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 DC resistive circuits
- develop screencasts on DC 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. Burrel 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" (Burrel & 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 (Burrel & 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.

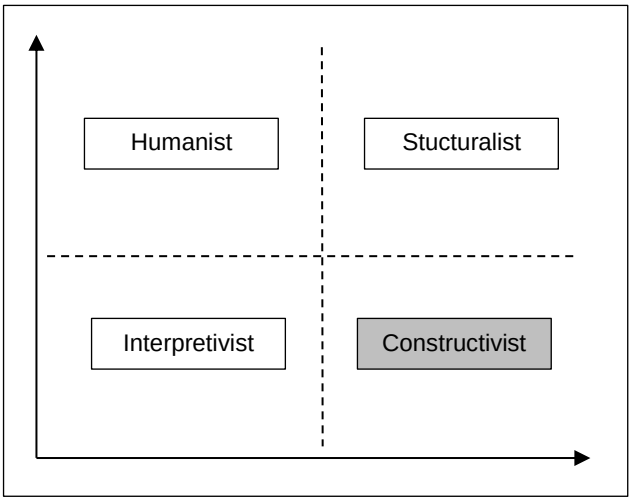

Figure 3.1: Four paradigms for the analysis of social theory (Burrel & Morgan, 1979, p. 22)

3.2.2 Design-based research

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, and 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.

DBR is a methodology planned by and for teachers, that pursues to 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 (Collins, Joseph, & Bielaczyc, 2004; Perraton, 2010). 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 merely at enhancing training; it also addresses theoretical quenstions and challenges. 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	• 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	• 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	• 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	• 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	• 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 TEL 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 (Auerbach & Ferri, 2010). Higher education institutions frequently use ICTs to deliver knowledge "where learners learn *from* the technologies rather than *with* them as cognitive tools" (Auerbach & Ferri, 2010). DBR combines experimental research with the design of education settings embedded in theory and presents the opportunity to advance teaching and learning (Auerbach & Ferri, 2010). DBR offers an inclusive approach to explore the usefulness of dependable education designs (Auerbach & Ferri, 2010; 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 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.

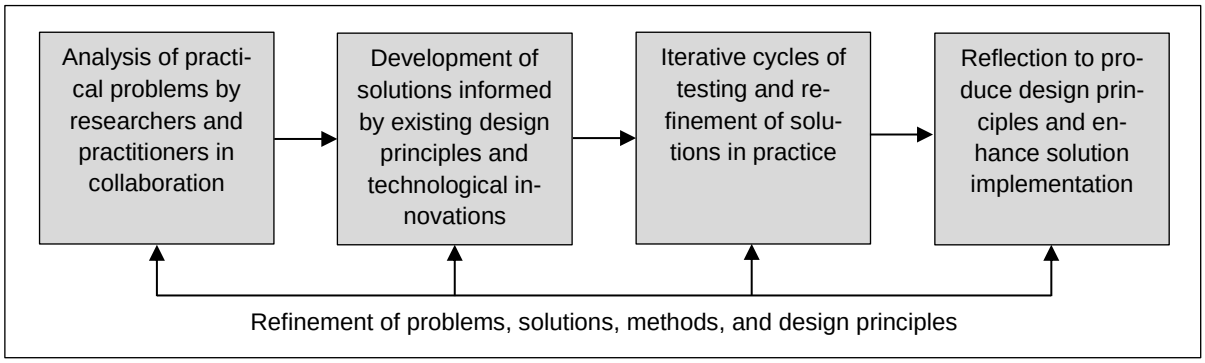

Figure 3.2: **Adopted version of the four stages of design-based research** (Amiel & Reeves, 2008)

KcKenney, Nieeven, 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).

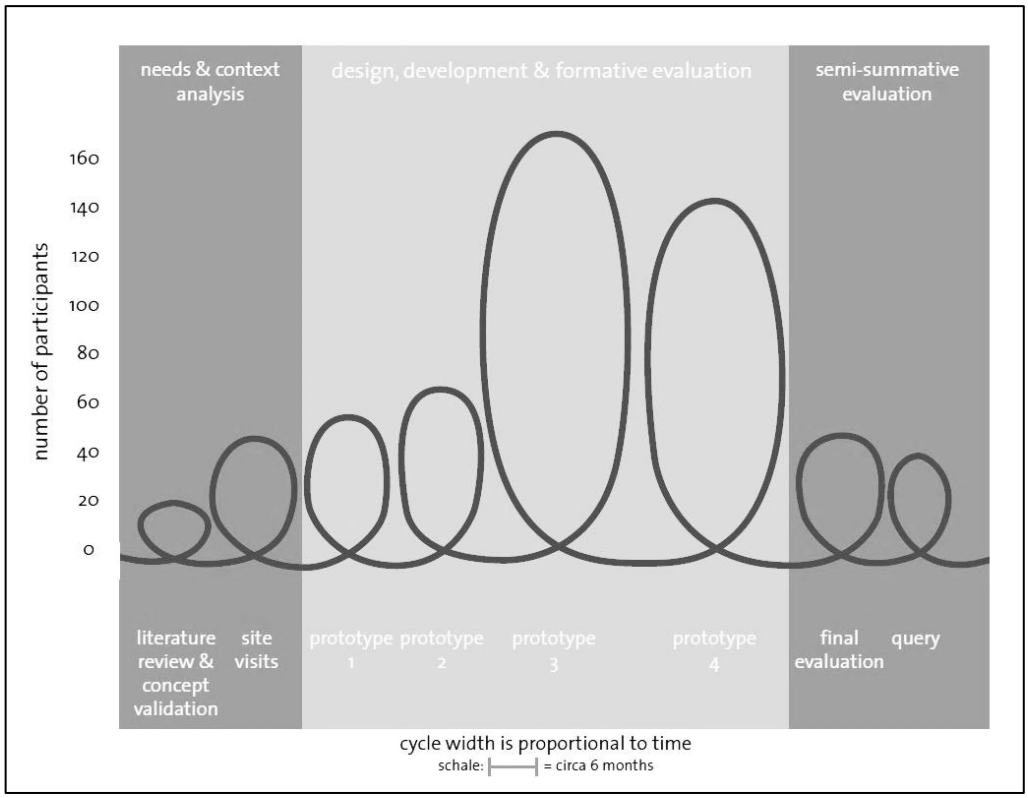

Figure 3.3: Typical cyclical progress of a design-based study (KcKenney et al., 2006, p. 73)

3.2.1.2 Research functions

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

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 DC 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, 2010a; Jordaan, 2005; Mamba, 2005; Turro et al., 2010; Welder, 2012). The design and development of the screencasts focused on implementing educational technologies in order to create authentic learning tasks (Auerbach & Ferri, 2010; 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 DC 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.

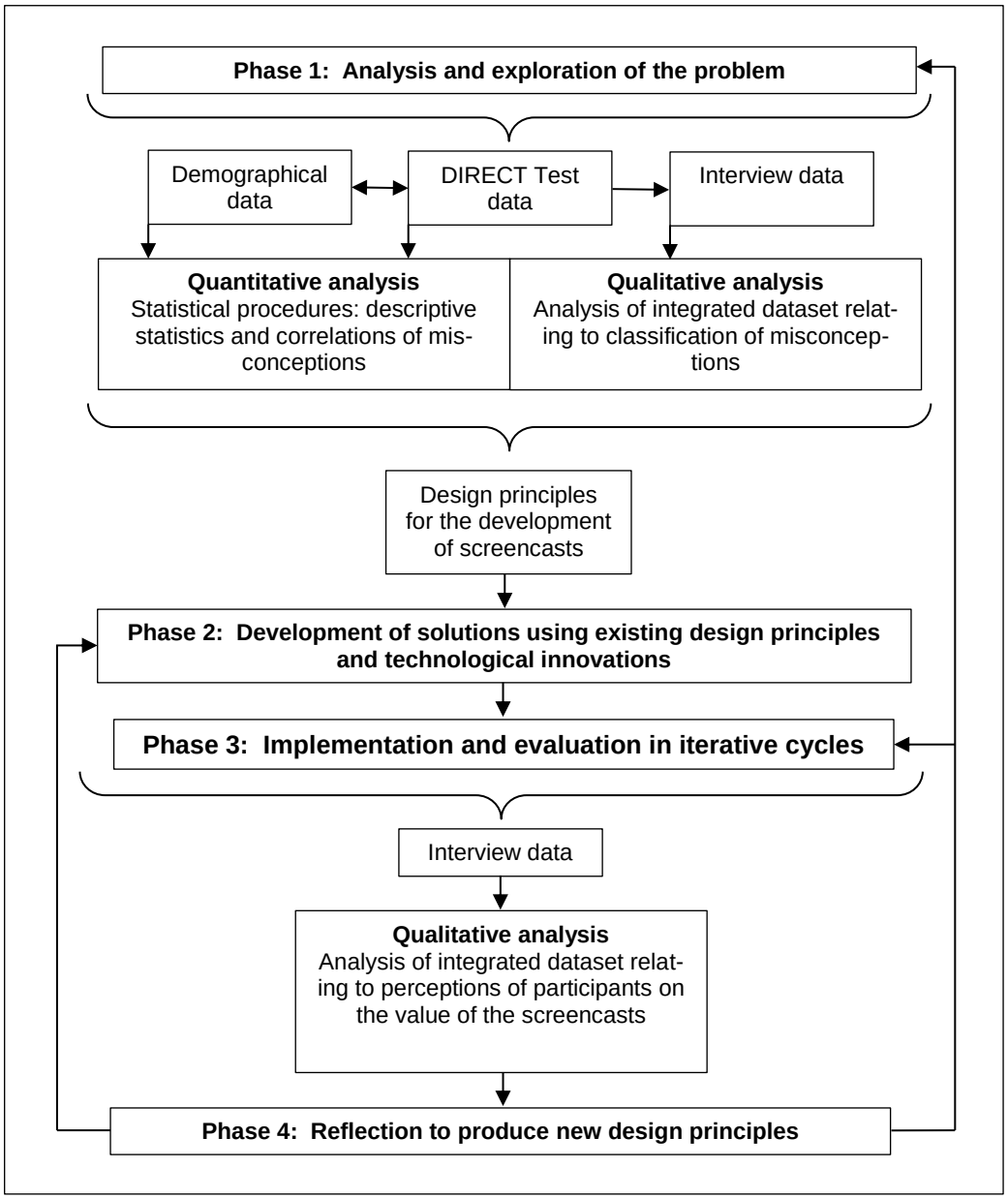

Figure 3.4: Research design and methodology followed during this study

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 (Burrel & 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 (Perraton, 2010). 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).

3.3 Population

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 fledge 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.

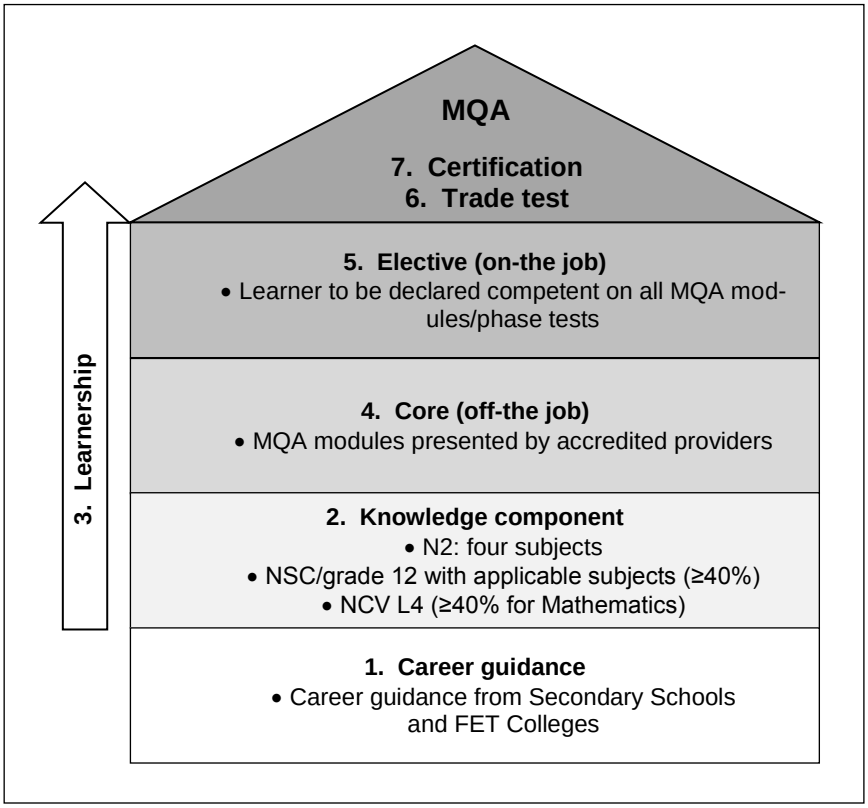

Figure 3.5: Adapted seven-step process to become an artisan (Pretorius, 2011)

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 (Pinder-Grover et al., 2008).

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, 1996).

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 judgement 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 DC 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 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
- 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

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 scrunity 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; Herrington et al., 2007; Juuti & Lavonen, 2006; Perraton, 2010).