'll say that (P1: 12)
>
> A. Because in a circuit there's friction current flows (P2: 12)
>
> A. The filament has charges I think (P6: 12)
>
> A. This is what happens, it allows the charges to light up the filament, it heats it up until it glows and let the globe shines (P7: 12)[1]
>
> A. It heats up the element before it can light (P8: 12)
>
> A. Because it produced the heat (P10: 12)
>
> A. Because the light it glows the light that's way it emitted (P5: 12)
>
> C. Because innovatory is source of the positive side and the negative side so in a positive sides the side that takes out the discharges the discharges go directly to the bulb then it reaches to the bulb it return to the source again those charges that are returning to the batteries are the one that is lost that have been used (P3: 12).

Two respondents chose the correct answer, but one of these respondents demonstrated that he/she had a misconception about energy:

> D. Electricity is part of energy. It cannot get lost or used up. It gets transferred to something else (P 4: 12)[2]
>
> D. Because if the class of the bulb get too much heat it gonna blow (P9: 12).

In Question 5 of the interview questions three of the interviewees chose A as correct, and according to their explanations they are unclear about the terms potential difference (closed circuit voltage) and electromotive force (open circuit voltage). No respondent selected option B as correct, but two respondents selected option C as correct which showed that the respondents were unsure of the effect of current on voltage. Three respondents selected option D, which was the correct answer. Two respondents selected option E as correct—indicating that voltage was dependent on current. The comments from the respondents were:

> A. because its potential difference it's a difference between 2 points and a second regarded if the second is close if the second is close that's when I'm gonna get a poten-

---

[1] A. Dit is wat gebeur laat die charges die lig filament hy maak hom warm sodat dit gloei en die lig laat die lig skyn (P7: 12)

[2] D. Elektrisiteit is mos nie deel soos energie nie. Dit gaan nie verlore of gedinges nie. Dit word net omgeskep na iets anders (P 4: 12).

tial difference but if the second is open that's when I'm gonna get an IMF which is the total voltage so the potential difference is 0 (P1: 61)

A. Because the switch is open. There is no current flowing in the bulbs in the circuit (P5: 70)

A. There's no connection between (P10: 55)

C. Because the potential difference is a difference between two points in a circuit (P2: 66)

C. Because it has two resistors and this resistor is going to get a certain amount and the other resistor is going to get a certain amount (P9: 67)

D. Because the circuit is open and it is the EMF (P4: 70)[3]

D. The circuit is just broken at A (P7: 55)[4]

D. She forgot the answer in English and she only knows it in Setswana (P8: 67)

E. Because sir it's like there are 2 points and there's a switch in between so the time you test the continuity still the continuity will be there (P3: 56)

E. Because I cannot calculate it right now (P6: 70).

### 4.3.2 Misconception 2: Understanding short circuit theory

From the DIRECT concept test used in phase 1 of this study, question 10 focussed on misconceptions relating to short circuit theory. Question 10 (Figure 4.5) shows that 63.8% (Table 4.8) of the respondents selected option C, that bulb C would be the brightest bulb. Though, the correct response was option E, that bulb in option A and option C were the same brightness since the bulb in option B was shorted out. Concealed within this correct response were possible misconceptions.

10) Compare the brightness of bulbs A, B, and C in these circuits. Which bulb or bulbs are the BRIGHTEST?

(A) A

(B) B

(C) C

(D) A = B

(E) A = C

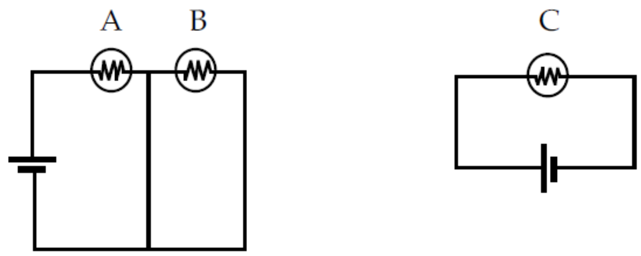



**Figure 4.5: Question 10 of the DIRECT concept test**

[3] D. Want die circuit is oop en dis mos die EMF (P4:70)
[4] D. Die stroombaan is maar net gebreek by A (P7: 55).

**Table 4.8: Frequencies and percentages relating to question 10**

| Question 10 (DIRECT test) | | |
|---|---|---|
| **Option** | **Frequency** | **Percentage** |
| A | 2 | 2.5 |
| B | 2 | 2.5 |
| C | 51 | 63.8 |
| D | 4 | 5.0 |
| E | 21 | 26.3 |
| Missing | 1 | 2 |
| **Total** | **81** | **100** |

There were a number of groupings of these circuit interpretations and views that resulted in the respondents selecting option C. Table 4.8 provides the frequencies and percentages of the responses of the respondents to question 10 (Addendum 3.1). A respondent believing that the current was depleted and the battery was a constant current source would claim that option A and option C were similarly bright since the battery supplied both with current, and option B was dimmer since it is connected after bulb of option A which has used a certain amount of the current. In this circumstance, the respondents may have viewed the bulbs in series or in a series/parallel combination. The respondents who selected that bulb in option C only would be the brightest were viewing the circuit with bulbs in option A and option B in either as in series, in parallel, or in a series/parallel combination. The respondents may also have believed that the battery was a constant current source and/or current was depleted. The researcher calculated *misconception 2* (understanding short circuit theory) with the biographical information (*gender*, and *cultural background*) using cross tabulation (Chi-square $X^2$) and effect size (Cramér V) (Addendum 3.5) to determine if there were significant differences between misconception 2 and gender and culture (Tables 4.9 and 4.10).

**Table 4.9: Cross tabulations between Gender, and Understanding Short Circuit Theory**

| | | Gender | | |
|---|---|---|---|---|
| | | **Male** | **Female** | **Row total** |
| **Misconception 2: Understanding Short Circuit Theory** | **Yes** | 35 | 14 | 49 |
| | | 78 | 67 | 73 |
| | **No** | 25 | 7 | 32 |
| | | 24 | 33 | 27 |
| **Column total** | | **100** | **100** | **100** |

Phi coefficient=0.08
Cramer's effect sizes=0.08
Pearson's Chi-square (p value)=0.501

There was not a significant effect (V=0.08) between gender and understanding short circuit (p=0.501). Many of the male (78%) and the female (67%) respondents did not understand short circuit theory (Table 4.9).

**Table 4.10: Cross tabulations between Culture, and Understanding Short Circuit Theory**

| | | Culture | | | |
|---|---|---|---|---|---|
| | | **Black** | **Coloured** | **White** | **Row total** |
| **Misconception 2: Understanding Short Circuit Theory** | **Yes** | 20 | 12 | 17 | 49 |
| | | 59 | 50 | 74 | 61 |
| | **No** | 14 | 12 | 6 | 32 |
| | | 41 | 50 | 26 | 39 |
| **Column total** | | **100** | **100** | **100** | **100** |

Phi coefficient=0.19
Cramer's effect sizes=0.19
Pearson's Chi-square (p value)=0.237

There was not a significant effect (V=0.19) between culture and understanding concepts (p=0.237). The black (59%), coloured (50%), and white (74%) respondents encountered difficulties to understand short circuit theory (Table 4.10).

Problem 3 of the interview questions related to the misconception which identified and explained short circuits (more current follows the path of lesser resistance). It also observed respondents' knowledge of complete circuits and the effects of shorting wires on the circuit. The problem comprised four answer options which could be considered as result of a misconception about short in a circuit (Figure 4.5). All except one of the interviewees selected option C as their correct interpretation.

Respondents had additional challenges in classifying the truthful depiction of a circuit from a diagram. Overall, respondents could identify a whole circuit. The challenges arose when respondents were requested to decide whether the circuit functioned or not, often including circuits that contained short circuits (Figure 4.6).

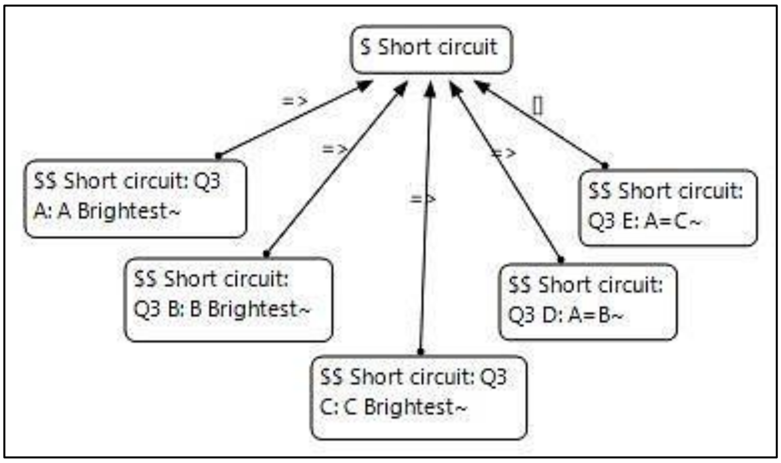



**Figure 4.6: Codes relating to the misconceptions relating to short circuits**

The comments from the interviewees related to short circuits:

> C: First it's a circuit with 2 bulbs but the resistor maybe an indication of. I'll say sir they are equal but. I'll take C (P1: 39)
>
> C sir because it doesn't share its C sir because it's the only bulb (P3: 34)
>
> C. Because the power will divide at A and B but at C it cannot divide (P4: 41)[5]
>
> C. It is connected alone and then they do not share the potential deference (P5: 41)
>
> C. Because it's the only one bulb and one battery (P6: 41).
>
> C. It is in series. Because the voltage flowing through it will let shines brightly and with A and B they are connected in parallel (P7: 33)[6]
>
> A. Because the lights are two and there the lights are two it's going to be brighter than one light if it's one it's going to be ok but not as bright as when there are two (P8: 40)
>
> C. Because it's the only one bulb. It's connected (P9: 40).
>
> C. At number C it's only one bulb (P10: 44).
>
> C. Because current do not split somewhere it do not go around it doesn't have to split like this one (P2: 39).

The respondents did not consider the short that eliminated the bulb option B. All, except one respondent, regarded the circuit with bulb option A and option B as a series circuit; a parallel circuit or a series/parallel combination circuit. According to the respondents, the single bulb would be brighter than either option A or option B. The respondent remarked that two lights will be brighter than one! Some respondents used battery superposition which indicated that if one battery lights the bulb, then two, regardless of the arrangement, it would make the bulb twice as bright.

### 4.3.3 Misconception 3: Battery as a constant current source

Answer option B and option D of question 2 (Figure 4.7) of the DIRECT test related to the misconception that a battery will always produce the same amount of current no matter the load applied to it. Nearly forty per cent (39.5%) of the respondents chose option D and 9.9% selected option B (Table 4.11) (Addendum 3.4). In both cases the respondents did not take in consideration that the current would reduce with the addition of another resistor which would result in that the power in resistor option A was also reduced.

[5] C. Want die krag sal verdeel by A en B maar by C is hy net in C (P4: 41)

[6] C. Hy is in serie. Want die voltage wat deur hom loop laat hom helder skyn en hier by A en B is hulle in parallel gekonnekteer so hy deel hulle (P7: 33)

2) How does the power delivered to resistor A change when resistor B is added to the circuit? The power delivered to resistor A _____.

(A) Quadruples (4 times)

(B) Doubles

(C) Stays the same

(D) Is reduced by half

(E) Is reduced to one quarter (1/4)

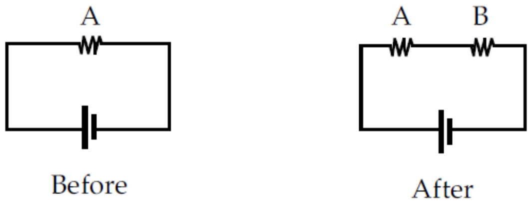



**Figure 4.7: Question 2 of the DIRECT concept test**

**Table 4.11: Frequencies and percentages relating to question 2**

| Question 2 (DIRECT) | | |
|---|---|---|
| **Answer** | **Frequency** | **Valid Percentage** |
| A | 2 | 2.5 |
| B | 8 | 9.9 |
| C | 36 | 44.4 |
| D | 32 | 39.5 |
| E | 3 | 3.7 |
| **Total** | **81** | **100** |

The researcher calculated *misconception 3* (battery as a constant current source) with the biographical information (*gender*, and *cultural background*) using cross tabulation (Chi-square $X^2$) and effect size (Cramér V) (Addendum 3.5) to determine if there were significant differences between misconception 3 and gender and culture (Tables 4.12 and 4.13).

**Table 4.12: Cross tabulations between Gender, and Battery as Constant Current Source**

| | | Gender | | |
|---|---|---|---|---|
| | | **Male** | **Female** | **Row total** |
| **Misconception 3: Battery as a Constant Current Source** | **Yes** | 30 | 9 | 39 |
| | | 50 | 42 | 46 |
| | **No** | 30 | 12 | 42 |
| | | 50 | 57 | 54 |
| **Column total** | | 100 | 100 | 100 |

Phi coefficient=-0.06
Cramer's effect sizes=0.06
Pearson's Chi-square (p value)=0.573

There was not a significant effect (V=0.06) between gender and understanding concepts (p=0.573). Many of the male (50%) and the female (42%) respondents did not understand that a battery will not produce the same amount of current with different loads. More than fifty per cent (57%) of the female respondents understood that a battery will not produce the same amount of current with different loads (Table 4.12). However, the effect size indicates that this difference was not important in practice.

**Table 4.13: Cross tabulations between Culture, and Battery as Constant Current Source**

| | | Culture | | | |
|---|---|---|---|---|---|
| | | Black | Coloured | White | Row total |
| **Misconception 3: Battery as Constant Current Source** | **Yes** | 18 | 11 | 10 | 39 |
| | | 53 | 46 | 44 | 48 |
| | **No** | 16 | 13 | 13 | 42 |
| | | 47 | 54 | 57 | 52 |
| **Column total** | | **100** | **100** | **100** | **100** |

Phi coefficient=0.08
Cramer's effect sizes=0.08
Pearson's Chi-square (p value)=0.754

There was not a significant effect (V=0.08) between culture and understanding concepts (p=0.754). The black (53%), coloured (46%), and white (44%) respondents encountered difficulties to understand that a battery will not always produce the same amount of current with different loads. More than fifty per cent (50%) of the coloured (54%) and white (57%) respondents understood that a battery will not always produce the same amount of current with different loads (Table 4.13). However, the effect size indicates that this difference was not important in practice.

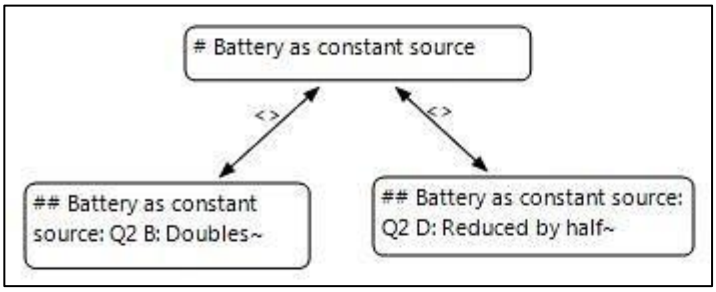



**Figure 4.8: Misconceptions relating to batteries as constant current source**

Most of the respondents in the DIRECT test selected option D (power reduced by half) as the correct option, the majority of the respondents in the interview selected option B (power doubled) which is contradicting to what was found in the DIRECT test. A respondent summarised the misconception that the voltage source produced a constant current whatever the load attached to it. Further examples of misconceptions were:

> B. Because when a resistor is added, they will be in circuit and the power will be the same because it will be in circuit (P2: 23)
>
> B. Because they are connected in circuit (P5: 23)
>
> B. Because they are now two and they are not going to be the same as number A (P8: 23)
>
> B. Because it's still number A sir. The current removing thru resistor A is the same (P10: 23).

Confirming the results of the DIRECT test, three respondents selected option D (power reduced by half) as the correct answer to this question. The respondents demonstrated the misconception that the voltage source would supply the circuit with a constant current. According to a respondent, the voltage would rather be reduced:

> D. I know it's gonna drop because of the resistor it's gonna be reduce by half sir. I need to for the calculation to be sure but I'll say its half (P1: 24)
>
> D. The force will be brought down by resistor 1. The voltage will reduce (P4: 23)[7]
>
> D. Because the resistor it reduce the voltage and the voltage from the power supply. (P9: 23).

### 4.3.4 Misconception 4: Rule application

Question 2 (Figure 4.7) of the DIRECT test options A and option C related to the application of Ohm's law. Few respondents (2.5%) selected option A and almost half of the respondents (44.4%) selected option C (Table 4.14). This demonstrated that the respondents could not apply Ohm's law in cases where the resistance in a circuit increased and the voltage remained constant, resulting in the current in the circuit to reduce.

**Table 4.14: Frequencies and percentages relating to question 2**

| Question 2 (DIRECT test) | | |
|---|---|---|
| **Option** | **Frequency** | **Percentage** |
| A | 2 | 2.5 |
| B | 8 | 9.9 |
| C | 36 | 44.4 |
| D | 32 | 39.5 |
| E | 3 | 3.7 |
| **Total** | **81** | **100** |

The researcher calculated *misconception 4* (rule application) with the biographical information (*gender*, and *cultural background*) using cross tabulation (Chi-square $X^2$) and effect size (Cramér V) (Addendum 3.4) to determine if there were significant differences between misconception 4 and gender and culture (Tables 4.15 and 4.16).

**Table 4.15: Cross tabulations between Gender, and Rule Application**

| | | Gender | | |
|---|---|---|---|---|
| | | **Male** | **Female** | **Row total** |
| **Misconception 4: Rule Application** | **Yes** | 44 | 14 | 58 |
| | | 73 | 67 | 72 |
| | **No** | 16 | 7 | 23 |
| | | 27 | 33 | 28 |
| **Column total** | | **100** | **100** | **100** |

Phi coefficient=-0.07
Cramer's effect sizes=0.07
Pearson's Chi-square (p value)=0.560

[7] D. Die krag sal deur die resistor 1 gaan en dit 'n bietjie afbring. Die voltage minder maak (P4: 23).

There was not a significant effect (V=0.07) between gender and rule application (p=0.560). Many of the male (73%) and the female (67%) respondents could not apply Ohm's law in cases (Table 4.15).

**Table 4.16: Cross tabulations between Culture, and Rule Application**

| | | Culture | | | |
|---|---|---|---|---|---|
| | | **Black** | **Coloured** | **White** | **Row total** |
| **Misconception 4: Rule Application** | **Yes** | 26 | 14 | 18 | 58 |
| | | 77 | 58 | 78 | 72 |
| | **No** | 8 | 10 | 5 | 23 |
| | | 24 | 42 | 22 | 28 |
| **Column total** | | **100** | **100** | **100** | **100** |

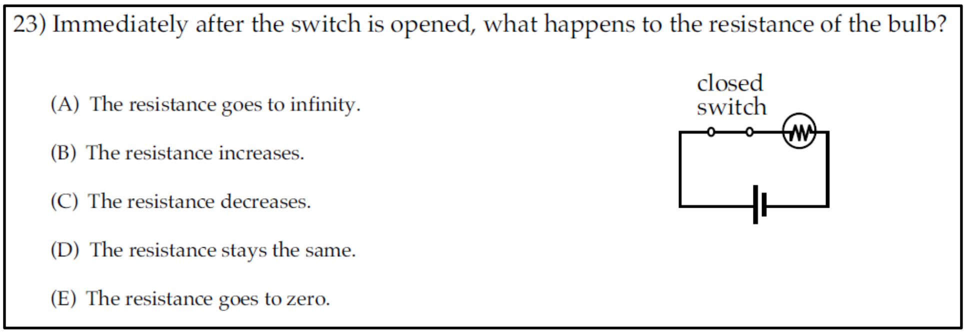
Phi coefficient=0.19
Cramer's effect sizes=0.19
Pearson's Chi-square (p value)=0.226

There was not a significant effect (V=0.19) between culture and understanding concepts (p=0.226). The black (77%), coloured (58%), and white (78%) respondents encountered difficulties to apply Ohm's law in cases (Table 4.16).

In the interviews three of the respondents selected option C which strengthened the DIRECT test results, indicating that the respondents did not understand Ohm's law. A respondent confused Ohm's law with Kirchhoff's current law:

> C. Because ohm law stated that the current is the same in a series not like in parallel (P3: 23)
>
> C. Because they are in circuit and the power is delivered to resistor A as the same as the power of resistor B (P6: 23).
>
> C. The force that travels in the circuit. So it stays the same (P7: 23)[8].

In question 23 (Figure 4.9) of the DIRECT test the incorrect application of Ohm's Law was portrayed in the participants' selections of answers. Only 12.7% (Table 4.17) of the respondents got this question right. About half of the respondents (48.1%, Table 4.17) selected option E (resistance goes to zero) that indicated that the respondents applied Ohm's law directly, not considering that resistance in the circuit stayed a constant value.


23) Immediately after the switch is opened, what happens to the resistance of the bulb?

(A) The resistance goes to infinity.

(B) The resistance increases.

(C) The resistance decreases.

(D) The resistance stays the same.

(E) The resistance goes to zero.



**Figure 4.9: Question 23 of the DIRECT concept test**

[8] C. Die krag wat in die stroombaan loop is in circuit. So hy bly dieselfde (P7: 23).

**Table 4.17: Frequencies and percentages relating to question 23**

| Question 23 (DIRECT test) | | |
|---|---|---|
| **Option** | **Frequency** | **Percentage** |
| A | 9 | 11.4 |
| B | 10 | 12.7 |
| C | 12 | 15.2 |
| D | 10 | 12.7 |
| E | 38 | 48.1 |
| Missing | 2 | 4.7 |
| **Total** | **81** | **100** |

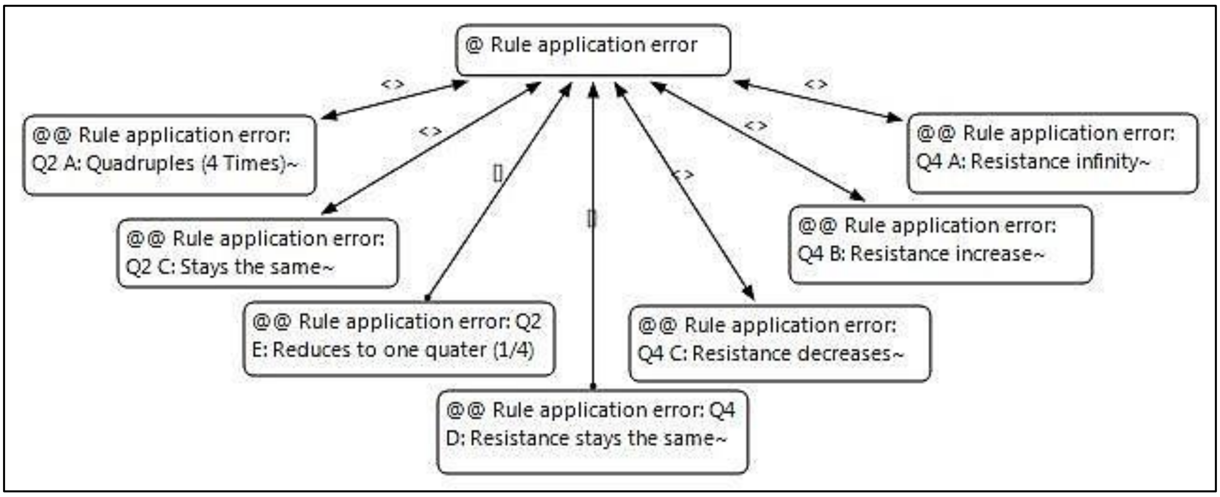



**Figure 4.10: Misconceptions relating to application of rules**

During the interviews, question 4 demonstrated similar misconceptions (Figure 4.10). Three respondents selected option A (resistance infinity) as correct as they could not apply Ohm's Law:

> A. If ever the switch is open the current stops flowing meaning that current and voltage will drop and resistance will increase. Definitely infinity. It's gonna increase, I know if ever I reduce current and voltage that's when resistance is definitely gonna increase because it's an opposition to current and voltage but if ever I open the switch those 2 would stop flowing I think it gonna go to infinity (P1: 50)
>
> A. The reading will be there when the switch is open (P 5: 52)
>
> A. Because of the switch when it's open it cannot measure resistance (P6: 52).

Only one respondent selected option B (resistance increase) and again the application of Ohm's law was incorrectly applied:

> B. Because when the switch is open the current one flow thru it so the resistance will increase (P8: 51).

Three respondents selected option C as the correct answer. The incorrect application of Ohm's law indicated the respondents' thinking that if the current decreased or stopped, the resistance would also decrease:

> C. Because if the switch is open there will be no current flowing (P2: 50)
>
> C. The resistance it turn the current flow into a resistance the resistor resist flow and then when the power cut of the resistance reduce that flow that the resistance was

carrying those not reduce lane it reduces because oppose the flow sir something like opposing the flow so it grabs the flow then after when it an open circuit it comes to reduce the flow that it was carrying (P3: 45)

C. With ohm's law, it is directly proportional to it (P4: 52)[9].

### 4.4 Identification of design principles

The quantitative and qualitative analyses identified design principles to be used during the development, implementation and evaluation of the screencasts prepared for DC resistive circuits as part of phase 4 of the DBR cycle. The identified design principles were:

- Understanding of concepts
- Understanding short circuit theory
- Battery as a constant current source
- Rule application.

### 4.5 Chapter summary

In summary, respondents could identify a complete circuit. The trouble started when the respondents were questioned to indicate whether the circuit worked or not. They combined circuits that contained shorted-out components and indicated them as working. The short-outs took the form of an additional connection in parallel across a component or the connections from the battery coupled to the corresponding point on the bulb. Respondents appeared to have a void in their declarative understanding about light bulbs. They did not distinguish where to make the exact contacts. The most outstanding outcome was when a respondent shared his/her perception "when there is no current; there is also no voltage and therefore no resistance.

[9] C. Met ohm se wet hy is direk eweredig daaraan (P4: 52).