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 (Sengupta & Wilensky, 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 (Grotzer & Sudbury, 2000; Pulé & McCradle, 2010).

Chapter Four discussed the uncovering of certain misconceptions in DC resistive circuits (§4.3), and the use of TEL 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.

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; İpek & Çalık, 2008). 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 (Oud, 2009; Pinder-Grover et al., 2008), 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 (Hoadley, 2004).

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 aimed 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 Barker et al. (2010). 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; (ii) 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 (Mukora, 2008). 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 TEL could add value to the learning of students
- determine content areas where TEL 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 TEL tools to replace out-dated traditional education approaches
- incorporate TEL in lecture halls (Sahin, 2011).

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 (Sahin, 2011). 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 (Wang & Hannafin, 2005). 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 (Jesus & Moreira, 2009; Periago & Bohigas, 2005; Toto, 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 (Mangieri, 2009; Wang & Hannafin, 2005).

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 contemplated 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: Planning 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 (Auerbach & Ferri, 2010; 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 (Wang & Hannafin, 2005). Herrington cautions that the use of TEL is often cultivated with designs that put importance on the conduction of info, rather than acceptance of the use of TEL as perceptive tools to inspire rationality and perception (Auerbach & Ferri, 2010). 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 interventions and the processes to design and develop them (Wang & Hannafin, 2005). Figure 3.2 illustrates the process of DBR.

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. 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). 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.

Ethical clearance will be obtained 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 DC 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% had the misconception that a battery will always produce the same amount of current no matter the load, and 72% could not apply Ohm’s law in 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 a N2 Industrial Electronics 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.

Step 3: 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 DC 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

In order to determine the nature of misconceptions of students the DIRECT concept test were used to determine the general misconceptions. Four common misconceptions were identified for further analysis:

- Students exhibited shared misconceptions with electric circuits as they had *inadequate understanding of the basic concepts*. They had difficulty differentiating between basic concepts like current and energy. Most of the respondents selected the option that represented that properties of energy were given to current, and respondents credited the effect of electrical charge in the bulb’s filament to current—which is incorrect.

- The student could *not apply their knowledge to practical electric circuits*, for example, the electric field distributes the force which triggers the charges to increase speed, causing in a current to flow.
- Students *used terminologies like electricity, current, voltage, potential difference, energy, and power interchangeably and incorrectly*. They had the misconception that current and voltage always happened together; current was the cause for voltage, and if one increased, the other would also increase. This illustrated the issues relating to current/voltage *term confusion*.
- Students had *poor understanding of short-circuits*. For example, they indicated same brightness in circuits where bulbs were shorted out. Respondents arguing that the current was exhausted and that a battery was a continuous current source.
- The students had many misconceptions relating to *series or series/parallel combinations*. 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 argued the misconception that a battery was a constant current source and/or current was depleted.
- Overall, respondents could recognise a complete circuit. The challenges arose when respondents were requested to make decisions whether the circuit was functional or not, often included shorted circuits. Answer option B and option D of question 2 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. Almost forty per cent of the respondents selected option D and almost ten per cent selected option B. 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 to be reduced.
- Students had misconceptions relating to the application of Ohm's law. They demonstrated that they 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. They also applied Ohm's law directly, not considering that the resistance in the circuit stayed a constant value.

6.3.2 Research question 2: Explore students' perceptions regarding the usefulness of screencasts as cognitive learning tools

The students perceived the screencasts as important TEL tools in their education environment. In general, the students found the screencasts constructive:

- Forty one per cent (41%) found screencasts useful and thirty four per cent (34%) very useful.
- Most respondents favoured handwriting and about a quarter of the students (25%) favoured typing, with seven per cent not answering the question.
- The students found the screencasts useful for different reasons: almost seventy per cent (69%) selected to watch the screencast more than once, more than half (55%) of the students

found a screencast useful because it provided an explanation of how to find what they needed.

- Almost half (48%) of the respondents found the ability to see what the lecturer was doing valuable.
- Most respondents (66%) used the screencasts for revision before a test or examination, rather than using it for clarity on a specific concept. The ability to watch the screencast more than once helps the students with the revision of the concepts before a test.
- The respondents found screencasts easier to understand than a textbook.
- The use of screencast did not risk the continuation of the traditional lecture but it could strengthen its potential.
- Screencasts could improve students' learning, but they could also be used for the training of lecturers at higher education institutions.

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

In order to compile guidelines for screencasts in DC resistive circuits one has to know the nature of the misconceptions the screencast are going to address. 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:

(i) **Start with a summary:** A general set of instructional policies focused on offering a general idea of a specific concept by introducing the concept, providing a motivation for learning the concept, and linking the concept to future lessons.

(ii) **Describe the process:** The emphasis on delivering practical information containing audio account and the presentation of procedures and assignments.

(iii) **Present the concept**: In addition to teaching practical information in screencasts, an explanation must be offered of a specific concept related to the screencast topic.

(iv) **Provide details on the concept**: Elaborate outside the topic with respect to a specific concept, or additional feature of the screencast. This instructional approach enables chances to enrich students' perception and to inspire students to contemplate other features of the procedure or concept related with the screencast's subject-matter. By supplying these supplementary particulars, the lecturer makes background references to comparable instructional surroundings that are related to the screencast content. Do not use complicated terminology; describe the concepts as plainly as possible without causing a misconception. When recording use the methods you would have in your normal lecture—this will personalize it for the student

(v) **Emphasis on the concept**: Attention directing is additional instructional approach used. The account and/or arrow position guide students' attention to a specific component on the screen or to a certain portion of a general process. Start with easy examples then move to more difficult examples. Stay with the facts.

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 1 of the DBR cycle.

The identified design principles were:

- Understanding of concepts
- Understanding short circuit theory
- Misconception that a battery is a constant current source
- Rule application.

Evaluation of the screencasts prepared for DC resistive circuits as part of phase 4 of the DBR cycle related to:

- Start the screencast with a summary about what the topic is about
- Describe the process that will be followed in the screencast
- Presenting the concept in such a manner that it is understandable for the student
- Provide details on the concept so the student could understand the concept and focus on the facts
- Emphasise the reason and use of the concept.

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 DC 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 cycle (Figure 3.3), but because of time constraints and the scope of a Master's dissertation, it was not possible to do more during this study. 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 TEL 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.