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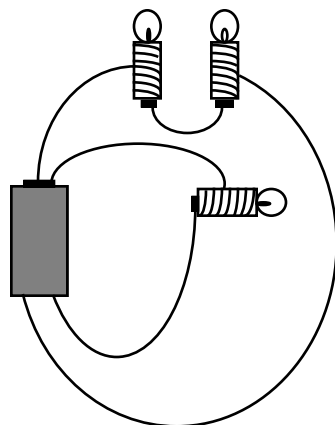
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Determining and Interpreting Resistive Electric Circuits Concepts Test

Version 1.2

Instructions

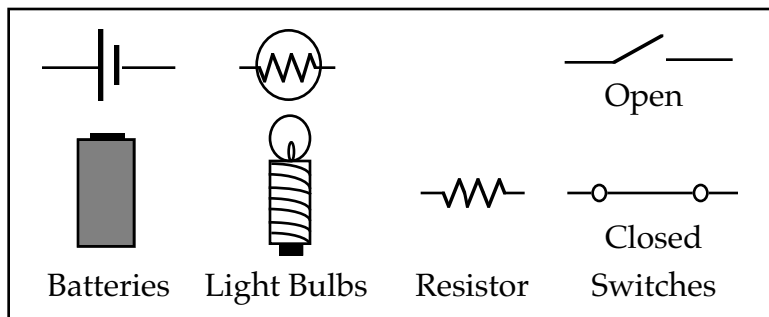
Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a calculator and scratch paper if you wish.

Use a #2 pencil to **record your answers** on the Opscan sheet, but please **do not write in the test booklet**.

You will have approximately 30 minutes to complete the test. If you finish early, check your work before handing in both the answer sheet and the test booklet.

Additional comments about the test

All light bulbs, resistors, and batteries are identical unless you are told otherwise. The battery is ideal, that is to say, the internal resistance of the battery is negligible. In addition, the wires have negligible resistance. Below is a key to the symbols used on this test. Study them carefully before you begin the test.



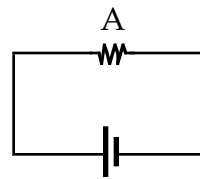
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 Robert J. Beichner
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 Department of Physics
 Raleigh, NC 27695-8202
 (919) 515-7226
 Beichner@NCSU.edu

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

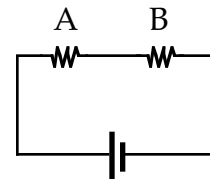
- (A) Yes, charge is used up. Charges moving through the filament produce "friction" which heats up the filament and produces light.
- (B) Yes, charge is used up. Charges are emitted as photons and are lost.
- (C) Yes, charge is used up. Charges are absorbed by the filament and are lost.
- (D) No, charge 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.

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 ($1/4$)



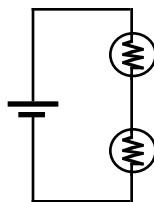
Before



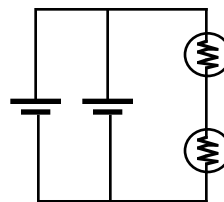
After

3) Which circuit or circuits have the GREATEST energy delivered to them per second?

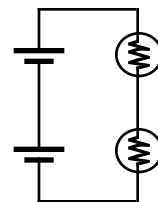
- (A) Circuit 1
- (B) Circuit 2
- (C) Circuit 3
- (D) Circuit 1 = Circuit 2
- (E) Circuit 2 = Circuit 3



Circuit 1

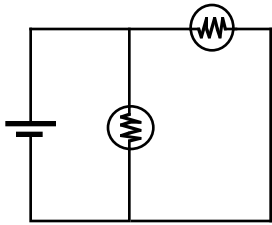


Circuit 2

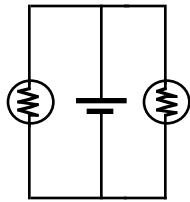


Circuit 3

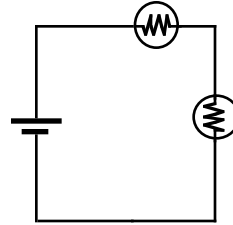
4) Which circuit or circuits below represent a circuit consisting of two light bulbs in parallel with a battery?



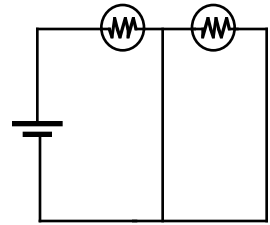
Circuit 1



Circuit 2



Circuit 3

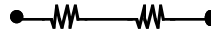


Circuit 4

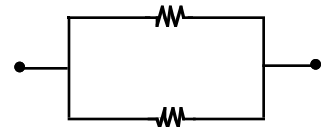
- (A) Circuit 1
- (B) Circuit 2
- (C) Circuit 3
- (D) Circuits 1 and 2
- (E) Circuits 1, 2, and 4

5) Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. The resistance of branch 1 is ____ branch 2.

- (A) Four times
- (B) Double
- (C) The same as
- (D) Half
- (E) One quarter (1/4)



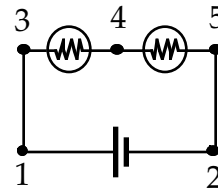
Branch 1



Branch 2

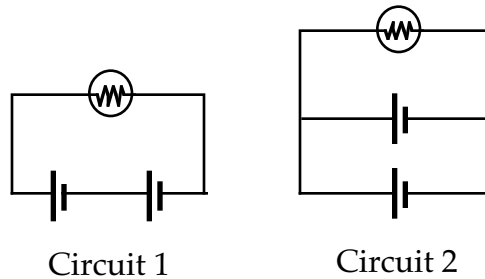
- 6) Rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown below from HIGHEST to LOWEST.

- (A) 1 and 2; 3 and 4; 4 and 5
 (B) 1 and 2; 4 and 5; 3 and 4
 (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



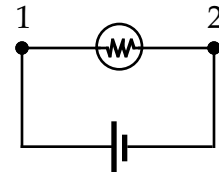
- 7) Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is BRIGHTER?

- (A) Bulb in circuit 1 because two batteries in series provide less voltage
 (B) Bulb in circuit 1 because two batteries in series provide more voltage
 (C) Bulb in circuit 2 because two batteries in parallel provide less voltage
 (D) Bulb in circuit 2 because two batteries in parallel provide more voltage
 (E) Neither, they are the same



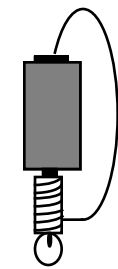
8) Compare the current at point 1 with the current at point 2. At which point is the current **LARGEST**?

- (A) Point 1
- (B) Point 2
- (C) Neither, they are the same. Current travels in one direction around the circuit.
- (D) Neither, they are the same. Currents travel in two directions around the circuit.



9) Which circuit(s) will light the bulb? (The other object represents a battery.)

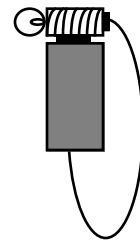
- (A) Circuit 1
- (B) Circuit 2
- (C) Circuit 3
- (D) Circuits 1 and 3
- (E) Circuits 1, 3, and 4



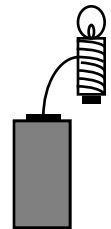
Circuit 1



Circuit 2



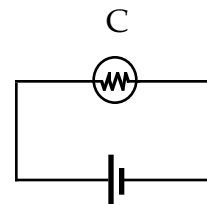
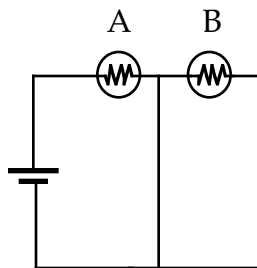
Circuit 3



Circuit 4

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



11) Why do the lights in your home come on almost instantaneously when you turn on the switch?

- (A) 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.
- (E) Charges in the wire are like marbles in a tube. When the circuit is completed, the charges push each other through the wire.

12) Consider the power delivered to each of the resistors shown in the circuits below. Which circuit or circuits have the LEAST power delivered to them?

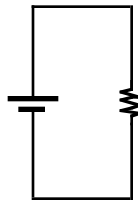
(A) Circuit 1

(B) Circuit 2

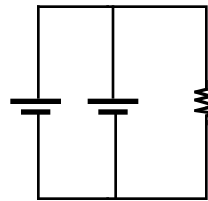
(C) Circuit 3

(D) Circuit 1 = Circuit 2

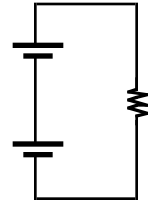
(E) Circuit 1 = Circuit 3



Circuit 1



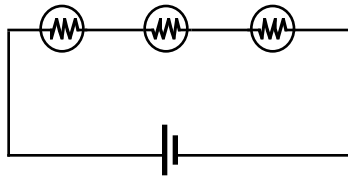
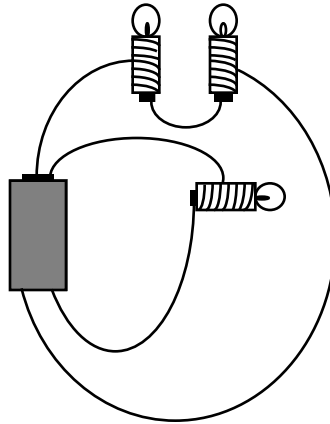
Circuit 2



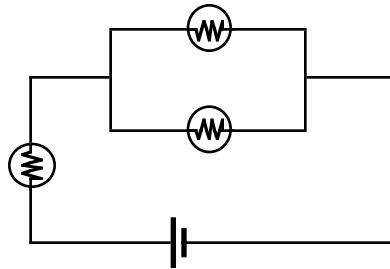
Circuit 3

13) Which schematic diagram best represents the realistic circuit shown below?

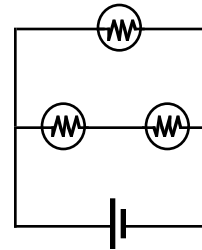
- (A) Circuit 1
- (B) Circuit 2
- (C) Circuit 3
- (D) Circuit 4
- (E) None of the above



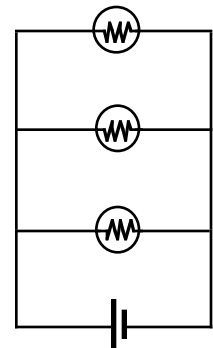
Circuit 1



Circuit 2



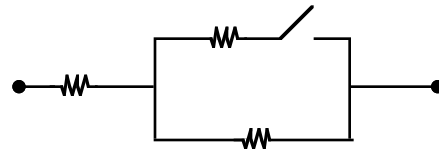
Circuit 3



Circuit 4

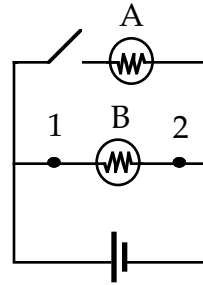
14) How does the resistance between the endpoints change when the switch is closed?

- (A) Increases by R
- (B) Increases by $R/2$
- (C) Stays the same
- (D) Decreases by $R/2$
- (E) Decreases by R



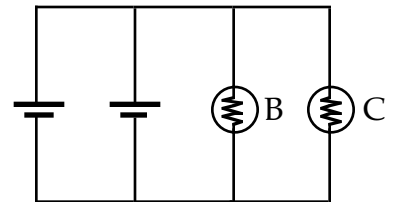
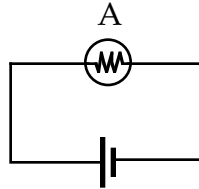
15) What happens to the potential difference between points 1 and 2 when the switch is closed?

- (A) Quadruples (4 times)
- (B) Doubles
- (C) Stays the same
- (D) Reduces by half
- (E) Reduces by one quarter (1/4)



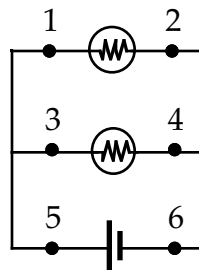
16) Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as Bulb B.

- (A) Four times as
- (B) Twice as
- (C) Equally
- (D) Half as
- (E) One fourth (1/4) as

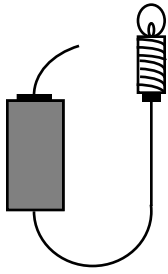


17) Rank the currents at points 1, 2, 3, 4, 5, and 6 from HIGHEST to LOWEST.

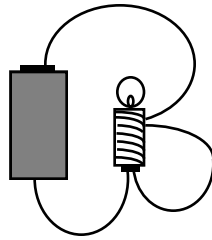
- (A) 5, 3, 1, 2, 4, 6
- (B) 5, 3, 1, 4, 2, 6
- (C) 5 = 6, 3 = 4, 1 = 2
- (D) 5 = 6, 1 = 2 = 3 = 4
- (E) 1 = 2 = 3 = 4 = 5 = 6



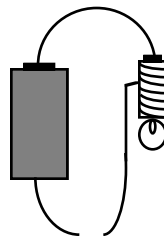
18) Which circuit(s) will light the bulb?



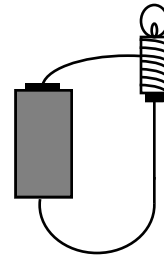
Circuit 1



Circuit 2



Circuit 3

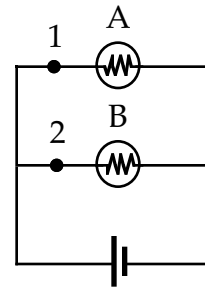


Circuit 4

- (A) Circuit 1
- (B) Circuit 2
- (C) Circuit 4
- (D) Circuits 2 and 4
- (E) Circuits 1 and 3

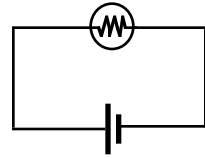
19) What happens to the brightness of bulbs A and B when a wire is connected between points 1 and 2?

- (A) Both increase
- (B) Both decrease
- (C) They stay the same
- (D) A becomes brighter than B
- (E) Neither bulb will light



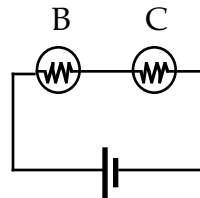
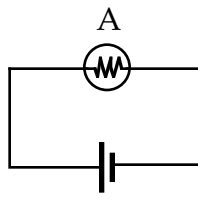
20) Is the electric field zero or non-zero inside the bulb filament?

- (A) Zero because the filament is a conductor.
- (B) Zero because a current is flowing.
- (C) Zero because there are charges on the surface of the filament.
- (D) Non-zero because a current is flowing which produces the field.
- (E) Non-zero because there are charges on the surface of the filament which produce the field.



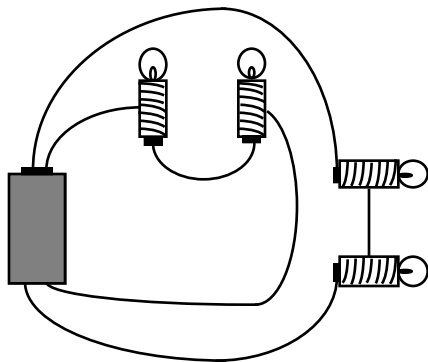
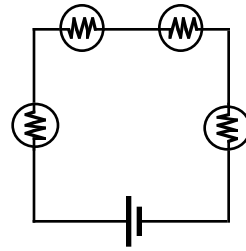
21) Compare the energy delivered per second to each light bulb shown below. Which bulb or bulbs have the LEAST energy delivered to them per second?

- (A) A
- (B) B
- (C) C
- (D) B = C
- (E) A = B = C

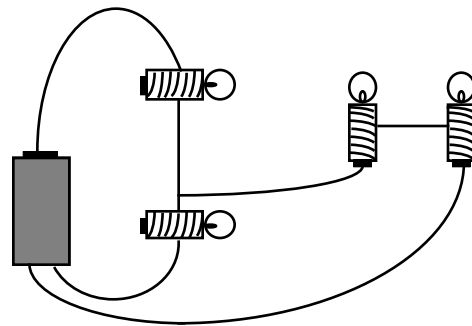


22) Which realistic circuit or circuits represent the schematic diagram shown below?

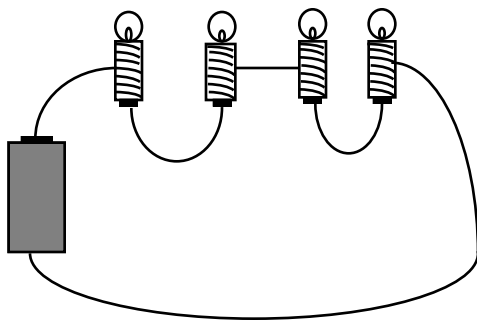
- (A) Circuit 2
- (B) Circuit 3
- (C) Circuit 4
- (D) Circuits 1 and 2
- (E) Circuits 3 and 4



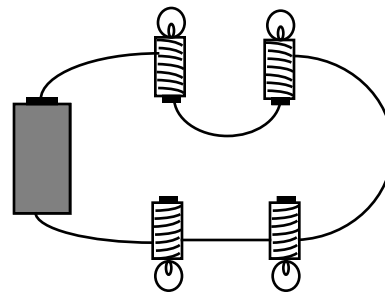
Circuit 1



Circuit 2



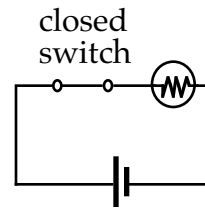
Circuit 3



Circuit 4

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.

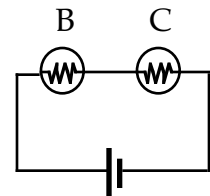
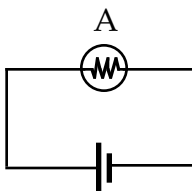


24) If you double the current through a battery, is the potential difference across a battery doubled?

- (A) Yes, because Ohm's law says $V = IR$.
- (B) Yes, because as you increase the resistance, you increase the potential difference.
- (C) No, because as you double the current, you reduce the potential difference by half.
- (D) No, because the potential difference is a property of the battery.
- (E) No, because the potential difference is a property of everything in the circuit.

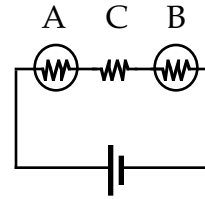
25) Compare the brightness of bulb A with bulb B. Bulb A is _____ bright as bulb B.

- (A) Four times as
- (B) Twice as
- (C) Equally
- (D) Half as
- (E) One fourth ($1/4$) as

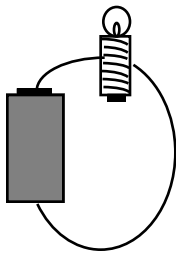


26) If you increase the resistance C, what happens to the brightness of bulbs A and B?

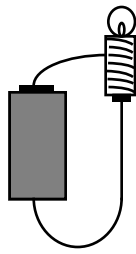
- (A) A stays the same, B dims
- (B) A dims, B stays the same
- (C) A and B increase
- (D) A and B decrease
- (E) A and B remain the same



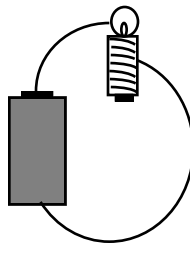
27) Will all the bulbs be the same brightness?



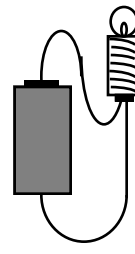
Circuit 1



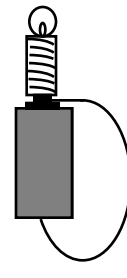
Circuit 2



Circuit 3



Circuit 4

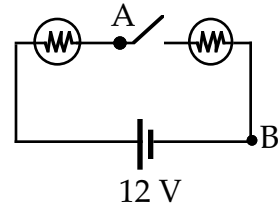


Circuit 5

- (A) Yes, because they all have the same type of circuit wiring.
- (B) No, because only Circuit 2 will light.
- (C) No, because only Circuits 4 and 5 will light.
- (D) No, because only Circuits 1 and 4 will light.
- (E) No, Circuit 3 will not light but Circuits 1, 2, 4, and 5 will.

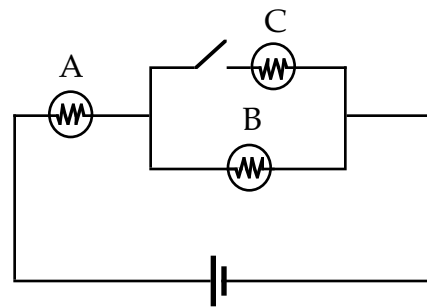
28) What is the potential difference between points A and B?

- (A) 0 V
- (B) 3 V
- (C) 6 V
- (D) 12 V
- (E) None of the above



29) 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



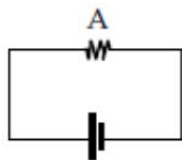
Interview problem questions:

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

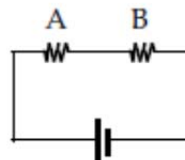
- (A) Yes, charge is used up. Charges moving through the filament produce "friction" which heats up the filament and produces light.
- (B) Yes, charge is used up. Charges are emitted as photons and are lost.
- (C) Yes, charge is used up. Charges are absorbed by the filament and are lost.
- (D) No, charge 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.

Reason:

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



Before

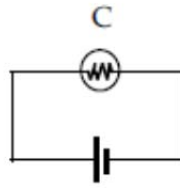
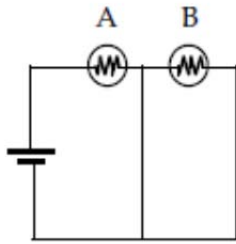


After

- (A) Quadruples (4 times)
- (B) Doubles
- (C) Stays the same
- (D) Is reduced by half
- (E) Is reduced to one quarter (1/4)

Reason:

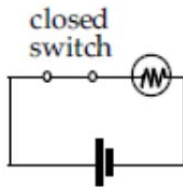
3) Compare the brightness of bulbs A, B, and C in these circuits. Which bulb or bulbs are the **BRIGHTEST**?



- (A) A
- (B) B
- (C) C
- (D) A = B
- (E) A = C

Reason:

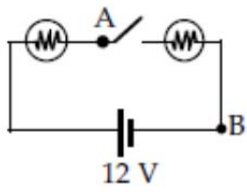
4) Immediately after the switch is opened, what happens to the resistance of the bulb?



- (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.

Reason:

5) 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

Reason:



Prof S Blignaut & Dr. J Kruger

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South Africa 2520

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Ethics Committee

Tel +27 18 299 4850
Fax +27 18 293 5329
Email Ethics@nwu.ac.za

ETHICS APPROVAL OF PROJECT

The North-West University Ethics Committee (NWU-EC) hereby approves your project as indicated below. This implies that the NWU-EC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title : Using ICTs in an ODL programme															
Project Leader: Dr J Kruger															
Student on project: SC Beukes and C Beukes															
Sub title of project: Using a range of ICT's in assisting facilitators and students in teaching and learning															
Ethics number:	N	W	U	-	0	0	1	0	9	-	1	1	-	S	2
	Institution			Project Number					Year		Status				
Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation															
Approval date: 2013/03/07								Expiry date: 2018/03/07							

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The project leader (principle investigator) must report in the prescribed format to the NWU-EC:
 - annually (or as otherwise requested) on the progress of the project,
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-EC. Would there be deviation from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-EC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-EC retains the right to:
 - request access to any information or data at any time during the course or after completion of the project;
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the NWU-EC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof Amanda Lourens
(chair NWU Ethics Committee)



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

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Faculty of Education Sciences
Tel: +2718 2994589
Fax: +2718 2994558
Email: janette.kruger@nwu.ac.za

21 January 2013

Me. M.M. Reed
Campus Head: NCRFET: Kathu Campus
Hans Coetzee ave.
Kathu
☎: 053-723 3281
☎: 053-723 3091
micheller@kat.ncrfet.co.za

Dear Me.Reed

Permission to do research

I hereby request permission to do research at the Northern Cape Rural Further Education and Training (NCRFET) College. The aim of this study is to do research for my dissertation to complete a M Ed degree at the North-West University. The title of the research project is:

Screencasts as learning and teaching tools in an engineering course: A case study

During the first phase of the project the N2 students will complete the Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT). Interviews will then be conducted with selected students. I will then develop screencasts to address the identified misconceptions. The screencasts will be implemented with the distribution of DVDs to all the students. At the end of each trimester the researcher will interview the students using a similar set of questions as the set used in the first phase. A semi-structured open-ended questionnaire will be given to the students to determine their perceptions of the value of the screencasts as a cognitive learning tool in an authentic learning environment.

The guidelines of the NWU ethical committee will be followed which in turn ensures complete confidentiality. I will obtain permission from the CEO of NCRFET College and informed consent from the students.

Yours sincerely

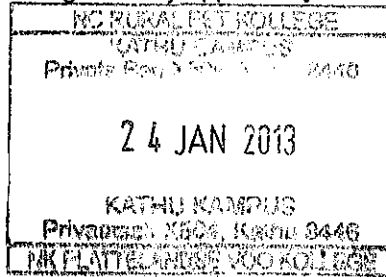
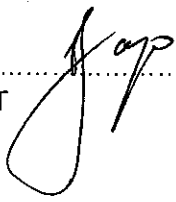
Mr C Beukes
Student number: 11160454
Telephone number: 0825530155

Dr J Kruger
Senior Lecturer/ Study leader
018 299 4589

APPROVAL FORM

I, P. Sago CEO of the Northern Cape Rural FET College hereby approves your request to carry out the study describe above.

.....
P. Sago CEO NCRFET



Private Bag X 1532

Post Net suite 79

Kuruman

6 May 2013

Dear Participant,

I am registered for the M.Ed. degree at the North-West University. As part of my studies I have to complete a research project.

I would thus appreciate your participation. Participation is voluntary and you have the right to withdraw from the study at any time, without fear of being penalised. Your responses will be treated with confidentiality.

I request you to please complete the following test. Interviews will then be conducted with selected students. I will then develop screencasts to address the identified misconceptions. The screencasts will be implemented with the distribution of DVDs to all the students. At the end of the trimester the researcher will interview the students using a similar set of questions as the set used in the first phase. A semi-structured open-ended questionnaire will be given to all the students to determine their perceptions on the value of the screencasts as a cognitive learning tool in an authentic learning environment.

Any enquiries may be addressed to:

Dr Janette Kruger

Senior lecturer: Research Methodology

North-West University, Potchefstroom campus.

Private Bag, x6001, Potchefstroom, 2520

E-mail: janette.kruger@nwu.ac.za

Thank you.

Tiaan Beukes

Student: Date: _____

Consent:

I, the undersigned, _____ has read and fully understand the conditions of the project and I hereby declare that I am participating voluntarily in the project.

Signed:

_____ Date: _____

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by SEUGNET BLIGNAUT

WORD COUNT 31954
CHARACTER COUNT 189552

TIME SUBMITTED 02-DEC-2013 08:40PM
PAPER ID 379149161

**Misconceptions regarding direct-current resistive theory
in an engineering course for N2 students
at a Northern Cape FET college**

Christiaan Beukes

Student Number: 11160454

**Misconceptions regarding direct-current resistive theory
in an engineering course for N2 students
at a Northern Cape FET college**

Christiaan Beukes

Student Number: 11160454

1

Dissertation submitted for the degree Magister Educationis in Curriculum Studies at the
Potchefstroom Campus of the North-West University

Student Number: 11105976

Supervisor: Prof Dr A Seugnet Blignaut

Assistant Supervisor: Mrs Dorothy Laubscher

November 2013

Acknowledgements

Several people contributed to accomplishing my goals during the compilation of this dissertation.

These people guided and encouraged me throughout the various stages of my study:

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The aim of this study is to ascertain what misconceptions N2 students have about direct current resistive circuits and how could screencasts could affect on the rectification of these misconceptions. This study was conducted at the Kathu Campus of the Northern Cape Rural Further Education and Training College in the town Kathu in the arid Northern Cape. The empirical part of this study was conducted during the first six months of 2013. A design-based research (DBR) method consisting of four phases was used. DBR function is to design and develop interventions such as a procedure, new teaching-learning strategies, and in the case of this study a technology-enhanced tool (screencast) with the purpose of solving a versatile didactic problem and to acquire information about the interventions of the technology-enhanced tool (screencast) on the learning of a student. In the first and second phase of DBR quantitative data for this research were gathered with the Determining and Interpreting Resistive Electric circuits Concepts Test (DIRECT) in order to determine the four most common misconceptions. The DIRECT test was conducted in the first trimester to find the misconceptions; the test was conducted in the second trimester also to confirm the misconceptions. Further quantitative data were collected from a demographic questionnaire. The qualitative data were collected by individual interviews in the fourth phase of the research project. Phase three of this study was the development of screencasts in the four most prominent misconceptions in direct current resistive circuits of the students. The respondents of this study were non-randomly chosen and comprised of two groups, one in the first trimester of the year and one in the second trimester of the year, which enrolled for the N2 Electrical or Millwright courses. The respondents were predominant male and representing the three main cultural groups in the Northern Cape namely: Black, Coloured and White. The four misconceptions on direct current resistive circuits that were identified were: (i) understanding of concepts, (ii) understanding of short circuit, (iii) battery as a constant current source, and (iv) rule application error. Screencasts clarifying the four misconceptions were developed and distributed to the respondents. On the foundation of the results of this research, it can be concluded that the students have several misconceptions around direct current resistive direct current circuits and that the use of technology like screencasts can be used to solve some of these misconceptions. Screencasts could supplement education when they were incorporated into the tutoring and learning for supporting student understanding. The results of this research could lead to the further development and refinement of screencasts on direct current resistive circuits and also useable guidelines in creating innovative screencasts on direct current resistive circuits.

Keywords: Industrial Electronics; DIRECT test; misconceptions; screencasts; design-based research; resistive circuits; FET College; conceptual-theoretical framework; coaching; and scaffolding.

Opsomming

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Die doel van hierdie studie was om te bepaal watter wanopvattinge N2 studente het met betrekking tot gelykstroom resistiewe stroombane en of "screencasts" diesulke wanopvattinge effektief kan aanspreek. Hierdie studie het plaasgevind op die Kathu-kampus van die Noord-Kaap Plattelandse Verdere Onderwys en Opleiding Kollege, in die dorp Kathu in die dorre Noord-Kaap. Die empiriese gedeelte van die studie is gedurende die eerste ses maande van 2013 uitgevoer. 'n Ontwerp-gebaseerde navorsings (OGN) metode bestaande uit vier fases het die studie ondersteun. OGN het betrekking op prosedures, nuwe onderrig-leer strategieë, en in hierdie geval van hierdie studie 'n tegnologiese onderrig- en leerprodukt (screencast) tot gevolg gehad met die doel om 'n komplekse didaktiese probleem op te los en inligting oor die ingrypings te bekom en 'n produk (screencast) te ontwerp, ontwikkel en die gebruik te evalueer ten aansien van leerstrategieë van studente. In die eerste en tweede fases van die OGN het gebruik gemaak van die kwantitatiewe data ingesamel volgens die *Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT)* om die vier mees algemene wanopvattinge met betrekking tot gelykstroom resistiewe stroombane te bepaal. Die DIRECT toets is tydens die eerste trimester uitgevoer om studente wanopvattinge te bepaal en is gedurende die tweede trimester herhaal om die diesulke wanopvattinge te bevestig. Addisionele kwantitatiewe data is deur middel van 'n demografiese vraelys ingesamel. Die kwalitatiewe aspekte van die navorsing het langsaan die kwantitatiewe aspekte plaasgevind het betrekking gehad op data-analise wat tydens individuele onderhoude ingesamel is tydens die tweede en vierde fases van die projek. Tydens fase drie van hierdie studie het die ontwikkeling van die screencasts plaasgevind. Hulle het die vier mees opmerklike wanopvattinge van studente met betrekking tot gelykstroom resistiewe stroombane van die studente aangespreek. Die gerieflikheidssteekproef van respondente van hierdie studie het bestaan uit twee groepe: een gedurende die eerste trimester van die jaar en een in die tweede trimester van die jaar. Die respondente wat ingeskryf is vir die N2 Elektriese of Millwright kursusse en was oorwegend manlik en het bestaan uit die drie mees prominente kultuurgroepe in die Noord-Kaap: Swart, Bruin en Wit. Die vier belangrikste wanopvattinge wat met betrekking tot gelykstroom resistiewe stroombane wat geïdentifiseer was, is: (i) begrip van konsepte, (ii) begrip van kortsluitings, (iii) batterye as 'n konstante stroom bron, en (iv) reël-toepassings foute. Screencasts ter verduideliking van die vier wanopvattinge is ontwikkel en aan die respondente beskikbaar gestel. Op gronde van die resultate van die evaluering van studente se persepsies en ervarings met betrekking tot die screencasts kon bevestig word dat die studente wanopvattinge met betrekking tot gelykstroom resistiewe stroombane het en dat die gebruik van tegnologiese hulpmiddels soos screencasts bygedra het om sommige van die wanopvattinge op te hef. Screencasts kan onderrig aanvul en kan in die onderrigsituasie inkorporeer word en ter ondersteuning (scaffolding) van leerinhoud met betrekking tot gelykstroom resistiewe stroombane aan studente. Die resultate van hierdie navorsing het ontwerpbeginsels bepaal wat gebruik kan word in die verdere ontwikkeling en verfyning van screencasts vir gelykstroom resistiewe stroombane. Die navorsingsverslag bied ook riglyne aan vir die skep van innoverende screencasts van gelykstroom resistiewe stroombane.

Sleutel woorde: Industriële Elektronika; DIRECT toets; wanopvatting; screencasts; ontwerp-gebaseerde navorsing; resistiewe stroombane; VOO Kollege; konseptuele-teoretiese raamwerk; pedagogiese ondersteuning; tegnologie-ondersteunde leer.

Solemn Declaration

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I hereby declare that I have linguistically edited the dissertation submitted by Mr Christiaan Beukes for the MEd degree:

Misconceptions regarding direct-current resistive theory in an engineering course for N2 students at a Northern Cape FET college



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Ethics Approval

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- Addendum 3.3:** Descriptive statistics of biographical information relating to frequencies and percentages
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- Addendum 3.8:** Permission from Campus Manager of Kathu Campus, NCR FET College
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- Addendum 3.10:** Turnitin™ report of similarities relating to the use of literature
- Addendum 5.1:** Example of screencast prepared for N2 Industrial Electronics
- Addendum 5.2:** Questionnaire to respondents during phase 3 evaluation
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The addenda are available on the DVD at the back of the dissertation.

List of Acronyms

DBR	Design based research
DC	Direct current
DE	Distance education
DIRECT	Determining and Interpreting Resistive Electric Circuits Concepts Test
HSRC	Human Sciences Research Council
ICT	Information and Communication Technology
NCRFET College	Northern Cape Rural Further Education and Training College
N	Nated
TEL	Technology-enhanced learning
TTB	Technical Test Battery

Chapter One

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Introduction to the cyclical implementation of design-based research for the improvement of teaching-learning in an Industrial Engineering course

1.1 Introduction

With the growth in the mining industry, Further Education and Training (FET) colleges should provide competent students to fill the gap created by the shortage of tradesmen in South Africa. Severe shortages of artisan labour in key technical fields in the South African labour market seriously hamper development (Ramdass, 2009). The biggest and growing demand for artisan labour is for metal, machinery and related trades in the Mining and Manufacturing sectors. To keep up with the demand FET colleges should provide competent students. With the use of technology, like the use of screen-casting, colleges could contribute towards students' experiences of quality education that will contribute towards teaching and learning relevant to their needs. In addition to understanding of subject content and information, students should acquire 21st century learning skills in order for them to become life-long learners. Within the South African context, many students attended dysfunctional schools and it is vital to improve and enhance these students' knowledge and skills for them to become 21st century tradesmen to be part of a progressively interconnected world in which they work and live in (South Africa, 1996a).

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Differences in terms of entry learning remain challenging in South Africa. These differences encompass the multiplicity of students in terms of age, gender, language, culture, inadequate Internet access and living conditions, especially in remote and rural areas. Engineering students enrolled for blended education courses need support and scaffolding to obtain skills and abilities often far removed from their daily realities and surroundings. Learning with technology offers the benefit of allowing students the freedom of choosing when, where, and how they want to study. Systematic combination of pedagogy with technology may contribute to addressing learning differences (Auerbach & Ferri, 2010; Ramdass, 2009).

This dissertation discusses how design-based research (DBR) could be used to design, develop and implement educational tools like screencasts on DVDs in order to resolve misconceptions regarding direct current (DC) resistive theory in an engineering course for N2 students at a Northern Cape FET college.

1.2 Review of relevant literature

1.2.1 Misconceptions in Electronics

The presence of student misconceptions is a well-known fact at college level in electrical circuits. As an illustration of problems students could have, consider the misconception that potential difference is initiated by current flow (while in fact, the opposite is true). The discrepancy of the initial conceptual framework triggers misunderstanding in future parts of the students' education. The term misconception refers to the concepts that students should know about any singularities that are conflicting with technical theories. The objective of successful electronics teaching is to inspire the student to build understanding that is in general coherent with acknowledged electronics theory. It is known that students use pre-existing ideas formed from preceding encounters to argue their skewed electronics concepts (Bull, Jackson, & Lancaster, 2012; Sencar, Yilmaz, & Eryilmaz, 2001).

Since electronics comprises numerous abstract theories, students may acquire them in various ways of which some are misconceptions of facts. For students to develop conceptual understanding of electronic theory, they have to comprehend not only the functioning of components, but also the use of the component. In particular the procedure of learning and the application of information develops better when students are permitted to learn fundamental concepts rather than remembering repetitive tasks and factual data (Wiig & Wiig, 1999).

1.2.2 Screencasts

Students' circumstances as well as their rational characters are extensively varied. Educational technologies can be employed to improve students' strengths and recompense for limitations. Screencasts can be used to complement learning materials to aid students in all theoretical fields. Presently the methods to learn electronics are evolving, improving and adjusting in order for lecturers to use new learning technologies (Perraton, 2010; Peterson, 2007)

A screencast is a recording of actions on a screen accompanied by audio explanations to enhance the interactive process of teaching and learning. Screencasts can be used to employ two senses; seeing and hearing. Screencasting can be used to explain, improve and clarify concepts which students may have problems with (Pinder-Grover, Millunchick, & Bierwert, 2008). A benefit of screencasting is that it offers students the freedom to choose when, what, where and how they study, which makes it a good educational tool (Peterson, 2007; Sugar, Brown, & Luterbach, 2010; Winterbottom, 2007). Screencasts in the engineering field have extensive applications:

- Lecturers produce theoretical work on a screencast and students can use the screencasts to learn about the theory.
- Screencasts can be used to provide an extensive part of the theoretical material of a course, thus freeing lecturers' time for individual teaching, discussion sessions, and practical teaching (Winterbottom, 2007). Online screencasts can support many students, who spend an increas-

ing amount of time on the Internet (Oud, 2009). Combining sound and images in a screencast enhances learning experiences (Sugar et al., 2010).

- Screencasts can be used not only as a lecturing instrument, but as personalized feedback to students, or during students' review of one another's work. A large number of students have access to computers, the Internet, or smartphones. Therefore screencasts can provide a simple means to ⁸³rich course content to students.
- Screencasts **promote an easy and cheap way of producing multimedia instructional material that** could be used in various educational settings. Short explanations of core content can be given to students as reference material via screencasts.
- Screencasting can be used to provide students with the means to revise and repeat the learning material for deep understanding of complex concepts. By using web-based media, presentation of material is independent of place, time and written text. Individuals can learn or revise their work according to their own needs (Peterson, 2007).
- Communication can also be established between lecturers and students by means of screencasts. Students respond positively to the use of screencasts in their online classes for a more personalized approach to a course (Mangieri, 2009).

From the above it becomes evident that screencasts could be used as cognitive learning tools to augment students' conceptions of resistive circuits.

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1.3 Purpose of the research

The purpose of this study is to:

- Determine the nature of misconceptions in the prior knowledge of students registered for Industrial Electronics.
- Compile guidelines for screencasts of direct current resistive circuits to enhance students' conceptual knowledge.
- Explore students' perceptions regarding the usefulness of screencasts as cognitive learning tools.

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1.4 Research design and methodology

1.4.1 Research design

Herrington warns that e-learning and blended learning often focus on strategies to disseminate information, rather than adopting the use of technology as cognitive tools to inspire thinking and understanding (Herrington, 2009). Colleges regularly use ICTs to distribute information "where students learn *from* the technologies rather than *with* them as cognitive tools" (Herrington, 2009, p. 1). DBR

combines empirical research with the design of education surroundings implanted in theory and presents the opportunity to advance teaching and learning (Herrington, 2009; Wang & Hannafin, 2005). DBR offers a comprehensive approach to explore the usefulness of authentic learning designs (Herrington, 2009; Herrington & Kervin, 2007; Herrington & Reeves, 2011).

Wang and Hannafin (2005) define DBR as a methodical, yet an adaptable methodology intended to improve educational practices through iterative analysis, design, development, and implementation, based on a partnership among researchers and practitioners in real-world settings, and leading to contextually susceptible design principles and theories. The foundation behind DBR is to shape an improved association amongst educational research and real-world problems (Amiel & Reeves, 2008). Amiel and Reeves (2008) point out the dissimilarity between DBR and customary pragmatic prognostic research. With DBR the importance is placed on an iterative research method that does not just assess a ground-breaking creation or intervention, but systematically improves the invention while also generating design principles that can guide similar research and development endeavours. This results in a cycle of research that is markedly different from what is currently pursued by many researchers in the field (Amiel & Reeves, 2008).

Drawing on the work of Herrington and colleagues, the design and development of the screencasts will focus on employing educational technologies in order to create dependable learning tasks (Herrington, 2006; Herrington, 2009; Herrington & Kervin, 2007; Herrington & Oliver, 2000; Herrington & Standon, 2000). The study will describe three cycles of interviewing and analysis based on quantitative and qualitative research.

1.5 Preliminary structure and chapter division

The dissertation is presented according to the following chapters:

- | | |
|-----------|---|
| Chapter 1 | Introduction to the cyclical implementation of design-based research for the improvement of teaching-learning in an Industrial Engineering course |
| Chapter 2 | Reviewing of literature relating to the conceptual theoretical framework |
| Chapter 3 | Design-based research design and methodology |
| Chapter 4 | Analyses and presentation of the integrated data of Phase I design-based research |
| Chapter 5 | Development, implementation and evaluation of a screencasts according to phase 1 design principles for an Industrial Engineering course |
| Chapter 6 | Synthesis, conclusion and reflections on the use of design-based research for developing a technology tool for N2 Industrial Electronics. |

Chapter Two

Review of literature relating to the conceptual theoretical framework

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2.1 Introduction

This chapter reviews the literature regarding the misconceptions in direct current resistive circuits, and the use of screencasts to address these misconceptions. The selection of the literature for this review is based on an adaption of the conceptual-theoretical framework for the implementation of educational technologies of Kruger (2012). As this study forms part of a bigger project on the implementation of educational technologies, the review comprises the following aspects: (a) the student in his/her specific context; (b) the interconnection and interrelationship between *content*, *pedagogy* and *technology*, focused on the *student*; (c) specific design principles related to the implementation of screencasts as learning and teaching tools; and (d) *personalisation* as a criterion for excellence.

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The literature study disclosed a gap in the literature regarding the specific use of screencasts as learning and teaching tools in engineering courses within the context of FET colleges. Therefore the focus of the study was on the evolvement of design principles necessary for the implementation of screencasts in this regard.

2.2 Conceptual-theoretical framework

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A conceptual framework is an interrelated set of thoughts (philosophies) around how a specific singularity is connected to its parts. The framework assists as the foundation for understanding, the underlying patterns of inter relations across actions, thoughts, annotations, theories, knowledge, understandings and supplementary components of know-how (Svinicki, 2010). A conceptual-theoretical framework is a plan or strategy guiding the literature review of the study (Sinclair, 2007). The conceptual-theoretical framework used in this study is an adapted version of the framework suggested by Kruger (2012), and as part of this study forms part of a project aimed at the implementation of a number of ICTs. Figure 2.1 illustrates the conceptual-theoretical framework of Kruger and highlights the aspects applicable to this study.

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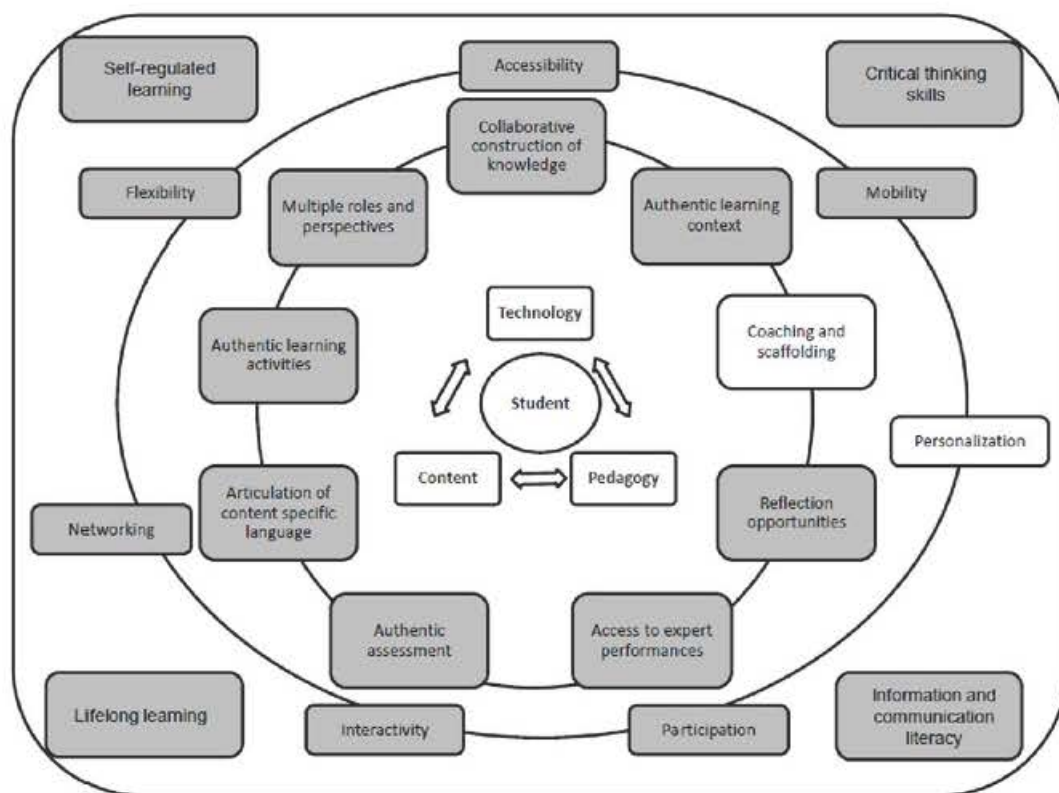


Figure 2.1: An adapted conceptual-theoretical framework for technology-enhanced learning (Kruger, 2012)

This conceptual-theoretical framework consists of five layers, namely the student in a specific context, the interconnection and interrelation between technology, pedagogy and content, focused on the student, design principles, criteria for excellence and higher level outcomes.

The adapted conceptual-theoretical framework that will guide this study is aimed at the implementation of screencasts as an Information and Communication Technology (ICT) in FET college programmes. The adapted framework consists of four aspects (from the centre outward): (a) the student in his/her specific context; (b) the interconnection and interrelation between content, pedagogy and technology, focused on the student; (c) specific design principles related to the implementation of screencasts as learning, teaching and scaffolding tool, and (d) personalisation as a criterion for excellence. Although higher level outcomes may be reached, it is not part of the focus of the study.

2.2.1 Student

Teaching and learning should be more than students sitting in lecture rooms, attaining skills and abilities that can be accurately assessed. It should be a process where a student acquires self-fulfilment in a process to acquire a better standard of living (Ramdass, 2009). According to the South African Bill of Rights every child has the right to education (South Africa, 1996a). However, after

nearly two decades into democracy, a large number of South African schools still have insufficient vital learning resources. This leads to students not receiving an effective education. The Humanities Research Council (HSRC) in South Africa reports that twelve million children live in poverty. Statistics reveal that 81% experience monetary and physical deprivation and many live in shacks. More than fifty per cent live in homes where nobody is working. Approximately 24% are in the wrong grade for their age and six per cent do not attend school. Of these children 24% live in households with a single parent and in some cases in child-headed households, being in charge of and responsible for their billings (Cohen, 2008). Children are forced to leave school and start working for minimal wages. HIV/Aids also has a large impact on the school attendance of learners. Children drop out of school to support ill parents and offer care or assistance economically by doing poorly paid jobs (Ramdass, 2009). Lecturers and teachers infected with HIV/Aids are often absent or too sick to deliver acceptable teaching. Auxiliary lecturers may not have the skills or qualifications to efficiently replace qualified lecturers (Ramdass, 2009). HIV/Aids consequently influences not only the students but also the lecturers and teachers in the education system. Despite nationwide efforts to bring back a culture of education, events of robbery, defacement, vandalism, break-in, rape and even murder are reported on college and school grounds. Education should essentially begin at home, with a disciplined upbringing which could be developed in future years in schools and colleges. The college and school surroundings are tainted through criminality and violence which threaten the educational procedure (Ramdass, 2009). In view of these influences on the academic development of some of the students enrolling for further education at our campus, interventions and guidance are vital in assisting these students to reach their full potential.

The Northern Cape is South Africa's largest province: 30,5% of South Africa's surface area. It is, however, also the most sporadically inhabited province in the country, with the concentration of its 1,1 million population (2,3% of the national population) that represents about three people per square kilometre (Figure 2.2).



Figure 2.2: Map of South Africa showing the Northern Cape Province

Much of this can be attributed to the natural environment of the Northern Cape. Apart from the narrow strip around the major rivers, which are widely used for irrigation, it is mostly semi-arid to the most dry Province, these irrigation areas forming a stark contrast with the adjacent Karoo, Kalahari and Namaqualand landscapes. Agriculture—which is one of the main industries in the province—consists typically of widespread stock farming due to the low carrying capacity of the land. At the same time though the Northern Cape has been blessed with some of the most extraordinary mineral prosperity in the world—the misuse of which has given rise to the foremost contributor to the provincial economy, ie the mining sector. The copper mines round Springbok and Okiep are the oldest mines of the colonial era in South Africa, going back to the late 17th Century. Then the Northern Cape, mainly the area between Kimberley and the Bushman land, is not only the origin of the modern diamond mining industry—which still continues to be a noteworthy contributor to the provincial economy to this day—but it is also known for some of the world’s largest limestone, iron ore and manganese mines (SouthAfrica.info, 2012).

The Northern Cape Rural Further Education and Training College (NCRFET College) is one of the fifty amalgamated colleges in the country and serves a part of the four per cent (Figure 2.3) of students attending Colleges in the Northern Cape.

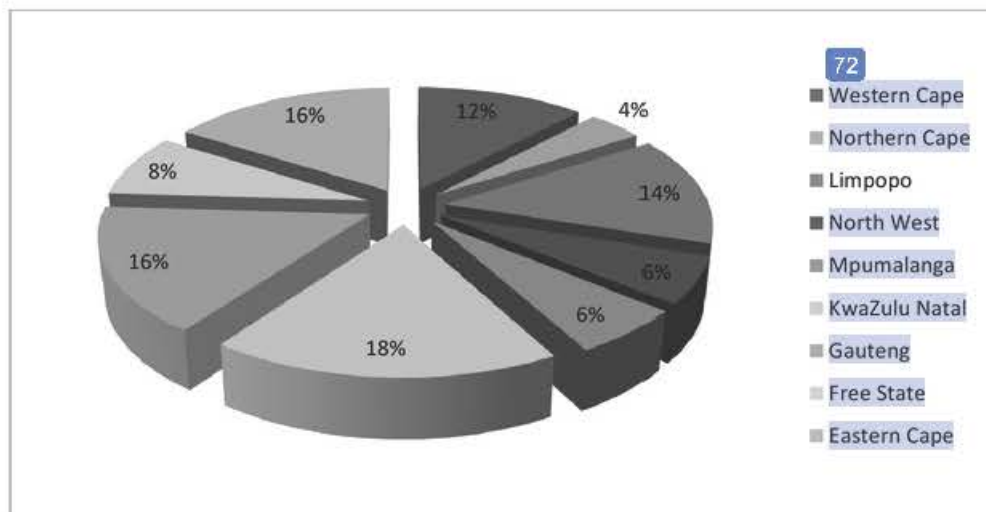


Figure 2.3: Percentage distribution of FET Colleges per province (Powell & Hall, 2002)

The NCRFET College consists of five campuses situated in the following towns: (a) Kuruman, (b) Kathu, (c) De Aar, (e) Upington and (f) Okiep. Only three of these campuses provide engineering courses namely: (1) Kathu, (2) Upington (3) Okiep. Figure 2.4 shows a map of the Northern Cape Province with the major towns.



Figure 2.4: Map of the Northern Cape Province indicating the major towns relating to this study

The Kathu campus serves an area from Kuruman and its surrounding rural towns in the East, Blackrock/Hotazel in the North, Postmasburg/Daniëlskuil in the South and Olifantshoek in the West. Students attending courses at the campus are predominantly Black (55%) with 29% Coloured and 19% White students (Figure 2.5).

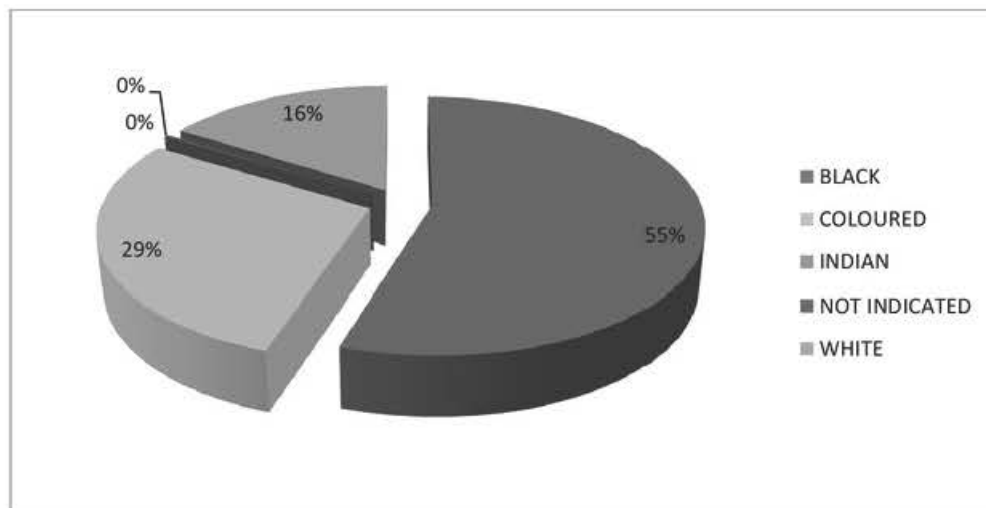


Figure 2.5: Percentage distribution of ethnic groups at Kathu Campus 2013 (Rens, 2013)

The students attending the Industrial Electronics course in the first trimester (n=43) resulted in a different representation where the white students were 44% the Black students 35% and the coloured students 21% (Figure 2.6).

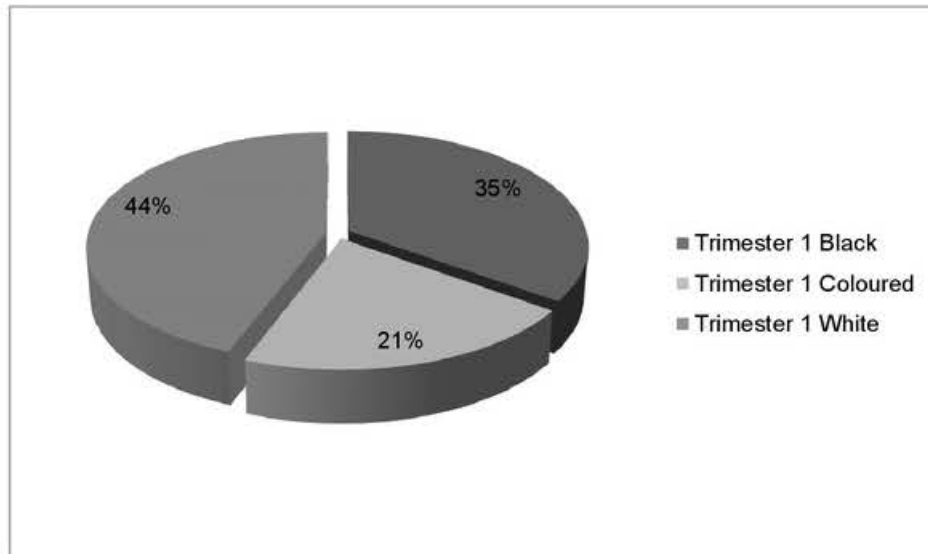


Figure 2.6: Percentage distribution of ethnic groups at Kathu Campus trimester 1 2013 (Rens, 2013)

Figure 2.7 presents the ethnic representations of students in the second trimester, noteworthy in this case similarity of ethnical distribution nationally.

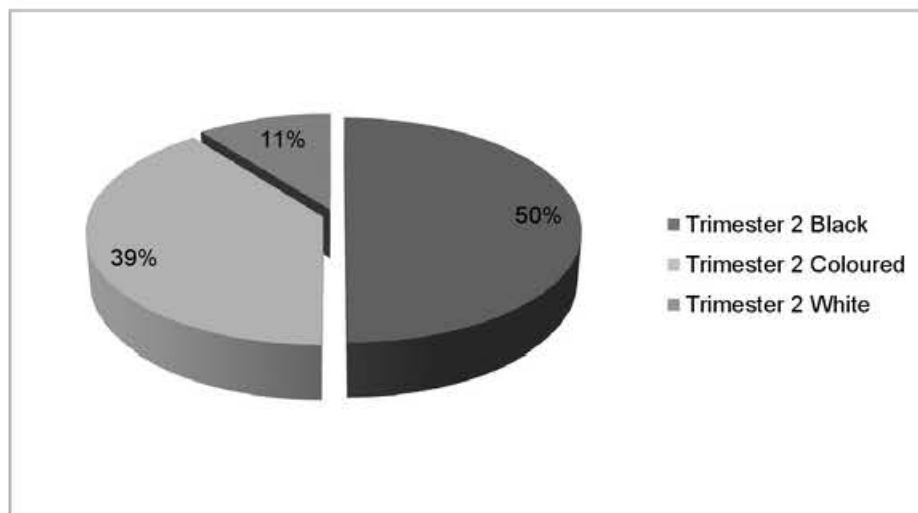


Figure 2.7: Percentage distribution of ethnic groups at Kathu Campus trimester 2 of 2013 (Rens, 2013)

The reason for these differences in the number of students enrolling is dependent on students that the mines and other employers send to the campus for further education and training (Figure 2.1). The population (n=38) consisted of fifty per cent Black students, 39% Coloured students and 11% White students.

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Within the South African context and explicitly the context of FET colleges numerous students 35 attended dysfunctional schools and it is vital to enhance these students' knowledge and skills so that they will be able to meet the demands of the society they will work and live in. Modern literature on pedagogy endorses pedagogical procedures using educational technologies to supplement the teaching and learning experience of students (Herrington, 2009; Moore, Fowler, & Watson, 2007).

2.2.2 Technology

For lecturers to be effective in their profession, it is essential to improve pedagogy with the use of educational technologies in their specific subject fields. By means of ICTs lecturers can track improvements in their subject fields. They can convey the modern-day methods and uses concerning instruction approaches into their teaching, and keep themselves informed. For these reasons, technology performs a significant part for lecturer knowledge development. In current years, computer and instructional expertise have developed in a vital portion of our lives by influencing our education and communication. Uses of these technologies in our day-to-day lives turn out to be extensive as these technologies offer persons with numerous advantages and chances (Figure 2.1). Screencasts is one of the aspects of technology that we as lecturers can use to adapt to the contemporary way of teaching and learning (Anderson & Shattuck, 2012; Sugar et al., 2010; Tredoux, 2011).

2.2.2.1 Screencasts

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There are different definitions for screencasts in the literature (Figure 2.1). In summary a screencast is a recording of actions on a monitor screen accompanied by audio explanations enhancing the procedure of instruction and learning. Thus screencasts can be used to employ two senses: seeing and hearing. Screencasts can be used to describe and clarify different concepts improving understanding of concepts. Screencasts provide lectures with the convenience of taking breaks at any time and the ability to repeat intellectually complex parts of a presentation (Ashdown, Doria, & Wozny, 2011; DiGiacinto, 2006; Razik, Mammo, Gill, & Lam, 2011).

From the literature the rationale for the use of screencasts comprises a wide range of whys and wherefores. Changing from teacher-centred to student-centred teaching have the advantage of stimulating the student's perceptive action and boosts the instructive value of the information learning contextual. Screencasts allow lecturers to be more effective for example they do not have to repeat an explanation several times in lecture hours; instead they can refer a student to one or two

screencasts and ask the student to return with queries. Students and lecturers can then add value to the lecturing hours to concentrate on resolving problems (Falconer, Nicodemus, De Grazia, & Medlin, 2012; Krouk, Zhuravleva, & Chupakhina, 2010).

Sugar et al. (2010) concluded that screencasts are becoming a significant tool for education environments. When used properly and sensibly, screencasts being vibrant visual representations plays a prospective important role in complementary learning. Educational technologies can be used to take advantage of students' strong points and compensate for weaknesses. Screencasts can be used to supplement teaching materials to assist DE students in all academic disciplines (Mohamad Ali, Samsudin, Hassan, & Sidek, 2011; Perraton, 2010; Peterson, 2007).

2.2.2.2 Application of screencasts

In my review of the literature focussing on the application of screencasts various authors reported interesting applications. Screencasts can be used not only as a tool to capture lecturing, but as a means to provide personalised feedback to students, or during peer-review where commented on their peers' work. Therefore screencasts can provide a simple means to enrich course content to DE students. Screencasting permits lecturers to provide learners with detailed response on questions and assessment explanations. Screencasts encourage an informal and inexpensive way of manufacturing audio-visual instructional material that could be used in various educational settings. Short explanations of core content can form part of reference material. Screencasting can be used to provide students with the means to revise and repeat the learning material for deep learning and understanding complex concepts. By using web-based media, presentation of material is independent of place, time and written text. Individuals can learn or revise their work according to their own needs. Communication can also be established between lecturers and students by means of screencasts. Students respond positively to the use of screencasts in their online classes for a more personalised approach to a course. Students are inspired to learn course material and theory because they can see the relevance in the real world (Ashdown et al., 2011; Beatty, 2000; Kamlaskar, 2007; Periago & Bohigas, 2005; Peterson, 2007; Sugar et al., 2010; Thompson & Lee, 2012; Winterbottom, 2007).

Falconer, De Grazia, Medlin, and Holmberg (2009) and Falconer et al. (2012) have categorised the use of screencasts as:

- *Example problems*: Screencasts that is solutions to numerical problems for example those found at the end of each module
- *Exam reviews*: Screencasts that present solutions to problems out of previous exam question papers
- *Software tutorials*: Screencasts explaining the use of software
- *Explanations of how to use tables or graphs*: Screencasts used to explain how to use RCL-vector diagrams
- *Explanations of confusing concepts*: Introduction to a new chapter or mini-lectures.

The use of screencasts fits well with the instruction of Industrial Electronics in that it offers digital video of how misconceptions in resistive circuits can be addressed. Screencasts with diagrams explaining the concepts in the lecturers own voice explaining the directions for a better understanding of the concept (Sugar et al., 2010).

2.2.2.3 Advantages of screencasts

Table 2.1 summarises the advantages of screencasts to students.

Table 2.1: Advantages of screencasts for students

Advantages of screencasts to the student	
Screencasts offers students the freedom to choose when, what, where and how they study and increases learners access to laboratory experience, no time and place constraint	(Kamlaskar, 2007; Mullamphy, Higgins, Belward, & Ward, 2010; Peterson, 2007; Sugar et al., 2010; Winterbottom, 2007)
Novice learners who have little domain-specific knowledge benefit most from screencasts and it is believed that this way of instruction enhances the encoding of information and increases learning speed and understanding of concepts	(DiGiacinto, 2006; Mohamad Ali et al., 2011; Mohorovičić, 2012; Mullamphy et al., 2010; Palaigeorgiou & Despotakis, 2010)
With the use of screencasts, learners are better equipped for learning new topics that integrates the basics of a subject	(Kamlaskar, 2007; Mullamphy et al., 2010; Palaigeorgiou & Despotakis, 2010; Toto, 2007)
Screencasts are a method of observational tutoring subsequently they endorse learning by observing and repeating conduct by others and improves the learner's assimilation and memory, it stimulates more of the learner's senses	(DiGiacinto, 2006; Mohamad Ali et al., 2011; Mohorovičić, 2012; Palaigeorgiou & Despotakis, 2010)
Students understand that screencasts offered them an explicit relation amongst well-known tutoring purposes and the expected minimum time requirements for completing them and provides complete control to review the learning material at one's own pace	(DiGiacinto, 2006; Kamlaskar, 2007; Mohamad Ali et al., 2011; Mohorovičić, 2012; Mullamphy et al., 2010; Palaigeorgiou & Despotakis, 2010)
Greater flexibility access	(Kamlaskar, 2007; Mullamphy et al., 2010)
Material can be viewed on computers, iPods and mobile phones	(Kamlaskar, 2007; Mullamphy et al., 2010)
One method for being more contemporary in e-learning, particularly in DE, is using screencasts through access anytime from any internet connection	(DiGiacinto, 2006; Jesus & Moreira, 2009; Kamlaskar, 2007; Mohamad Ali et al., 2011; Mohorovičić, 2012; Mullamphy et al., 2010; Palaigeorgiou & Despotakis, 2010)
Material can be played and rewind to recap multiple times	(Kamlaskar, 2007; Mullamphy et al., 2010)

Tabel 2.2 lists the advantages of screencasts to lecturers.

Tabel2.2: Advantages of screencasts for lecturers

Advantages	
Minimising repetition of explanations	(Kamlaskar, 2007; Mullamphy et al., 2010)
Additional screencasts can be given for high achievers	
Numerous examples can be created for reinforcement	
Providing digital resources	
Materials can be reused	

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The following is a summary from my review of the literature regarding the advantages of screencasts. Authors reported that students in the engineering field of study found the homework solution and mini-lecture screencasts helpful. Combining sound and images in screencasts enhances learner's

experiences in comparison to traditional text format. They used them most often as a study resource, particularly for exams. Screencasts can be used to complement education materials or as inquiries from distance education students. In contrast, the vast majority of students watched the mini-lecture screencasts from start to finish, most likely due to their brevity. Students who watched the screencasts completely (either homework solution or mini-lecture) were also significantly more likely to report gaining a deeper understanding of the material. Students appreciate the accessibility of education on the go and repetitive learning which colleges can use screencasts to offer education beyond the physical borders of the campus. Lecturers can use screencasts to enhance their instruction and to explain without boundaries in time or place. The use of screencast does not threaten the existence of the traditional lecture but expands its possibilities. Screencasts can enhance learning and they are more and more used for numerous purposes in higher education. They can be integrated into the instruction and learning process for supporting the student. Carefully manufactured detailed and spoken demonstrations through screencasts serve as a cognitive tool and a keen learning concept, which will improve the combination of learning material with the students present perceptual understanding and knowledge (Green, Pinder-Grover, & Millunchick, 2012; Peterson, 2007; Schreiber, Fukuta, & Gordon, 2010; Sugar et al., 2010).

Doering and Mu (2009) determined that the screencast nature of their CLEO system offers learners a prized source to enhance their electrical circuit analysis course and that the learners found the greatest worth in the screencast explanations for self-teaching and exam preparation. From the review of the literature it is clear that screencasts in the engineering field have extensive applications, lecturers produce theoretical work on a screencast and DE students can use the screencasts to learn about the theory. Screencasts can be used to provide an extensive part of the theoretical material of a course, thus freeing lecturers' time for individual teaching, discussion sessions, and practical teaching. Online screencasts support many students, who spend an increasing amount of time on the Internet. Combining sound and images in a screencast enhances learning experiences to a personal level in such a way that students can use it in their own time and a place of their choosing.

2.2.3 Pedagogy

What constitutes pedagogy is multifaceted and cannot be demarcated without difficulty. Even the definition of pedagogy gives the impression of being somewhat ambiguous. Pedagogy is the act of teaching composed by its related dialogue. It is what one requires to know, and the abilities one requires to grasp in order to make and validate the numerous diverse varieties of choices on which education is founded (Figure 2.1). Pedagogy involves not only the advancement of education in a constricted sense but it also necessitates a procedure of negotiating personalities amongst lecturers and scholars (Cogill, 2008; Murphy, 2008). Pedagogy is the skill and science of actual teaching. Pedagogy is conventionally comprehended to indicate the tutoring of students but it has gradually begun to be used in a more universal sense that encapsulates ideas of andragogy (Nichols, 2007).

2.2.3.1 Pedagogy of Industrial Electronics

Due to the abstract nature of Industrial Electronics' subject concepts, explanations often involve complex language of instruction. The traditional approach to teaching engineering subjects is inductive, beginning with the presentation of elementary principles in lectures and going on to the repetition and application of the lecture content by the students (Prince & Felder, 2006). The misconception with Industrial Electronics is the fact that the subject deals with abstract, unseen notions such as voltage, current and resistance. In complex electronic circuits, the grasping of variations in these concepts can be overwhelming for the student. Many students perceive the content and learning material initially not only as too difficult to understand, but also as being presented at too fast a pace (Aydin, Aydemir, Boz, Cetin-Dindar, & Bektas, 2009).

In order to address these challenges the use of visual representations could be introduced in teaching and learning at an early stage (Bernhard & Carstensen, 2009). Students often do not grasp abstract concepts relating to the microscopic world of electrical circuits as they cannot see the flow of electrons (Thompson & Lee, 2012). This is evident in research done by Pulé and McCradle (2010) who made use of the example of a pull-up resistor (a pull-up resistor is connected between the positive pole of the voltage source and the input of an operational amplifier to stabilise the input). These researchers asked learners to explain the function of the resistor and from the explanations the researchers deduced that the students did not understand the function of the resistor. They concluded that the way resistors were depicted in given diagrams confused students. In another study Razik et al. (2011) made use of a batteries and bulbs circuit to determine the understanding of current flow in a circuit. The students had to rate the brightness of the bulbs in three circuits. Half of the students who were tested, rated the bulbs incorrectly. Furthermore, Smail, Rowe, Godfrey, and Patton (2012) concluded that the misconceptions of students were on a deeper level than expected, for example many students could not differentiate whether a component was connected in series or in parallel in a circuit. From the above mentioned examples it can be concluded that there are some of the misconceptions that are generic to electronics courses. Periago and Bohigas (2005) list some ideas on assisting students to a better conceptualisation in electronics:

- The necessity for the circuit to be closed in order to work. Learners should see a circuit as a complete system in which all the components are interconnected.
- The battery is not a current source. It should be made clear that the potential difference is an independent variable and the current as the dependable variable.
- Discriminate between voltage source and power source. Analysing the differences between the two would help the learners to realise that a battery is a voltage source.
- Current is not synonymous with energy. Explanation on the conservation of electrical charge and power is necessary.
- Avoid sequential thought. The idea is to see a circuit as a whole, where one change can have a chain reaction.

- Maintain the theoretical control of potential and intensity. Prevent students from applying Ohm's law automatically and in a thoughtless manner.

Electric circuits are critical in elementary Industrial Electronics curriculums and have applications in everyday life. Improper rational representations, which are intensely entrenched in daily knowledge, can meaningfully interrupt a students' knowledge. Before the lecturer can begin to resolve the misconceptions in Industrial Electronics, it is necessary to analyse what knowledge is essential to get a comprehensive understanding of resistive direct current circuits in Industrial Electronics. After the identification of the misconceptions, lecturers can use technology like screencasts as a scaffolding method, not only to address the misconception but also to serve as basis for the next level of information.

2.2.4 Content

In the context of this study, the content relates to Industrial Electronics with specific referenece to resistive circuits (Figure 2.1). The understanding of electrical circuits can be divided into two main concepts.

- Circuit topology and Kirchhoff's laws. These deal with the spread of current and power in the series-parallel network. The purpose of series, parallel and series-parallel combinations of circuits is to reduce the current (parallel) or to reduce the voltage (series) in a circuit.
- The classification of components.

Because the syllabus only prescribes resistive circuits the second concept will not be addressed in this study. According to Métioui and Trudel (2012), the study of circuits and combinations of components within a circuit include more mathematics and less dynamics. A lecturer must keep in mind that the approach of concentrating on the circuit topology does not decrease the importance of the behaviour and working of a component such as a resistor. Figure 2.8 amalgamates the conceptual structure of electric circuits in a systemic approach (Métioui & Trudel, 2012).

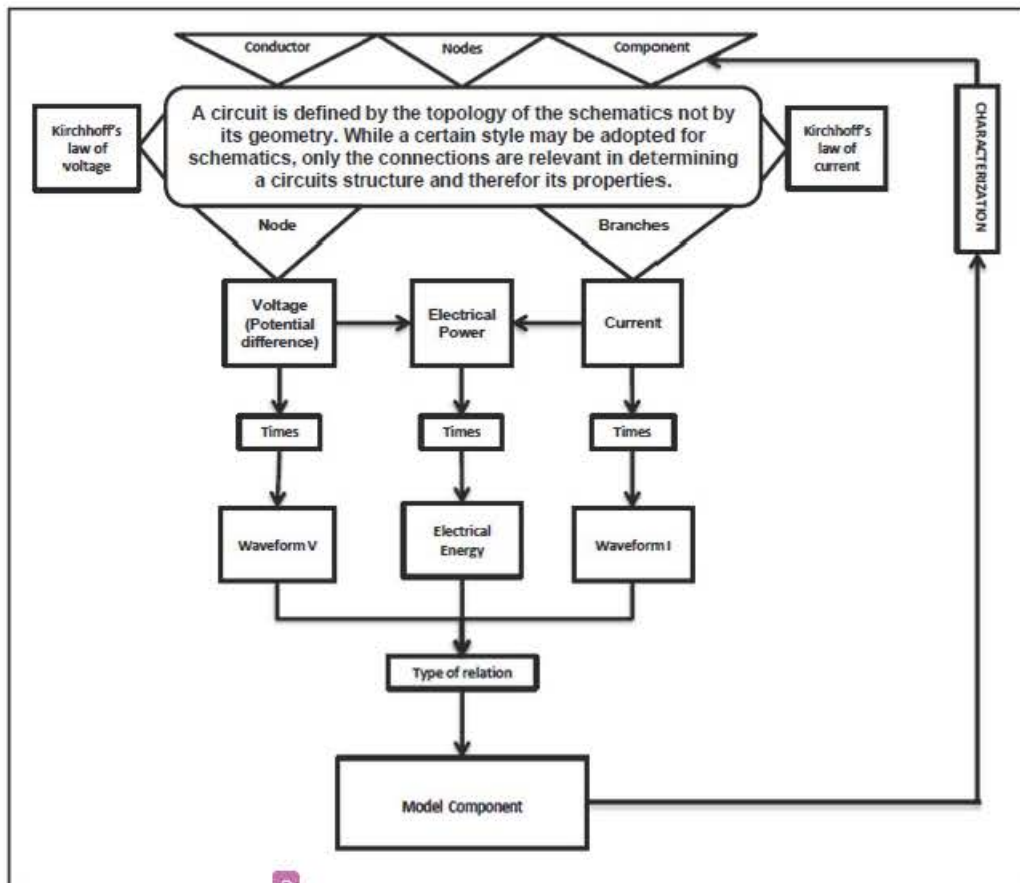


Figure 2.8: Adapted conceptual structure of the electric circuits in a universal approach (Métoui & Trudel, 2012)

The following summary indicates the importance for a student to comprehend electrical circuits according to Métoui and Trudel (2012):

- Current is specific in a conductor and, by allowance, associates to the whole branch
- Voltage across the terminals of a part is definite between the two terminals
- Network examination is restricted to linear circuits; it is a precise procedure using fictitious miniscule currents
- Potentials are immobile. They change with time, but they do not move around. Within the frame of circuit concept, potentials are precise only on conductors and on the terminals of components
- To measure the voltage between two nodes, we must plug the voltmeter between these two nodes, the shared border-mark on the node position
- To measure the current in a branch, we must connect the ammeter wherever in the branch, the communal perimeter mark on the side of the end of the branch.

2.2.4.1 Misconceptions

The term misconception refers to the understanding that students have of concepts that are not in line with accepted theory (Sencar et al., 2001). Incorrect pre-conceptions can influence the understanding of concepts that should be taught (Bull et al., 2012). Since Industrial Electronics comprises many abstract concepts, students may understand them in diverse ways. There are different reasons why students have misconceptions, e.g. instruction technique, preceding information, inadequate linking between concepts or between prior knowledge, and different textbooks. The challenge for the lecturer comprises the recognition of existing misconceptions and enhancing conceptual understanding to address these misconceptions.

2.2.4.2 Misconceptions in Industrial Electronics relating to resistive circuits

The study of Industrial Electronics, as an engineering discipline, consists of learning obstacles mainly caused by a lack of prior knowledge. Unlike other engineering courses such as Mechanical Engineering, Industrial Electronics offers fewer opportunities to develop a graphical sense of the subject. In Mechanical Engineering one can observe and touch a physical quantity. This physicality provides a scaffold for knowledge development. Research has shown that students find it challenging to view a circuit as a system and to comprehend those specific fluctuations in a circuit result in total fluctuations in the circuit. Therefore the use of circuit diagrams accompanied by graphs and mathematical equations is common practice. Industrial Electronics instruction is multi-layered since students need a solid understanding of the theoretic basis that leads the application of practical knowledge and problem-solving abilities (Auerbach & Ferri, 2010; Bernhard & Carstensen, 2009).

Insufficient conceptual knowledge combined with misconceptions relating to circuit theory is reported as causing learning problems with Industrial Electronics. In a recent study by Razik et al. (2011) at Montana State University engineering students were given a simple test. From three circuits given to them, they had to predict the brightness of the bulbs. This study showed that fifty per cent of the students got the problem correct, and fifty per cent got it wrong due to misconceptions regarding basic electrical circuits. If the students' prior knowledge is not corrected, students build further knowledge on misconceptions and a snowball effect is created. Most typical misconceptions are failures to relate theoretical representations of electric circuits to the real circuits, restricted understanding of basic perceptions of electrical energy, and ineffectiveness to reason about the behaviour of electrical systems (Papadimitriou, 2012). Turgut, Gültepe, and Turgut (2011) also witnessed that learners could not differentiate among some perceptions such as potential difference, current, power and energy since they were using these perceptions interchangeably. Emanating from the literature review the most common misconceptions of basic electronics can be summarised as follows:

- Concepts of current energy and potential difference are used interchangeably
- The battery is a power source that provides the charges moving in the circuit

- The power supply as constant current source, in which any power supply is believed to deliver an electrical circuit with a constant electrical current rather than electrical energy
- Current has been consumed by a close circuit's components. Therefore current reduces when it returns to the battery
- One pole connection. Merely one connection between a battery and a bulb is needed to give light
- The pooled current model, in which an electrical current is thought to be shared equally by electrical devices
- Current as impact. The current originates from both poles from the battery, when they bump into each other in the bulb, the bulb gives light
- Electrons carry a positive charge
- The consecutive model, in which it is presumed that a variation at a point in an electrical circuit affects the circuit frontward in the direction of the current, not backward
- The short circuit misunderstanding, in which wires with no electrical devices are overlooked when examining an electrical circuit
- The parallel circuit misconception, in which resistors are thought of as a hindrance to current flow, supposing any escalation in number of resistors in parallel to raise the total resistance
- Limited reasoning, when a change in a portion of an electrical circuit, the local portion is focused on instead of overall examination
- The experiential rule model, in which the further away a bulb is from the battery, the dimmer the bulb would be
- Voltage across parallel branches is different for each branch
- Current can change in a branch
- The potential difference is a result of current flow, not its source
- Inappropriate use of Ohm's Law
- Light given off by a light bulb increases with the number of batteries connected to it (free from the kind of connection)
- Bulbs in series are always brighter (Bernhard & Carstensen, 2009; Bull et al., 2012; Küçüközer & Kocakulah, 2008; Periago & Bohigas, 2005; Peşman & Eryilmaz, 2010).

A particular external representation of a circuit could have positive as well as negative effects on conceptual understanding and could lead to certain misconceptions about electronic concepts. Conceptual knowledge is a result and not an initiator of learning activities, thus prior experiences of a student either promote or hinder intent concept formation. In an attempt to bypass conceptual difficulties, students resort to trivial and often incorrect interpretations, which lead to inappropriate reasoning (Ashdown et al., 2011; Mangieri, 2009; Von Aufschnaiter & Rogge, 2010).

Turgut et al. (2011) posit that the main features of misconceptions are the following:

- Misconceptions of learners who have different culture, faith and language are normally comparable to each other

- Misconceptions may deeply infiltrate into learners' minds and fight changing
- Everyday language, culture and belief can cause the development of misconceptions
- Misconceptions can be similar to the descriptions made by former researchers in understanding scientific occurrences
- Misconceptions may progress after an official education.

The misconceptions in Industrial Electronics outlined above were described in research conducted with students in different countries and with diverse age groups. The research emphasised a magnitude of student misconceptions, including the effort of differentiating amongst voltage and current. The misconception of current is used up by circuit components. What is recorded above is practically stated in entirely all the research about electronic circuits. The goal of effective Industrial Electronics teaching is to inspire the student to build an understanding that is usually dependable with recognised electrical theory. Once misconceptions in certain concepts emerge, the basis of the students' knowledge is not stable. The research above advocates the significance of education about the nature of interconnection, although education about specific examples of interconnection in aiding students is moving away from their misconceptions about the way in which electrical circuits operate. How to identify these misconceptions is vital to a student's education, as is teaching of simple electronic circuits to start with an effective teaching method for each individual student.

The didactic procedure in the hands of educators armed with modern technologies is moving in the direction of the rationalisation of education. Should the instruction material unconditionally back the learning procedure, it has to have evident qualitative features of which the most significant can be thought in particular to be the educational ones. The philosophy of pedagogy is not capable of offering an assessment structure according to which it would be likely to assess and, founded on detailed principles, obviously identify and recognise the quality of numerous instruction resources and their appropriateness (Herrington, McKenney, Reeves, & Oliver, 2007; Juuti & Lavonen, 2006; Küçüközer & Kocakulah, 2008; South Africa, 1996b).

In current pedagogical procedure it is general to use the expression didactic technology in the background of physical didactic technology, while it is a limited perception of the outset of this expression in the pedagogical educational development, utilised in subsequent purposes:

- Motivational and simulative tools, i.e. technologies inducing an primary relation of the student to education, resolving misconceptions and thought-provoking conditions helpful to creative probing, learning, and accomplishment
- Sources of information conveying the subject matter closer to the student so that the process of attainment of info is made as informal as conceivable
- The instruction materials are planned to help the student—as the technology to understand the core of actions and influences through numerous means

progressively transferred to the student. Accountability is understood in this appraisal in a comprehensive sense: it can refer to learners' cognitive or metacognitive actions or to learners' affect. The accountability for knowledge is moved when a learner takes increasing control (Brush & Saye, 2002; Van de Pol et al., 2010).

From shadowing and collaboration with the varying aspects of the problem, students cultivate an inner depiction of articles, occasions and relations between them. As a student takes part in the problem resolving undertaking, conceptual images are fashioned or improved, and information transmission, if any, that appears is guided by the picture moulded in the mind of the student. The character and worth of the activities that take place in supplementary growth of a challenge solution will depend upon the fruitfulness of the conceptual illustrations that the student has fashioned. Conventionally lecturers have been the enablers of knowledge for their students. Whether this education has taken place through lecturer centred or student centred methods, the lecturer's part has been one of starting the education structure and scaffolding its expansion through numerous means of support. Scaffolding is commonly considered as backing for students though they are occupied in undertakings just outside their competences. It may range from supporting students while finishing a complete assignment to offering intermittent support. As the students' experiences develop, the lecturer progressively lessens the backing up until the student has grown to become self-sufficient with the allotted problem. Through frequently observing the development of all students, a more student centred method is adopted through engagement with multifaceted problems that include an analysis according to a grounded method to education (Brickell & Herrington, 2006; Brush & Saye, 2002). These shared characteristics are summarised in a theoretical model, portrayed in Figure 2.9.

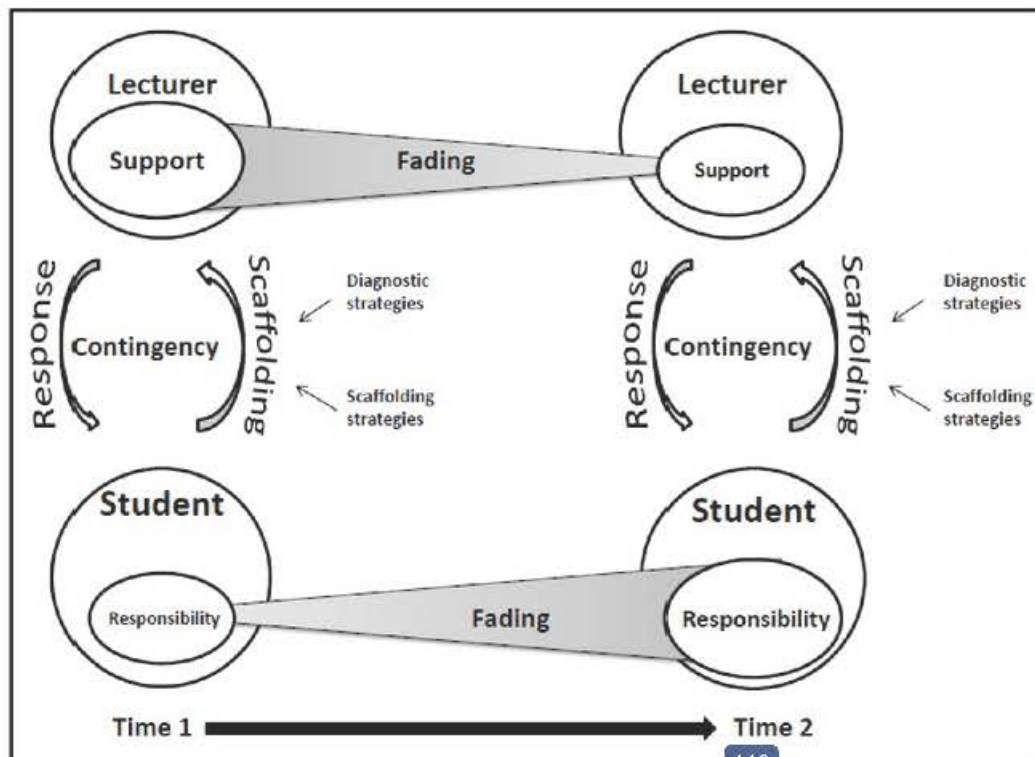


Figure 2.9: Adapted conceptual model of scaffolding (Van de Pol et al., 2010)

With the use of screencasts as initial backing and scaffolding the students' dependence on the screencasts will decline as they progressively take responsibility for their learning.

2.4 Personalisation

Up to the very recent, most theoretical learning and teaching structures have not been personalised. However, even today, personalisation structures are still mostly limited to practical teaching (Figure 2.1). In broad, to permit personalisation, prevailing structures use one or more categories of knowledge (learners' knowledge, education material knowledge, education process knowledge, etc.). Script by itself is not all the time the favoured method of communiqué, as web-based hypermedia construction and delivery tools including auditory (podcasting, Skype), photograph (Flickr) and audio-visual (screencasting, YouTube, Stickam) proficiencies are increasing. In general, personalisation in theoretical learning and teaching structures concerns adaptive communication, adaptive course conveyance, content discovery and gathering, and adaptive association backing. The classification of adaptive course conveyance represents the most collective and extensively used gathering of alteration procedures applied in theoretical learning and teaching structures. Characteristic examples include active course rearrangement and adaptive selection of learning objects, as well as adaptive course-plotting maintenance, which have all endorsed from the rise of using commendation policies to create new and applicable associations and items. In fact, one of the new procedures of

personalisation in learning and teaching environment is to give commendations to learners in order to support and help them through the learning and teaching process. Personalisation of learning provisions means that learning practices will be increasingly more adapted permitting the inclinations of the student. Personalisation of learning can contain the adapting of apparatuses, workstations, infrastructures, content, etc. to the requirements of the individual student (Alfaro et al., 2005; Khribi, Jemni, & Nasraoui, 2009; McLoughlin & Lee, 2008).

Personalised learning is a teaching and learning methodology which is positioned on the requests, abilities, and welfares of individual learners. Personalised learning is a distinctive learner-centred methodology to education that is progressively being used to guarantee that learners are able to meet their objectives and their potential. The abstract description for the consequence of personalisation is forthright: Using the person as an orientation point increases the student's attentiveness, which in turn inspires the student to use accessible perceptive capacity for active perceptive dispensation of the received material during education (Mayer, Fennell, Farmer, & Campbell, 2004)

Personalised learning necessitates an obligation to function cooperatively with learners to ascertain their individual learning requirements. Recognising the way an individual learner absorbs knowledge is critical to the procedure. If personalised learning is to be successfully applied in colleges, then educational institutions must likewise be dedicated to assist educators through applicable and actual on-going specialised improvement. Personalising education also obliges training organisations to have an obligation to lifelong learning and to arrange for learners with flexible education settings. Personalised learning ought not to be confused with individuals sitting unaided, learning and working through coursework. Personalised learning is about colleges encouraging a lifelong learning tactic which promotes sturdy relations between home, community, resident organisations and industries (Dostá et al., 2012).

In fact, the concept of personalisation is not completely new to educationalists, and it is frequently connected to the term learner-centred teaching, an anticipated state where students recognise in what way to select and make conclusions concerning their individual education requirements. However, notwithstanding the efforts of numerous constructivist lecturers, the controller philosophy of education triumphs and pre-packed content and pre-planned programmes remain to dictate, denying students choice and independence in determining their own education routes (McLoughlin & Lee, 2008).

Personalised learning changes the old-fashioned role of lecturers. Lecturers must transfer their emphasis from instructing learners as a collection of learners toward teaching learners according to their specific abilities and interests. Lecturers become facilitators and knowledge agents assisting learners to make the best appropriate choices. They must also react to the dissimilar behaviours of learners to achieve their best. An initial phase is for lecturers to recognise specific requirements, abilities, and preferred learning styles. This will enable them to modify their instruction and valuation exercise so that every single student has the chance to accomplish the highest conceivable standard.

In personalised learning, lecturers customarily set distinct learning goals and frequently observe and analyse development toward these. They provide students with organised responses and demonstrate to them how to use these to improve their work. They also assist students to study by providing them with guidance on how to consolidate their learning and relate training abilities which have been established to be effective. They inspire students to participate in important self-assessment. In personalised learning, it is critical for lecturers to have high prospects for all students irrespective of background and capability levels, and monitor education requirements and development through continuing discussion and determinative valuation. Personalised learning necessitates students to use material on student development to adjust their learning. The grouping and availability of diverse media offer students a variety and accommodate dissimilarities such as character individualities, reasoning styles, inclinations, and education styles (Baylari & Montazer, 2009; Xu & Wang, 2006).

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Personalisation increases the learner's curiosity; increased curiosity instigates the learner to apply more determination to involve in dynamic cognitive processing throughout learning, and a growth in dynamic cognitive processing throughout learning consequences in deeper learning, which is demonstrated in enhanced transmission functioning (Mayer et al., 2004). Adult students more and more anticipate an individual or tailored education environment. Students need education possibilities, selections, and personalisation.

By providing students independence of choice, lecturers can set the stage for student success (Bolliger, Supanakorn, & Boggs, 2010). Further, the instructive use of technology such as screencasts, permits more personalisation of the learning resources for students (Birch & Sankey, 2008). In terms of addressing misconceptions in resistive circuits, personalisation is vital to the acceptance of new technologies like screencasts.

2.5 Chapter summary

In conclusion: to help the student become a fulfilled learner, the use of screencasts as a method to enhance the learning experience can have positive effects. Not only can the use of screencasts resolve some deep-rooted misconceptions, it can also be personalised to suit the individual student. Furthermore screencasts can form part of a *scaffold* of information to be used as a basis for new information.

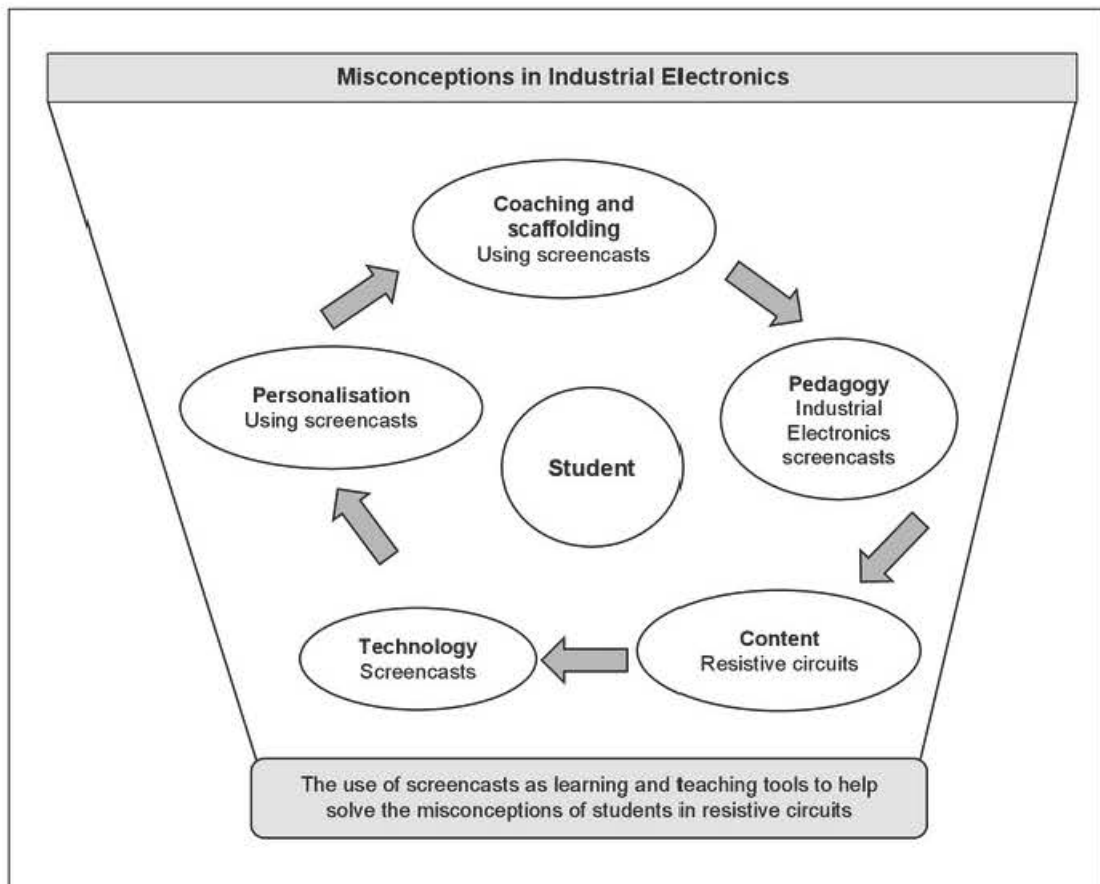


Figure 2.10: Summary of literature review in terms of misconceptions in resistive circuits

As seen in Figure 2.10, all the concepts (personalisation, coaching and scaffolding, pedagogy, content and technology) should interact with one another in order to improve the learning experience of the student by addressing the misconceptions in Industrial Electronics regarding resistive circuits.

Chapter Three

Planning design-based research design and methodology

3.1 Introduction

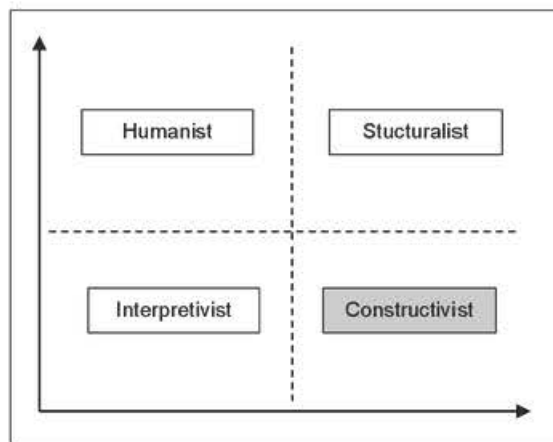
This chapter outlines the research design and methodologies followed during this study. The proposed research design integrates quantitative and qualitative methods. While an analytic instrument, Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) (Addendum 3.1) (Engelhart, 1997) assessed students' grasp of direct current resistive electric circuits and endeavoured to ascertain any core misconceptions, individual interviews (Addendum 3.2) ascertained why students selected specific distracters. The purpose of the study was to:

- determine the nature of misconceptions in the prior knowledge of students registered for Industrial Electronics N2, especially in direct current resistive circuits
- develop screencasts on direct current resistive circuits to enhance students' prior knowledge
- explore students' perceptions regarding the usefulness of screencasts as cognitive learning tools.

3.2 Research design and methodology

3.2.1 Research paradigm

At the onset of a study, researchers have to decide about the philosophical assumptions that underpin their research. Burrell and Morgan (1979) describe four philosophical assumptions: *ontology*, *epistemology*, *human nature* and *methodology* (Figure 3.1). The *ontology* of a research relates to the "very essence of the phenomena under investigation" (Burrell & Morgan, 1979, p. 1). The main decision is whether researchers view the reality to be investigated as external or internal to them. *Epistemology*, which investigates the nature and origin of knowledge (Burrell & Morgan, 1979). This study aims to directly improve instructional practices and therefore relates to the constructivist paradigm. The study made use of pragmatist methodologies of mixed methods (Wang & Hannafin, 2005) in order to provide design principles for the setting of best practices (Engelhart, 1997) relating to the instruction of an Industrial Electronics course.



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Figure 3.1: Four paradigms for the analysis of social theory (Burrell & Morgan, 1979, p. 22)

3.2.2 Design-based research

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 DBR is the methodical study of designing, developing and evaluating instructive involvements (such as procedures, teaching-learning policies and resources, produces and structures) as answers for multifaceted difficulties in educational practice, which also aims at evolving knowledge on the features of these involvements and the procedures of designing and developing them (Plomp, 2010). In numerous ways, DBR is essentially related to, and its improvement nurtured by, numerous design and research methodologies. Researchers undertake the purposes of creators and academics, drawing on processes and approaches from both fields in the form of a hybrid methodology. DBR does not replace the use of other methodologies, but rather offers a different method that accentuates direct, accessible, 129 synchronised progresses in research, theory, and practice. It represents the coming together of design research, theory, and practice outspreads current (Wang & Hannafin, 2005). Wang and Hannafin (2005) define DBR as a methodical but flexible methodology intended to increase learning practices through iterative examination, design, development, and application, founded on partnership amid researchers and practitioners in real-world surroundings, and leading to contextually-delicate design principles and philosophies. 23

DBR is a methodology planned by and for teachers, that pursues 5 upsurge the influence, transferal, and conversion of education research into enhanced procedure. Design experiments were developed as a way to carry out developmental research to test and improve educational designs founded on theoretical philosophies derived from past research (Anderson & Shattuck, 2012; Collins, Joseph, & Bielaczyc, 2004). The method of progressive improvement in DBR included putting a leading variety of an intervention into the classroom to see how it works. DBR is proposed if previous teaching or intermediations regularly confirm ineffectivity (Kelly, 2010). The intervention design is continually reviewed until all glitches are worked out. DBR is not intended 7 merely at purifying training. It should address theoretic queries and problems. DBR is suggested when the problem facing education or training is considerable and intimidating how-to-do strategies accessible for addressing the problem

are unattainable (Kelly, 2010). Because design experiments are customary in education surroundings, there are numerous variables that cannot be controlled. As an alternative, design researchers improve the design and attempt to cautiously perceive how the dissimilar components are working out together. Such observation requires both qualitative and quantitative interpretations. Once some facet of the design is not operational, the researcher should contemplate diverse selections to improve the design in practice, and introduce design modifications as regularly as needed (Collins et al., 2004).

The five basic features of DBR relate to: (a) pragmatic; (b) grounded; (c) collaborating, iterative, and flexible; (d) integrative; and (e) circumstantial. As noted before, many features are not exclusive to design-based research, but the nature of their use differs and these methods are frequently extended into design-based research. Table 3.1 summarises the characteristics of DBR according to Wang and Hannafin (2005)

Table 3.1: Features of design-based research (Wang & Hannafin, 2005)

Characteristics	Explanations
Pragmatic	<ul style="list-style-type: none"> Design-based research improves both theory and practice The value of theory is assessed by the degree to which philosophies enlighten and develop practice
Grounded	<ul style="list-style-type: none"> Design is theory-driven and based in appropriate research, theory and practice Design is conducted in real-world locations and the design procedure is rooted in, and studied through, design-based research
Collaborative, iterative and flexible	<ul style="list-style-type: none"> Designers are involved in the design processes and work together with partakers. Procedures are iterative cycle of examination, design, application, and redesign. Preliminary proposal is typically inadequately comprehensive so that designers can make considered modifications when needed
Integrative	<ul style="list-style-type: none"> Mixed research methods are used to make the most of the integrity of on-going research Approaches differ throughout different stages as new requirements and problems arise and the attention of the research grows Rigor is decisively preserved and self-control applied suitable to the development phase
Circumstantial	<ul style="list-style-type: none"> The research procedure, research conclusions, and variations from the original design are documented Research outcomes are linked with the design procedure and the location The content and complexity of produced design philosophies differ Assistance for applying produced philosophies is necessary

Herrington warns that the use of technology-enhanced learning is often developed with designs that put emphasis on the transmission of information, rather than embracing the use of technology as cognitive tools to encourage thinking and understanding (Herrington, 2009). Higher education institutions frequently use ICTs to deliver knowledge “where learners learn *from* the technologies rather than *with* them as cognitive tools” (Herrington, 2009). DBR combines experimental research with the design of education settings embedded in theory and presents the opportunity to advance teaching and learning (Herrington, 2009). DBR offers an inclusive approach to explore the usefulness of dependable education designs (Herrington, 2009; Herrington & Kervin, 2007; Herrington & Reeves, 2011; Wang & Hannafin, 2005). Plomp (2010, p. 12) describes DBR research as “a methodical but flexible methodology intended to advance learning practices through iterative examination, design,

improvement, and application, founded on cooperation amongst researchers and practitioners in real-world situations, and leading to contextually-sensitive design philosophies and concepts. The rationale behind design-based research is to shape an enhanced relationship amongst educational research and real-world difficulties (Amiel & Reeves, 2008). Amiel and Reeves (2008) also point out the differences between DBR and traditional empirical predictive research. With DBR the importance is positioned on "an iterative research procedure that does not just appraise a ground-breaking invention or interference, but methodically tries to improve the invention but also creating design philosophies that can lead to related research and advance activities" (Amiel & Reeves, 2008, p. 34). This brings about a series of research that is decidedly dissimilar from what is presently followed by numerous researchers in the field (Amiel & Reeves, 2008). Figure 3.2 illustrates the process of DBR.

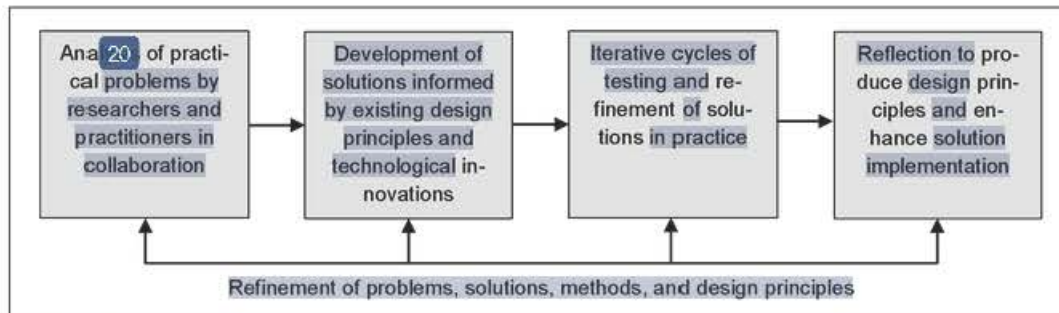


Figure 3.2: Adopted version of the four stages of design-based research (Amiel & Reeves, 2008)

KcKenney, Nieveen, and Van den Akker (2006) formatted this seemingly linear process into a cyclical process, adding proposed number of participants and a time scale to the axes. This study embarked on the cyclical development of a typical prototype technology development of about forty participants over a period of about six months (Figure 3.3).

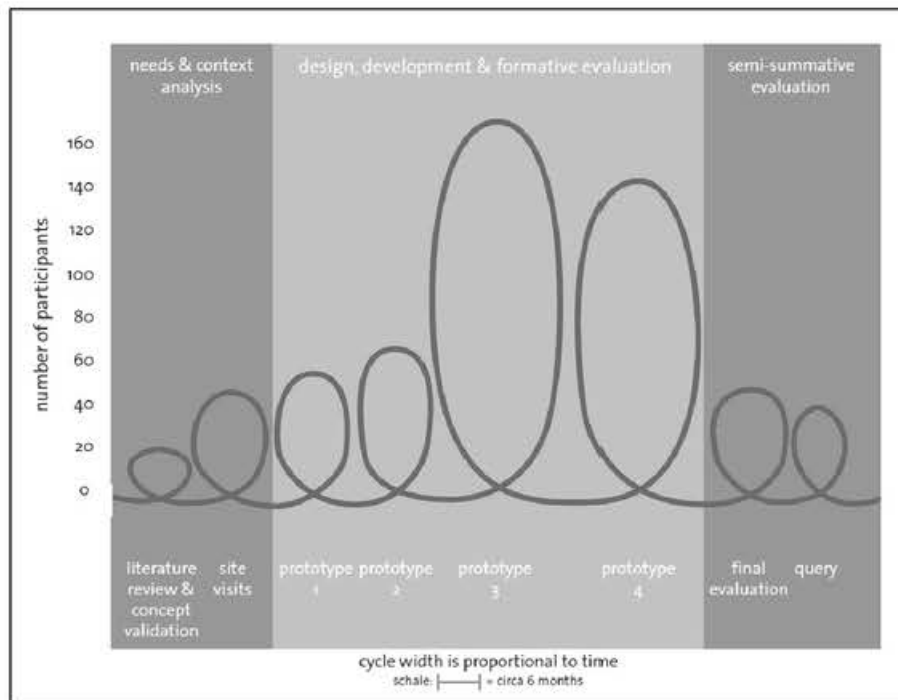


Figure 3.3: Typical cyclical progress of a design-based study (KcKenney et al., 2006, p. 73)

3.2.1.2 Research functions

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DBR is to design and develop interferences (such as procedures, teaching-learning policies and resources, products and structures) with the goal to resolve a multifaceted educational challenge and to develop our knowledge around the features of these interferences and the procedures to design and develop them (Wang & Hannafin, 2005).

3.2.2 Quantitative component

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Quantitative research refers to the systematic empirical investigation of social phenomena with statistical, mathematical or computational techniques. Quantitative research is about explaining phenomena by collecting numerical data that are analysed using mathematically based methods (Muijs, 2004). The quantitative data in this study took the format of a multiple-choice questionnaire. Multiple-choice tests have advantages above other methods of data collection. They were quantitatively categorized so that the minimum of errors take place due to prejudice. Statistical approaches were consequently used to analyse the data.

The multiple-choice questionnaire provided a set of responses from which the respondents had to choose a single answer (Maree, 2007). The test can include an extensive assortment of behaviours from recollect to the higher level abilities, such as function and can give exceptional subject matter sampling, which normally precedents supplementary content-valid total clarifications. If the distracters

are grounded on student misconceptions, then the questions have the possibility to provide analytic understanding into problems that specific students may have. Multiple-choice questions are free from reply answers; they offer to students a different response when the identical subject matter is represented in a dissimilar form (Creswell, 2008). Table 3.1 describes the advantages and disadvantages of multiple-choice questionnaires.

Table 3.1 Advantages and disadvantages of multiple-choice questionnaires *

Advantages	Disadvantages
Allow for evaluation of an extensive variety of learning objectives	Restricted feedback to accurate misconceptions in student perception
Impartial character limits scoring favouritism	Tend to concentrate on low level learning objectives
Students can rapidly be manipulated by regulating resemblance of misconceptions	Results may be biased by reading skill or test wiseness
Effective to manage and score	Development of worthy items is time consuming
Incorrect answer patterns can be studied	Measuring capability to organise and articulate ideas is not possible
Less prejudiced by questioning and true-false	

* (Cohen, Manion, & Morrison, 2007; Creswell, 2008; De Vos, Strydom, Fouche, & Delport, 2005; Denzin & Lincoln, 2005)

3.2.3 Qualitative component

Qualitative research focuses on occurrences that take place in normal settings and also studies the occurrences in all their intricacy by means of interviews, observation and recording procedures as they occur unaffectedly (Leedy & Ormrod, 2005; McMillan & Schumacher, 2001). Qualitative research has specific features that are common to all qualitative studies:

- The normal setting is the direct resource of data
- The researcher is the crucial instrument in the research
- Qualitative data is portrayed in words and pictures
- The researcher is concerned with procedure as well as result
- The researcher examines the data inductively
- How people make sense of their lives is of apprehension to qualitative researchers (Fraenkel & Wallen, 2008).

The data collection strategy used during this research was individual interviews. The interview is an adaptable instrument for data collection, permitting multi-sensory means to be used. Interviews allow participants to deliberate their understandings of the misconceptions and express how they look at situations from their own point of view (Cohen et al., 2007; Fraenkel & Wallen, 2008). A structured interview was used where each participant received the same set of questions to be answered. Structured interview utterances could consequently be compared and contrasted (Fraenkel & Wallen, 2008).

3.2.4 Research process

The study followed four phases of testing, interviewing and analysing based on qualitative and quantitative data collection:

Phase 1: Analysis and exploration of a problem: Testing respondents with the DIRECT Test and analysis of data to ascertain the shared misconceptions of the respondents regarding resistive circuits.

Phase 2: Development of solutions using existing design principles and technological innovations: Development of screencasts based on design principles ascertained from the previous phase (Askew & Wiliam, 1995; Bamberger & Schultz-Ferrell, 2010; Jordaan, 2005; Mamba, 2005; Svinicki, 2010; Welder, 2012). The design and development of the screencasts focused on implementing educational technologies in order to create authentic learning tasks (Herrington, 2009; Herrington & Kervin, 2007; Herrington & Oliver, 2000; Herrington & Standon, 2000).

Phase 3: Implementation and evaluation in iterative cycles: Distribution and implementation of screencasts based on the identified misconceptions of the respondents. The interviews were conducted with ten students on the four shared common misconceptions relating to resistive circuits. At the end of the second trimester a semi-structured open-ended questionnaire was submitted to the respondents in order to determine their perceptions of the value of the screencasts as a cognitive education tool in an authentic learning environment.

Phase 4: Reflection to produce design principles: Analysis and consideration of data to create design principles in order to improve screencast application with the aim to:

- build on outcomes from previous research, as well as best practices
- use research methods in a methodical procedure of exploring prospects
- develop tools, and practices for their use, through imaginative design and consecutive modification founded on using research methods to get rich and comprehensive response in well-specified situations (Burkhardt, 2006).

Figure 3.4 depicts the procedure that the researcher followed during data analysis.

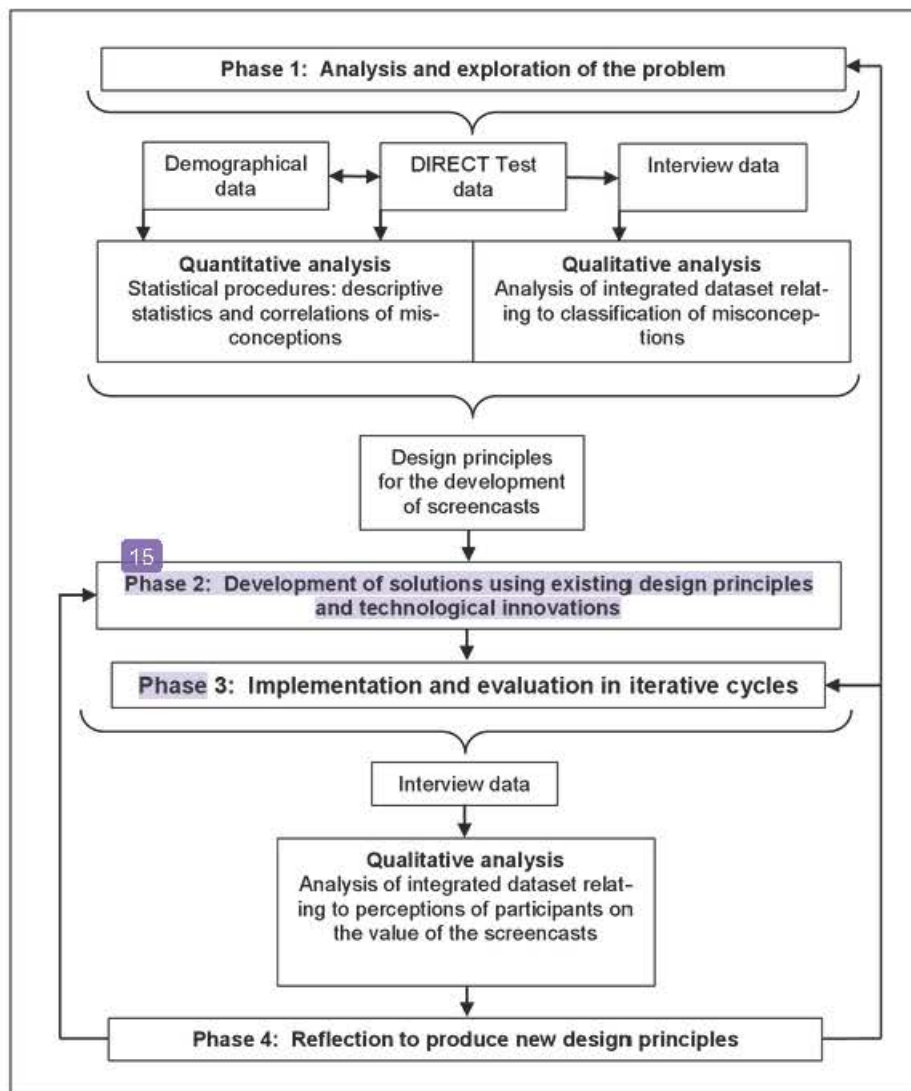


Figure 3.4: Research design and methodology followed during this study

Phase 1 will be discussed in Chapter Four, phases 2 and 3 in Chapter Five, and phase 4 will be presented in Chapter Six as a concatenation of the results and a reflection on the process.

3.2.4.1 Iterative procedures

Involving the philosophies of pragmatism (Burrell & Morgan, 1979), a DBR assignment in the field of science teaching starts in the context, when the researcher recognises the problematical situation. One significant characteristic of the DBR in the background of science education is that not just researchers, but also conventional teachers in the field with little understanding about the intended object and its learning theory background are capable to use it positively. Design-based intermediations are seldom planned and applied flawlessly; thus there is continuously room for

enhancements in the plan and succeeding assessment. This development through numerous iterations is nonetheless one of the challenges of the methodology in that it is hard to distinguish as soon as the research programme is finalised (Anderson & Shattuck, 2012). The DBR procedure is consequently adductive using real-world thinking. Juuti and Lavonen (2006) argue that in DBR, the particular design task or particular reproduced problem in action controls the data gathering and examination.

3.2.4.2 Designing of technology

From the practical point of view, the role of the intended technological solution is to aid a lecturer to act more perceptively. This necessitates the cognitively dynamic part of the lecturer. The lecturer, eventually, improves teaching and learning through his/her actions in the classroom. Therefore, each intended technological solution has inherent undecided characteristics that establish on a classroom act and are likely to treat only through the lecturer's rational. The lecturer customises every aspect used during his/her lecturing. The being and nature of an item differentiate DBR from other activities (Juuti & Lavonen, 2006).

3.2.4.3 Extract original educational knowledge

The fact of educational research is to gain new information so that lecturers are able to perform more perceptively. Designing, creating and analysis procedures suggest numerous varieties of skill. DBR offers opportunities to obtain information about knowledge (Juuti & Lavonen, 2006). From the realist point of view, through action, it is likely to attain information and lacking information, activities are directed by behaviours. Context makes activities comprehensible.

3.2.4.4 Reliability

DBR delivers an original item and original information extremely interrelated with each other. Therefore they help researchers to possibly lecture more perceptively. In this study there are two levels for reliability (Juuti & Lavonen, 2006). The first level is *systemic validity*, the complete design-based research. *Unity trustworthiness* has the characteristics of originality, practicality and intensity. The researcher demonstrated that through the development of something fresh (item and information) he/she has created and founded on analysis and reviewing, enhanced lecturing in certain situations. Another level reflects one stage of the development. *Fractional reliability* is the situation when a researcher resolves, how he or she will try to comprehend lecturers' domains, how to gather data throughout the testing, how to examine the data etc., how to assist lecturers to reflect on their experiences. Here detailed standards of different research approaches (interviews, observations, etc.) were used (Hoadley, 2004; Juuti & Lavonen, 2006).

A population is a whole accessible collection of components or circumstances, whether persons, items or actions, that obey to precise conditions and to which we aim to generalise the outcomes of the research (De Vos et al., 2005; Fraenkel & Wallen, 2008; McMillan & Schumacher, 2001). The population used for this study is the N2 students studying at Further Education and Training (FET) Colleges. To become a full fledged artisan the student must not only comply with the theoretical standards, the theory forms only part of a seven step process to become an artisan. The seven steps are indicated in Figure 3.5.

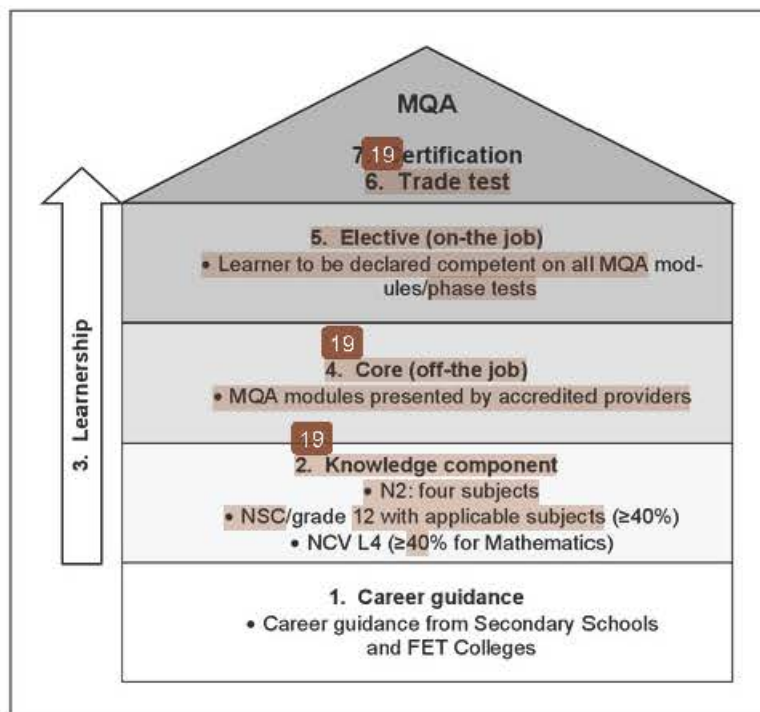


Figure 3.5: Adapted seven-step process to become an artisan (Pretorius, 2011)

The study took place at the Kathu Campus of the Northern Cape Rural FET College. Students who participated were enrolled for the course Industrial Electronics on N2 level that constitutes one of the pre-requirements to become a qualified artisan (Figure 3.5). The participants all received a learnership from a mine in the area as either an artisan or a trainee-artisan. They enrolled for the subject as part of their knowledge component for qualifying as an artisan over a period of ten weeks after which they wrote a national examination (Figure 3.5). Students had to comply with certain pre-requirements to enrol for either the Electrical N2 or Millwright N2-trade. The requirements for enrolment were

- a grade 12 certificate with Mathematics and Physical Science not below forty per cent
- passed the Technical Test Battery (TTB) conducted by one of the regional mines.

The TTB test covers three distinct tests, each intended to measure a different part of technical aptitude. These parts are the capability to reason with mechanical perceptions, the capability to deal with and handle three dimensional spatial relations and the capability to rapidly and precisely find a route through a composite two dimensional labyrinth (Tredoux, 2011).

3.4 Sampling

Sampling comprises a small amount of the considered population for the definite inclusion in the study (De Vos et al., 2005; Fraenkel & Wallen, 2008). The students participating in this study met the pre-requirements of previously passing:

- grade 12 with Mathematics and Physical Science above forty per cent.
- the Mines Technical Test Battery (TTB) test
- the necessary physical fitness and medical tests.

The reasons for these requirements were: (i) the student will receive a learnership with one of the surrounding mines (Kumba, Kolomela, Khumani, Blackrock, PPC Lime, Finch and Beeshoek); (ii) student must have the ability to become an artisan, hence the TTB test; and (iii) to become an artisan certain physical and medical requirements are needed to comply with the Mines Health and Safety Act 29 of 1996 (South Africa, 1996b).

For the first phase of this study that took place in the first trimester of 2013, I have used nonprobability purposeful sampling. The sample group used for this part of my study is a selective group of students who enrolled for N2 Electrical or Millwright in the first trimester.

Non-probability sampling is where the researcher used participants who were available with the characterised categories of features (McMillan & Schumacher, 2001). Cohen et al. (2007) states that the refinement which is built into a non-probability sample, originates from the researcher affecting a specific group, in full knowledge that it does not characterise the wider population; it simply characterises itself. Purposeful sampling is based on the judgment of the researcher, in which most of the characteristics or attributes of the population is found (De Vos et al., 2005; McMillan & Schumacher, 2001). For the second phase of this research the same sampling characteristics were used during the first phase except it was students enrolled for the second trimester of 2013. In the fourth phase non-random purposeful sampling were also used with the interviewing of ten students out of the first two phases.

3.5 Data collection

Phase 1 (Figure 3.4) of the study took place a week before the closing of the first trimester of 2013, after the students had done the module on direct current theory, and in the first week of the second trimester with a different group of students who had not done the module on direct current theory. In both cases the study starts with a biographical questionnaire combined with the DIRECT multiple-choice questionnaire. The combined questionnaire consists of open-ended and closed questions. Open questions give the respondents the opportunity to share their perceptions and experiences relating to their misconceptions in the spaces provided (De Vos et al., 2005). Open questions empowered the respondent to write a unrestricted explanation in particular terms, to clarify the explanation and evade the restrictions of pre-set groupings of replies (Cohen et al., 2007). Closed questions offered the respondent the opportunity of selecting one or more responses from a number provided (De Vos et al., 2005). Closed questions recommend the replies from which the respondent may pick (Cohen et al., 2007). Multiple-choice questionnaires have several advantages over other forms of data collection. They are quantitatively categorised so there are negligible inaccuracies due to subjectivity. Multiple-choice questions are normally utilised to obtain information that can be logically divided into hard and fast categories (De Vos et al., 2005). Multiple-choice questions is intended wherever a variety of selections is intended to capture the probable variety of selections to specified statements (Cohen et al., 2007).

The DIRECT diagnostic instrument used to determine the misconceptions comprised 29 questions. Engelhardt and Beichner developed the instrument in order to determine the conceptual difficulties students have either before or after instruction relating to resistive electrical circuits. Traditional lecture hall lecturers can use this information to appraise their instructional practices and bring about growth in the theoretical standard of their teaching, and also to address the difficulties of their students (Engelhart, 1997).

Data in the second part of each trimester were captured by means of interviews with the students who met the criteria of the sample. The interviewer obtained clarification on questions about common misconceptions about resistive electrical circuits used in Industrial Electronics in the first phase. In the second phase of the study the researcher produced four screencasts of the most common misconceptions in resistive circuits. The purpose of interviewing is to determine what is on a persons' mind, or how a person feels about a certain issue (Fraenkel & Wallen, 2008). A semi-structured interview will be used. The semi-structured interview will help the researcher to gain a comprehensive image of the participant's misconceptions about electronic components. This method will allow the participant as well as the researcher more flexibility. Semi-structured interviews are suitable as the researcher is interested in the complexity of an issue (De Vos et al., 2005).

In the third phase (Figure 3.4) the researcher had the participants complete a semi-structured open-ended questionnaire to determine the value of the screencasts as a cognitive learning tool in an

authentic learning environment, after the students have viewed the screencasts. In the fourth phase the researcher had analysed the data received in the first three phases.

3.6 ¹¹⁰ Data analysis

The qualitative data analysis related to the demographic and DIRECT Test data. The measurement level of the data were nominal because it was classified into categories of sex, gender, race, home language, province and technology use. The age was in ratio levels of measurement. There were numerical values given to the data to calculate statistics. Descriptive data analysis were used. The data was analysed by the Statistical Consultation Services of the North West University (Potchefstroom Campus) using the Statistical Package for Social Scientists (SPSS). The following techniques were included:

- descriptive statistics of biographical information relating to frequencies and percentages (Addendum 3.3)
- descriptive statistics of misconceptions relating to frequencies and percentages (Addendum 3.4)
- descriptive statistics relating to cross-tabulations with Cramer's V of biographical information and misconceptions (Addendum 3.5).

Qualitative analysis was performed with Atlas.ti™, a computer-based qualitative analysis program.

The step followed comprised:

- Preliminary analysis of each open-ended answer in the interview and writing a comment about the findings. Data gathering and examination go hand in hand to build a logical understanding of the data
- ¹² Transcribing the interviews to get a better insight into the misconceptions
- Organising the data misconceptions and writing memos
- Generating codes and categories relating to the content analysis (De Vos et al., 2005).

The integrated Atlas.ti™ dataset comprising the interviews, coding structure, analysis and networks relating to the identification of misconceptions is available as Addendum 3.6.

3.7 Ethical clearance

¹ Ethical clearance was obtained from the Ethics Committee of the North-West University (Potchefstroom campus) (Addendum 3.7). Permission was also be obtained from the Northern Cape Rural Further Education and Training (NCR FET) College CEO and the Campus Manager of Kathu Campus (Addendum 3.8). Although the interviews may be intrusive in some way, and may demand time from the respondents, measures were put in place to minimise discomfort of respondents. Ethics can be defined as standards for behaviour that differentiate between satisfactory and undesirable

conduct (Mji & Makgato, 2006). Therefore it is necessary to take the following steps to ensure that the rights of the respondents are protected (Cohen et al., 2007):

- Obtain informed consent from respondents in writing (Addendum 3.9)
- Inform the respondents of the nature of the research
- Inform the respondents of their right to withdraw from the study at any stage
- Inform the respondents of the potential that the research can benefit their situation and the situation of others
- Give the guarantee that the research will not harm them
- Guarantee confidentiality, anonymity and non-traceability of their identity.

The researcher also submitted his dissertation to Turnitin™ for scrutiny regarding plagiarism as part of the ethical use of literature during this study (Addendum 3.10).

3.8 Chapter summary

Design-based research provides a sequence that encourages the insightful and lasting grounds upon which research can embark on. Educational expertise researchers ought to be alarmed with investigating the technological procedure as it develops in colleges and universities and its association to greater humanity. Design-based research approaches can constitute a comprehensible methodology that link theoretic research and educational procedure. Design based research, by substantiating itself in the wants, restraints, and connections of resident practice, can offer a way for comprehending how theoretical appeals about teaching and learning can be altered into effective learning in educational surroundings. The interventions (screencasts) have brought about developed results in student outlooks, and they offer valuable evidences as to the complement between the effective testing of the intervention and the background of procedure. It seems if DBR as established in current literature explains researchable problems within the pragmatic paradigm. Additionally, the pragmatic structure helps DBR academics to guide their proceedings. Particularly, the pragmatic opinion of truth highlights the association concerning a lecturer and a designed item (Amiel & Reeves, 2008; Anderson & Shattuck, 2012; Herrington et al., 2007; Juuti & Lavonen, 2006).

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	
2.6	Province of birth	48 Other	30	37
		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
2.7	Residing province	Other	2	2
		Gauteng	48	5
		Limpopo	2	2
		North West	8	10
		Northern Cape	60	74
		Western Cape	3	4
2.8	Mining apprenticeship	Yes	19	23
		No	62	77
2.9	Level of education	1 st year university	3	4
		2 nd 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
2.10	Access to devices	N4	3	4
		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% (Rens, 2013; 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 (Rens, 2013).

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 (Rens, 2013). 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 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, 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 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% did not understand 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 circuits, (iii) 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.

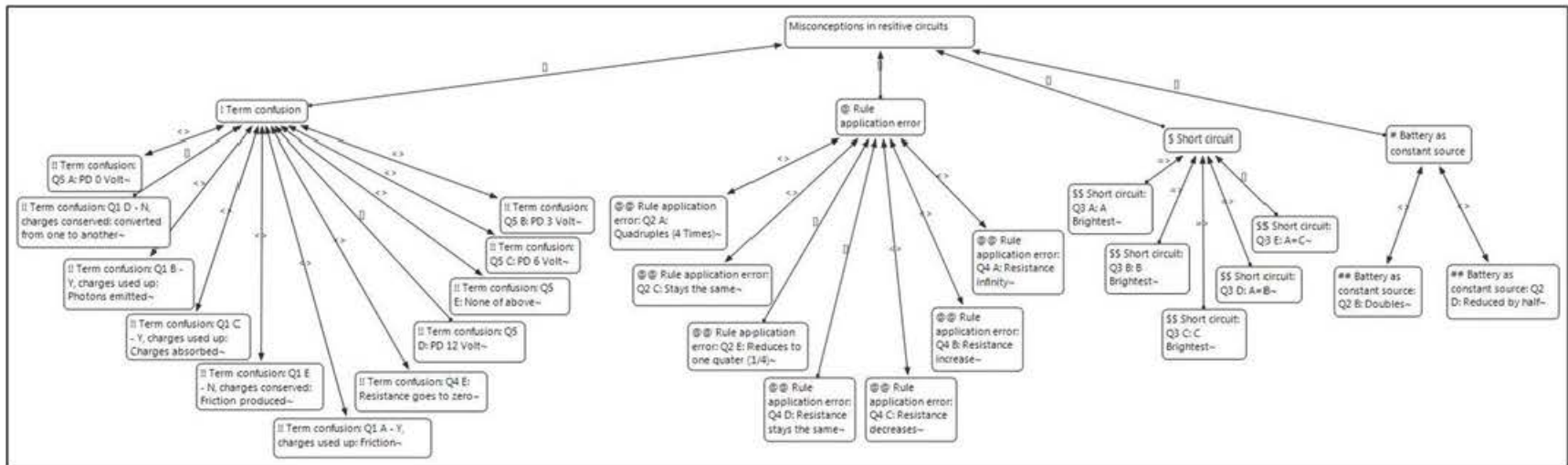


Figure 4.1: Four prominent misconceptions in electric circuits

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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 it as true 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
	No	3	1	4
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
	No	94	100	91	95
Column total		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).

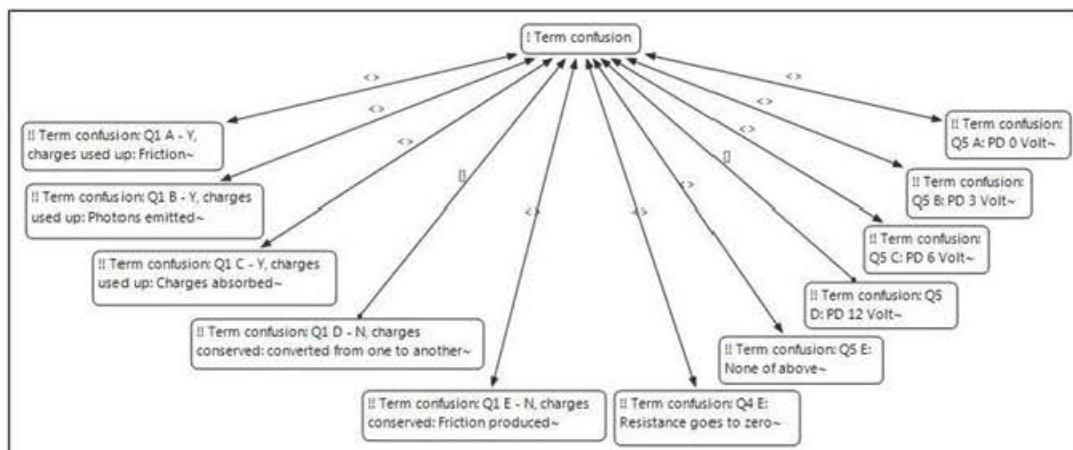


Figure 4.4: Misconceptions about term confusion

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

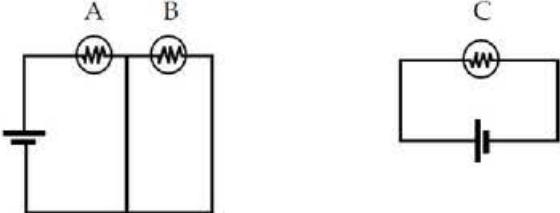


Figure 4.5: Question 10 of the DIRECT concept test

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)		
Op 79	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
	No	78	67	73
Column total		25	7	32
		24	33	27
		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
	No	59	50	74	61
Column total		14	12	6	32
		41	50	26	39
		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).

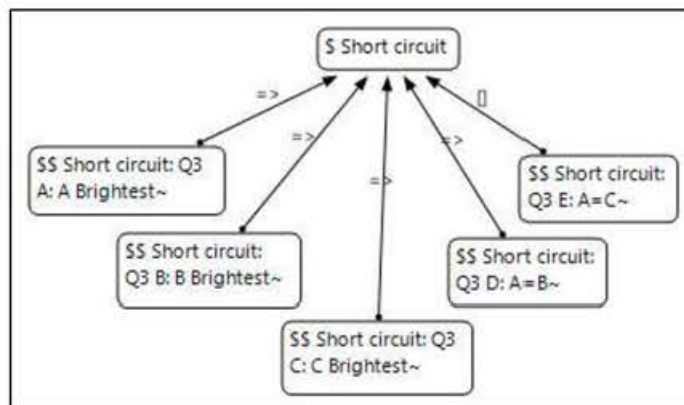


Figure 4.6: Codes relating to the misconceptions relating to short circuits

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 difference (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
	No	50	42	46
Column total		30	12	42
		50	57	54
		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 always produce the same amount of current no matter the load. More than fifty per cent (57%) of the female respondents understood that a battery will always produce the same amount of current no matter the load (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 always produce the same amount of current no matter the load. More than fifty per cent (50%) of the coloured (54%) and white (57%) respondents understood that a battery will always produce the same amount of current no matter the load (Table 4.13). However, the effect size indicates that this difference was not important in practice.

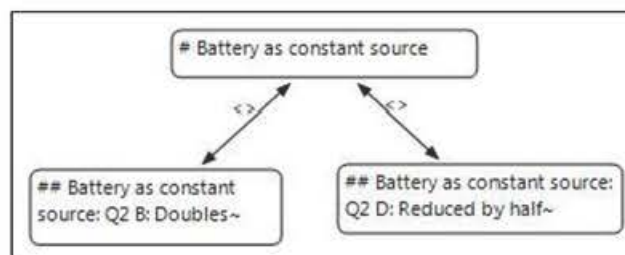


Figure 4.8: Misconceptions relating to batteries as constant current source

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 misconcep-

tion 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 (Cramer 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
	No	73	67	72
Column total		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
	No	77	58	78	72
Column total		8	10	5	23
		24	42	22	28
		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 Kirchoff'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?

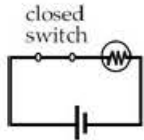
(A) The resistance goes to infinity.

(B) The resistance increases.

(C) The resistance decreases.

(D) The resistance stays the same.

(E) The resistance goes to zero.



closed
switch

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

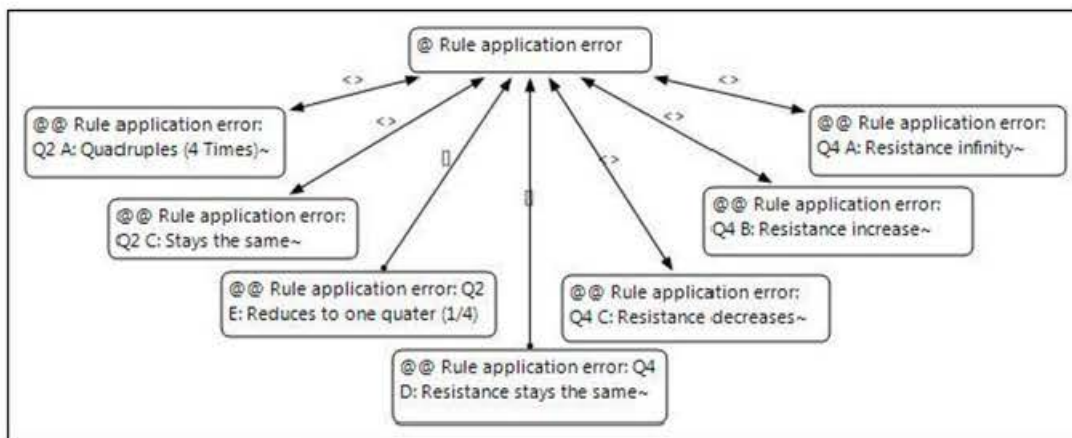


Figure 4.10: Misconceptions relating to application of rules

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 connection. 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).

Chapter Five

Development, implementation and evaluation of screencasts according to phase 1 design principles for an N2 Industrial Electronics course

5.1 Introduction

Current students, the so-called "Net Generation" or "Digital Natives," daily use digital devices and spend much time online (Tapscott, 2011). They are familiar with modern technology, hypermedia and online surroundings as they grew up with technology (Mohorovičić, 2012). Creation of multimedia educational material is becoming less complicated and less expensive. The use of screencasts is progressively becoming more widespread in higher education (Mullamphy et al., 2010). Screencasts allow lecturers to document what is on their computer screen and share it with students. When a student views a screencast, the outcome is like a live incident; it is like watching the lecturer's presentation in a classroom. Lecturers' presence remains vital in training. However, the use of screencasts can elongate a lecturer's presence when students are not in classrooms (Mohorovičić, 2012; Mullamphy et al., 2010).

5.2 Creating screencasts

A methodical workflow of creating screencast by stages will be described. When creating a screencast, there are five steps to follow. These steps are described as the researcher followed them.

5.2.1 Planning

Plan the part of the work you want to do before you start recording carefully. The planning incorporates whatever is recorded; whatever are the goals and content of the screencast. The draft should be thorough. It should consist of a word by word account of all that will be narrated and with the graphic structures of onscreen movement (Mohorovičić, 2012; Powell & Hall, 2002). I found it best for the theoretical parts to plan a verbal account of the screencast, so when the recording begins you can refer to it. In the case of calculations I found working out the example beforehand to be useful so as not to make mistakes in the recording phase. For the theoretical part a PowerPoint presentation was used and for the calculations I used Windows Journal™.

5.2.2 Preparation

In this phase, testing if the equipment is operational takes place. All resources used during the screencast must be prepared. Computer screen should be clear of unnecessary content that could

confuse the student or expose unnecessary information. Software applications, documents, etc. that will be utilised in screencast should be opened and sized to the recording window (Mohorovičić, 2012; Powell & Hall, 2002). I ensured that the antivirus program or other programs did not pop up during recordings and disabled them temporarily.

5.2.3 Recording

The computer screen and voice are simultaneously recorded. It is crucial to speak clearly when recording screencasts. It is also practical to pause the recording when a frame is opened and placed inside the recording area. Everything is recorded in the screencast, as well as mouse movements and clicks which can be edited. Mouse actions should be unhurried when something is being indicated. The rest of the time mouse movements should be coordinated not to become bothersome and confusing to the student window (Mohorovičić, 2012; Powell & Hall, 2002). I talked slower than normally and also pronounced the words correctly, which resulted in voice clarity.

5.2.4 Editing

After the recording, the video should be revised and corrected, if necessary. In the editing stage, the lecturer can: correct video, if some blunders have been made during the recording, they can be edited or cut out; correct audio; add pans and zooms; add titles and highlights; produce a heading and a concluding slide; create transitions, etc. (Mohorovičić, 2012; Powell & Hall, 2002). When the screencast contains minor errors, you could edit it. When larger problems transpire, the developer has to again record the entire episode in order to keep continuity.

5.2.5 Distributing

The screencast capturing program used in this study was Camtasia Studio™, which is a common screencasting software program (TechSmith, 2013). Camtasia Studio™ has a “track-based” interface with video track and audio tracking that permits for non-linear correcting and repositioning digital fragments to earlier or later in the production. Camtasia Studio™ also includes special effects like zoom, pan, locked captioning, splash screens, and transitions that can enhance the application. Completed screencasts can be viewed from almost any device from computers to mobile phones. (Song, 2009).

After recording and editing, everybody concerned agreed and signed off. The concluding files of the screencast should be compiled in the desired file format for publishing and distributing to students. Selecting a video file format will be determined by the distribution method. The screencast should be verified before the concluding publication (Mohorovičić, 2012; Powell & Hall, 2002). As many students had access to DVD players as the only technology, the screencasts were exported as Windows Media Video (WMV) and Audio Video Interleave Video File (AVI) formats. Figure 5.1 is a

screen dump as an example of the interface of the screencasts developed during this study. The complete screencast is available as Addendum 5.1.

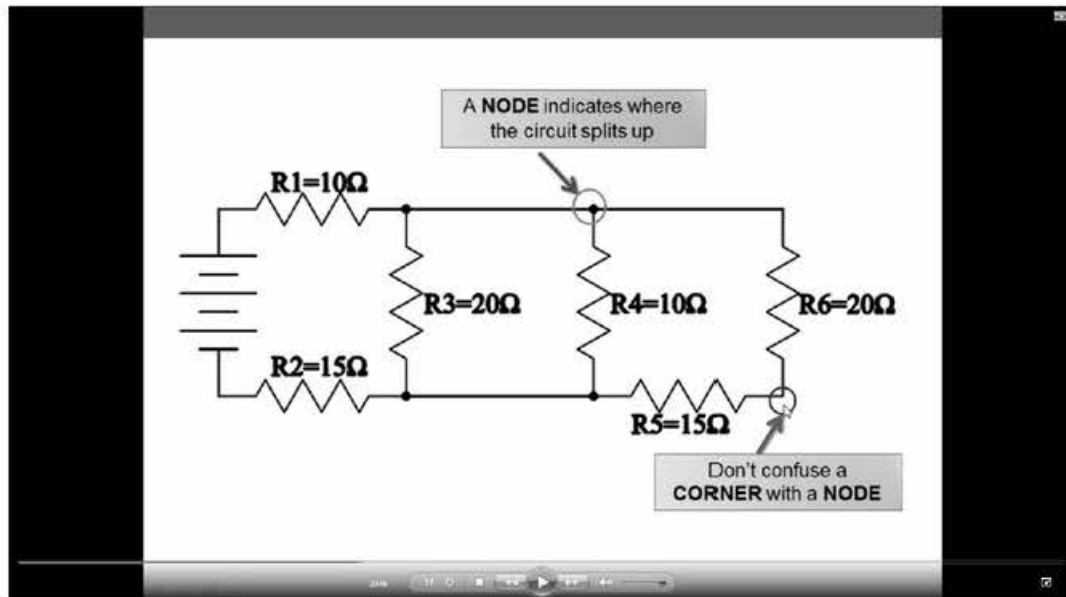


Figure 5.1: Screen dump of a screencast developed during this study

5.3 Implementation of screencasts

The screencast was implemented in the second trimester for the students in the Industrial Electronics N2 classes. The screencast was made accessible to all students and not only to the students that took part in the interviews. The screencast was handed out on a voluntary base. The few students who didn't use the screencast were those who did not have access to a computer; that problem was overcome when the computer class was put to their disposal after normal college hours. The screencasts were there to help the students with solving misconceptions formed in resistive circuits.

5.4 Evaluation of screencasts

At the end of the phase 2 and 3 of the research design the students were given a questionnaire (Addendum 5.2). The group that was surveyed was presented with screencasts that concentrated on the four chosen misconceptions. The questionnaire comprised ten questions, seven closed-end questions and three open-end questions. Though there were ten questions the questions of primary interest were:

- How useful do you find the videos?
- Do you want the screencast done in typing or handwriting?
- What things did you like most about the videos?

The students were given the opportunity to provide feedback on the positive or negative aspects of the screencasts. The survey was voluntary and anonymous and 29 of the 38 respondents (76%) participated in the evaluation (Addendum 5.3).

Table 5.1 Quantitative questions and data relating to the evaluation questionnaire on screencasts

Questions	Options	Counts	Percentage
1. Have you viewed the screencasts provided to you on the DVD?	Yes	27	93%
	No	2	7%
2. Are screencasts easier to understand than the text book?	Yes	25	86%
	No	2	7%
3. Do you want the screencast done in typing or handwriting?	Hand writing	20	69%
	Typing	7	24%
	Missing	2	7%
4. How many times did you use the screencast?	0 times	2	7%
	1-2 times	15	52%
	3-4 times	10	34%
	More than 5 times	2	7%
5. For what purpose did you use the screen cast?	Revision	19	61%
	Clarity	12	39%
6. How favourable or unfavourable is your opinion of the videos?	Poor	0	0%
	Fair	2	7%
	Good	12	41%
	Very good	7	24%
	Excellent	6	21%
7. How useful do you find the videos?	Not at all useful	0	0%
	Somewhat useful	0	0%
	Neutral	4	14%
	Useful	12	41%
	Very useful	10	34%
	Missing	3	10%
8. What things do you like most about the videos? (up to 3 responses)	Personalised	2	7%
	Demonstration	16	55%
	Time	2	7%
	Repeat	20	69%
	See lecturer	14	48%
	Hear lecturer	8	28%
9. What things do you like least about the videos? (up to 3 responses)	Too short	7	24%
	Difficult	3	10%
	Errors	0	0%
	Time	6	21%
	Do not know	4	14%
	Missing	9	31%

Overall, the students found the screencasts favourable with 41% finding them useful and 34% finding them very useful (Figure 5.1). This was very positive as 14% were neutral about the usefulness of screencasts, and no respondents (0%) found them somewhat useful or not at all useful (Figure 5.1).

In response to the question of how many students prefer handwriting in the screencasts above typing, 69% of the students preferred handwriting and 24% of students preferred typing, with seven per cent not answering the question (Figure 5.2).

On the question that asked the students what they liked about the screencasts, they could have chosen up to three options. Sixty nine per cent (69%) selected the ability to watch the screencast more than once, 55% found a screencast a demonstration of how to find what they need and 48% found the ability to see what the lecturer is doing. (Figure 5.3). Most respondents used the screencasts for revision (66%) before a test or examination, rather than using it for clarity on a specific concept (41%, Figure 5.4).

The written comments on the last open ended question were generally positive and concentrated on the flexibility and usefulness of screencasts. Students also appreciated watching supplementary theory and worked examples as well as the capability to watch it over and over again. An analytical set of responses were:

- Can watch it more than once & easier to understand
- When you see it demonstrated you understand it better, because you see how it is done
- The book does not explain everything and it is easier to understand with the screencasts
- With the aid of the screencasts the information can be broken down into understandable concepts.

And an interesting comment of a student about screencasts was: "We know and remember mostly what we see and hear because we are lazy to practise." Not all students learn at the same speed and the repeated use of screencasts could not only improve the learning curve, but will allow students to learn at their own pace.

5.5 Challenges

While there were many positive comments on screencasts, some challenges remain. They include:

- The potential of decreased class attendance
- Loss in student-lecturer relationship
- For a student inactively viewing events on a computer screen, things are occurring at lightning speed. This seemed crushing for some and intriguing to others
- Students who did not complete the questionnaire may not have used the screencasts
- Some students daily travel far from the deep rural areas to study at NCRFET Kathu Campus and they may not have had the time to view the screencasts
- Most students did not have the means to view the screencasts.

5.6 Design principles relating to phases 2 and 3

After the quantitative and qualitative analyses, the recognised design principles that were used during the development, implementation and evaluation of the screencasts prepared for DC resistive circuits as part of phase 2 and 3 of the DBR cycle related to:

- Developing teaching-learning strategies like screencasts to prevent or address misconceptions in DC resistive circuits
- Taking into account the embedded features of effective screencasts
- Assessing the use of the selected teaching-learning strategy like screencasts to improve instruction.

5.7 Chapter summary

The use of screencast does not only NOT jeopardise the continuation of the conventional lecture, it could even increase its potential. Screencasts could enrich learning as they could be included into the teaching and learning development in order to reinforce student learning, as well as during tutoring sessions. Lecturers can offer students a method to view the same learning event repeatedly.

Screen capturing software presents flexibility for a variety of intentions in engineering education. It calls for little or no teaching to use. In future, it can be anticipated that it can be used for other purposes not mentioned here and outside the ones described here (Kruger, 2012; Mullamphy et al., 2010).

Chapter Six

Synthesis, conclusion and reflections on the use of design-based research for developing a technology tool for N2 Industrial Electronics

6.1 Introduction

The term misconception refers to the erroneous perceptions students have about theoretical concepts relating to Industrial Electronics. Students of all ages perceive the theory on electricity as difficult (Sencar et al., 2001). Researchers propose that simple misconceptions about electricity start from a mismatch between simple and expert knowledge structures (Doering & Mu, 2009). The study of electronics as an engineering field, is burdened with learning difficulties because of such misconceptions. In contrast with other engineering fields such as structural mechanics, electronics pose fewer opportunities to acquire a deep sense for the subject (Pulé & McCradle, 2010; Schreiber et al., 2010).

Chapter Four discussed the uncovering of certain misconceptions in DC resistive circuits (§4.3), and the use of technology-enhanced tools like screencasts (§2.2.2.1) in order to support lecturing and to resolve or even prevent misconceptions. While the DIRECT concept test pinpointed misconceptions in DC resistive circuits, interviews provided further understanding of students' four most general misconceptions. The increased use of DBR in educational contexts simultaneously research pedagogical issues while developing TEL tools in order to address teaching-learning. DBR provides the researcher with the opportunity to not only uncover misconceptions in DC resistive circuits, but also develop TEL tools to resolve the identified misconceptions, as well as to evaluate the use of the tools while reflecting on both the outcome of the intervention and the change in students' learning.

31 The purpose of this chapter is to provide a synopsis of the research process, as well as to reflect on the process, the tool and the design principles that resulted from the DBR. This chapter provides a synopsis of each chapter, addresses the research questions, presents recommendations for further DBR according to the design principles which emanated from this study, poses questions that future studies should address relating to issues uncovered during this study, provides a description of value of the research, discusses the limitations of this study, and finally presents the researcher's reflection on his DBR research journey.

6.2 Summary of chapters relating to the research journey

The study was presented as of six chapters; each describing a different aspect of this study. A brief outline of each chapter follows to provide a condensed version of the aspects uncovered.

6.2.1 Chapter One: Introduction to the cyclical implementation of design-based research for the improvement of teaching-learning in an Industrial Engineering course

Industrial Electronics is a subject required for students to comply with the theoretical components of becoming an artisan. The world of electronics is saturated with concepts like the flow of electrons, the build-up of charge, the potential difference etc.—none of which is visible to the naked eye. For a student to deeply comprehend this invisible world of electronics, the researcher grappled with ways to make the abstract concepts more realistic to the students (Bernhard & Carstensen, 2009; Dictionary.com, 2013). Screencasts, a recording of activities that take place on screen which are complemented by audio descriptions to improve the cooperative procedures of teaching and learning (Pinder-Grover et al., 2008; Sugar et al., 2010), could provide a venue to elucidate problematic electronics concepts. Variances in terms of entrance learning continue to be demanding at FET Colleges across South Africa challenged with diverse students that differ in age, gender, language, culture, levels of Internet access, socio-economic conditions and distance to the campus. This is particularly applicable to those who live in remote and rural areas. Engineering students enrolled for blended training courses require support and scaffolding to develop capabilities often far detached from their everyday lives and environments. TEL proposes the advantage of permitting students the autonomy of choosing when, where, and how they want to study (Mohorovičić, 2012).

DBR methodology was ideally suited to this study which had the ultimate objective to construct links educational research and real-world challenges. Iterative research procedures that did not simply assess an intervention, but methodically to improve the design and development while yielding design principles (Amiel & Reeves, 2008), were emphasised throughout the study.

6.2.2 Chapter Two: Reviewing of literature relating to the conceptual theoretical framework

The selection of the literature for this review was based on the conceptual-theoretical framework for the implementation of TEL of Kruger (2012). This study formed part of a project on the use of learning technologies. The literature review comprised the following aspects: (i) the student in his/her specific context; (ii) the interconnection and interrelation between content, pedagogy and technology, concentrating on the student; (iii) design principles related to the implementation of screencasts as learning and teaching instruments; (iv) personalisation as a criterion for excellence; and (v) higher level outcomes (Figure 2.1).

The Northern Cape is South Africa's biggest province but the most sporadically populated. The NCRFET College is one of the fifty merged colleges and attends to four per cent (Figure 2.3) of students attending Colleges in the Northern Cape. The Kathu campus of the NCRFET College provides education to an area from Kuruman and its neighbouring rural towns in the East, Blackrock/Hotazel in the North, Postmasburg/Daniëlskuil in the South and Olifantshoek in the West. Students attending

courses at the campus are mostly Black (55%) with 29% Coloured and 19% White students (Figure 2.5).

Teaching and learning should reach further than students' deskbound lecture room experiences to develop skills and capabilities applicable to their workplace requirements. Students should through self-directed learning accomplish an improved standard of learning (Ramdass, 2009). When lecturers incorporate technology into teaching, students seem to become more interested in the subject matter. In order to accomplish this ideal, lecturers should be able to:

- recognise ways how information technology could add value to the learning of students
- determine content areas where learning technologies would contribute towards students' understanding of content that is difficult to understand or explain with traditional approaches
- launch education approaches to meet students' learning needs
- select suitable technology tools to replace out-dated traditional education approaches
- incorporate learning technology in lecture halls (Cogill, 2008).

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Pedagogy can be described as what one needs to know, and the skills one needs to understand in order to authenticate the miscellaneous choices created during education (Cogill, 2008). Due to the abstract character of Industrial Electronics' subject theories, explanations often comprise complicated teaching language. The traditional approach to tutoring engineering subjects is inferential; starting with a demonstration of basic principles, and then continuing to repetition and extension (Prince & Felder, 2006). In order to address these encounters with the learning content, the use of pictorial demonstrations could augment teaching and learning (Bernhard & Carstensen, 2009; Métioui & Trudel, 2012). A screencast is a digital record of computer screen production which often includes auditory descriptions (Ashdown et al., 2011). When used appropriately, screencasts could become important pictorial demonstrations to support students during their learning. Screencasts could supplement teaching materials and assist distance education students across all academic disciplines (Mohamad Ali et al., 2011; Perraton, 2010; Peterson, 2007).

Inaccurate pre-comprehension can affect the comprehension of concepts that ought to be tutored (Bull et al., 2012). Inadequate conceptual knowledge combined with misconceptions concerning circuit theory has been established to produce learning difficulties with Industrial Electronics. A specific peripheral illustration of a circuit will possibly have positive as well as negative influences on conceptual perception and could lead to particular misconceptions around electronic perceptions. Conceptual information is an outcome and not an originator of learning actions, thus previous capabilities of a student will either endorse or hamper concept development. In an effort to avoid conceptual complications, students resort to inconsequential and often misunderstandings, which lead to incorrect thinking (Ashdown et al., 2011; Razik et al., 2011).

Scaffolding is understood as support offered by a lecturer in assistance of the accomplishment of a task that the learner might otherwise not be able to accomplish. Scaffolding is generally contemplat-

ed as support for students whenever they are engaged in activities just beyond their capabilities. As the students' competencies develop, the lecturer reduces the support until the student has succeeded in developing self-sufficiency with the specific problem (Brickell & Herrington, 2006; Brush & Saye, 2002; Van de Pol et al., 2010). These communal features are summarised in a theoretical model (Figure 2.9)

Personalised learning is a teaching methodology which focuses on the needs, aptitudes, and interests of individual students. Personalised learning is increasingly used to assure that students are able to meet their learning outcomes and potential. Placing a student in the central position, students are encouraged to engage meaningfully with the learning content in order to gain active and insightful understanding of the learning content (Mayer et al., 2004). Personalised learning compels students to use the learning material in order to modify their learning. The grouping and obtainability of assorted media offer students a diversity of cognitive styles, dispositions, and teaching styles (Baylari & Montazer, 2009; Xu & Wang, 2006).

6.1.3 Chapter Three: Design-based research design and methodology

This study aimed to describe the research design and methodology used during this study. DBR is the systematic study of designing, developing and evaluating educational involvements (such as procedures, teaching-learning policies and resources, produces and structures) as answers for complex difficulties in educational practice, which also aims at developing knowledge on the characteristics of these involvements and the techniques of designing and developing them (Plomp, 2010). The process of DBR includes four phases (Figure 3.2): (i) Phase 1: analysis of a practical problem; (ii) Phase 2: development of solutions; (iii) Phase 3: iterative cycles of testing and refinement; and (iv) Phase 4: reflection to produce design principles and enhancement of solution (Figure 3.3). DBR amalgamates investigational research with the design of tutoring situations rooted in philosophy and offers the prospect to improve teaching and learning (Herrington, 2009; Wang & Hannafin, 2005).

The five principal characteristics that DBR relates to are: (a) pragmatic; (b) grounded; (c) collaborating, iterative, and flexible; (d) integrative; and (e) circumstantial (Ashdown et al., 2011). Herrington cautions that the use of technology-enhanced education is often cultivated with designs that put importance on the conduction of info, rather than acceptance of the use of technology as perceptive tools to inspire rationality and perception (Herrington, 2009). The reasoning behind DBR is to form an improved association between educational research and real-world difficulties (Amiel & Reeves, 2008). With DBR the significance is located on an iterative research process that evaluates a revolutionary development or intervention, but systematically attempts to advance the creation but also generates design principles that can direct associated research and improvement undertakings (Amiel & Reeves, 2008). DBR is to design and develop interventions with the objective to answer a complicated educational challenge and to develop our understanding around the structures of these inter-

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ventions and the processes to design and develop them (Ashdown et al., 2011). Figure 3.2 illustrates the process of DBR.

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Quantitative research is about explaining singularities by gathering arithmetical data that are analysed using arithmetically based procedures (Muijs, 2004). The quantitative data in this study took the format of a multiple-choice questionnaire. The questions were quantitatively characterised so that the least possible of errors take place due to prejudice. 102
Statistical methods were therefore used to analyse the data. The quantitative data in this study took the structure of a multiple-choice questionnaire. Qualitative research concentrates on incidences that take place in regular settings and also studies the manifestations in all their complexity by means of interviews, observation and recording processes as they happen unpretentiously (Cohen et al., 2007; Fraenkel & Wallen, 2008).

The population used for this study was the N2 students studying at Further Education and Training (FET) Colleges. To become a qualified artisan the student must not only comply with the theoretical standards, the theory forms only part of a seven step process to become an artisan. The seven steps are indicated in Figure 3.5. Students had to comply with certain pre-requirements to enrol for either the Electrical N2 or Millwright N2-trade. The requirements for enrolment were:

- A grade 12 certificate with Mathematics and Physical Science not below forty per cent
- Passed the Technical Test Battery (TTB) conducted by one of the regional mines.

Sampling comprises a small amount of the considered population for the definite inclusion in the study (De Vos et al., 2005; Fraenkel & Wallen, 2008). Non-probability sampling was used in Phase 1 of the research and can be defined as where the researcher used participants who were available with the characterised categories of features (McMillan & Schumacher, 2001). In the fourth phase non-random purposeful sampling was also used with the interviewing of ten students. In both the trimesters the study starts with a biographical questionnaire combined with the DIRECT multiple-choice questionnaire. Multiple-choice questionnaires have several advantages over other forms of data collection. They are quantitatively characterised so mistakes due to prejudice are insignificant. Multiple-choice questions are normally applied to obtain information that can be rationally divided into specific groupings (De Vos et al., 2005). 35
Data in the second part of each trimester were captured by means of interviews with the students who met the criteria of the sample. The interviewer obtained clarification on questions about common misconceptions about resistive electrical circuits used in Industrial Electronics in the first phase.

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Ethical clearance will be obtained 30 from the Ethics Committee of the North-West University, Potchefstroom campus. The data were analysed by the Statistical Consultation Services of the North West University, Potchefstroom Campus using SPSS. The following techniques were included:

- Descriptive statistics of biographical information relating to frequencies and percentages
- Descriptive statistics of misconceptions relating to frequencies and percentages

- Descriptive statistics relating to cross-tabulations with Cramer's V of biographical information and misconceptions.

Qualitative analysis was performed with Atlas.ti™, a computer-based qualitative analysis program.

The steps followed comprised:

- Preliminary analysis of each open-ended answer in the interview and writing a comment about the findings. Data gathering and examination go hand in hand to build a logical understanding of the data.
- Transcribing the interviews to get a better insight into the misconceptions.
- Organising the data concerning misconceptions and writing memos.
- Generating codes and categories relating to the content analysis.

6.1.4 Chapter Four: Analyses and presentation of the integrated data of Phase I design-based research

This chapter examines phase I of the DBR in terms of the analyses and examination of the research problem. The outcomes therefore incorporate the analyses of both quantitative and qualitative data. The quantitative analyses of the DIRECT concept test added to the descriptive statistics of the biographical information (§4.2), as well as the recognized misconceptions in order to understand and determine the significant variances between the biographical data and the identified misconceptions (§ 4.3) concerning electric circuits.

Most of the respondents (77%) were between the ages of 19-22 years. The male respondents (62%) were more than their female counterparts (38%) enrolled for the course. The cultural groups represented in this study were Black (43%), Coloured (31%), and White (26%). The majority of the respondents (54%) spoke Afrikaans at home, even though most of the respondents came from the black community. The majority of the respondents (63%) were born in the Northern Cape Province (Table 4.1).

The DIRECT concept test established the misconceptions of the respondents. The respondents answered the test, and on the basis of their replies, the researcher identified the most common misconceptions in resistive circuits. Therefore, the four most common misconceptions were accumulated in an open-ended interview test. The majority (95%) of the respondents did not understand concepts of electric circuits. Sixty per cent encountered difficulties to grasp theory of short circuits, 48% did not understand that a battery will always produce the same amount of current no matter the load, and 72% could not apply Ohm's law in the cases represented in Table §4.2.

6.1.5 Chapter Five: Development, implementation and evaluation of a screencasts according to phase 1 design principles for an Industrial Electronics N2 course

Screencasts can enrich learning and they can be included into the education and learning development for reinforcing student learning but also for tutoring the specialists in higher education establishments. Lecturers offer students a method to view the same event or procedure over, and over.

When creating a screencast, there are five steps to follow:

- Step 1: Planning: Plan the part of the work you want to do before you start recording.
- Step 2: Preparation: All resources used during the screencast must be prepared.
- Step3: Recording: The computer screen and voice are simultaneously recorded.
- Step 4: Editing: After the recording, the video should be revised and corrected, if necessary.
- Step 5: Distributing: As many students had access to DVD players as the only technology, the screencasts were exported as Windows Media Video (WMV) and Audio Video Interleave Video File (AVI) formats

The screencast was used in the second trimester for the students in the Industrial Electronics N2 courses. The screencast was made available to all students and not only to the students who took part in the interviews. The screencasts were there to aid the student with resolving of misconceptions developed in resistive circuits. In general, the students found the screencasts advantageous with 41% finding it beneficial and 34% finding it very beneficial (Figure 5.1). Through the question of how many students preferred handwriting in the screencasts rather than typing, 69% of the students preferred handwriting. While there were numerous positive comments relating to the screencasts, challenges remained. They related to the decrease in lecture attendance; harming student-lecturer relationships; students passively viewing actions on a computer screen of events that happen at high speed. Some students seemed overwhelmed while others seemed captivated by the use of new technology. Students who did not complete the questionnaire, may not have viewed the screencasts as some travel daily from far rural areas to attend classes at NCRFET Kathu Campus. They may perhaps not have had the means or opportunity to view the screencasts.

6.3 Addressing the research questions relating to this design-based research study

6.3.1 Research question 1: Determine the nature of misconceptions in the prior knowledge of students registered for Industrial Electronics

Using the DIRECT concept test can give a lecturer the ability to determine the problem areas in the subject. The lecturer can then adapt his/her learning programme by concentrating on the misconceptions. One characteristic of the DIRECT test that sets it apart from other tests that have been developed is the use of batteries connected in series or parallel. This allows a lecturer to investigate in what way students comprehend voltage and current in circuits containing these elements.

6.3.2 Research question 2: Compile guidelines for screencasts of direct current resistive circuits to enhance students' conceptual knowledge

Guidelines to use when producing outstanding screencasts in DC resistive circuits not only can help the researcher but can be helpful to lecturers wanting to use screencasts in the future for supplement to their classes. Though the researcher found the following guidelines to be helpful, the refinement of these guidelines can result in further research:

- Do not use complicated terminology; describe the concepts as plainly as possible without causing a misconception
- Start with easy examples then move to more difficult examples
- Refer from using the "water model" or other physicality's to describe current, voltage and resistance. Stay with the facts.
- When recording use the methods you would have in your normal lecture—this will personalize it for the student.

6.3.3 Research question 3: Compile guidelines for screencasts of direct current resistive circuits to enhance students' conceptual knowledge

A large number of students found screencasts very useful. Students mainly used it for revision, and for clarifying concepts. The ability to watch the screencast more than once helps the students with the revision of the concepts before a test. Students found screencasts also more understandable than a handbook. By using handwriting in the place of typed examples it improved the personalisation effect of screencasts.

6.4 Recommendations relating to design principles

The quantitative and qualitative analyses identified design principles to be used all through the development, application and evaluation of the screencasts made 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.

6.5 Future research

Further research can look into the effectiveness of screencasts over a longer period of time. One can even develop screencasts for a younger audience to address misconceptions before they develop. The data point out that there are differences between the performance of males and females in the sample. Efforts to discover the causes for this gap and that offer ways to close the gap should be followed. These variances might explain the small number of females that take engineering courses and pursue occupations like engineers, technicians and artisans. Additional research needs to be carried out to examine why students do not use a coherent model of circuit performance. The clarification of these occurrences may well justify why students have such trouble with this area of Industrial Electronics. The study reported in this thesis has been constrained to a specific engineering student group but could be used more widely with engineering students studying basic electricity.

6.6 The value of the research

There are two intentions for which DIRECT would be suitable. The first is measuring students' thinking about electric circuits to ascertain what misconceptions the class group has. The outcomes would allow the lecturer to modify the syllabus as needed to accommodate the requirements of the students. The second use would be as a research instrument to establish the influences of syllabus information or new teaching approaches on students' misconceptions. This study has taught the researcher not to assume that all students have the same pre-knowledge of direct current resistive circuits. The researcher's method of lecturing has transformed dramatically from the traditional "talk-and-chalk" to a more technology driven method of using PowerPoint, multimedia projectors and of course screencasts. The researcher also observed that it is better to use the facts on how current, voltage and resistance work than comparing it to other models.

6.7 Limitations of the study

A typical DBR process comprises more than one iteration, but because of time constraints and the scope of a Master's dissertation, it was not possible to do more than one iteration in this study (Figure 3.3). The researcher would have liked to do two or three iterations, and also applied the methods on other campuses throughout the country to compare the misconceptions. Furthermore one of the main characteristics of DBR is the development of a TEL product to enhance teaching and learning. In this study screencasts were developed for a limited part of the syllabus. The researcher would have liked to develop a series of screencasts to cover all the aspects of the N2 Industrial Electronics syllabus when more in-depth information becomes available on the design and development of quality educational use of screencasts.

During the interviews the students were intimidated by the presence of the researcher and stumbled over their words. They answered the questions and then looked for conformation from the researcher. To be more objective the interviews should be facilitated by an outsider. Because of the context of the students, the researcher should have considered other platforms to view the screencasts, other than DVDs. However, the researcher could not consider the use of e-mail as in the deep rural areas, 3G or even ADSL connectivity was not available. The infrastructure for the use of DVDs was not readily available to the students.

6.8 Reflection on my personal research journey

I began my research journey as a lecturer who taught his students in a traditional way. With the evolvement of my research I had a wake-up call: my way of teaching and lecturing can cause misconceptions with students. Sending out a student into the engineering field with a misconception in electronics can cause fatal accidents. With that in mind I began to transform my method of lecturing by using technology that the "Net-generation" can find more usable. The fact that students came back to me and asked if they could give the screencasts to their siblings, for them to view, gave me a warm feeling knowing that not only did I help my students but future students as well. By using screencasts to support my lecturing, I evoked a love in my students for electronics, they now see the subject as a challenge and not a threat.

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 - a. Yes.
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 - a. 0 times.
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 - a. Revision for test / exam.
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6. Overall, how favourable or unfavourable is your opinion of the videos? Please choose **ONLY ONE** response:

- a. Poor.
- b. Fair.
- c. Good.
- d. Very Good.
- e. Excellent.

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- a. Not at all useful.
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- c. Length of time it takes to watch.
- d. Ability to watch it more than once.
- e. Ability to see what the lecturer is doing.
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10. What recommendations do you have to improve the screencasts?
