# "WE SHOULDN'T HAVE TO DO THIS; WE'RE GIRLS!" AN EXAMINATION OF GENDER, SELF-EFFICACY AND CONCEPTUAL UNDERSTANDING IN ELECTRO-TECHNOLOGY FOR A CLASS OF TEACHER TRAINEES IN DESIGN AND TECHNOLOGY AT A SOUTH AFRICAN UNIVERSITY

by

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# ABSTRACT

This study examines the effect of contextualised learning of DC circuits by a group of design and technology teacher trainees at a South African University. Using a pragmatic approach to research design and drawing on two major theoretical frameworks, namely constructivism on the one hand and feminist theory on the other, data from diagnostic tests, questionnaires, classroom tasks and interviews were analysed to investigate the intersection between gender and learning electro-technology. Evidence from these data suggests that gender, more than educational background is the dominant factor not only in determining attitudes towards learning electricity, but also conceptual understanding on entry into the course. This research shows that female students in this particular context are more likely to exhibit unipolar thinking in their analysis of DC circuits than their male counterparts and that this pattern of thinking persists even after substantial exposure to instruction. Female students also have lower levels of self-efficacy, and greater levels of anxiety compared with male students when faced with performing electro-technical tasks such as physically wiring and soldering. This they attribute to the perception that electro-technology is the preserve of men and boys and that their identity as girls does not include them being able to perform electro-technical tasks. While contextualising the learning of electro-technology in a project that was meant to be attractive to female students did appear to make a difference to attitude, this research also showed that the effort to improve female students self-efficacy through a variety of initiatives, including developing mastery of electro-technical processes meant that in the end, female students performed as well as male students on the task. The implications of the findings of the four papers that make up the study suggest that further research needs to be carried out towards understanding issues surrounding the learning of electro-technology by female students, including the development of a unified theoretical framework to analyse such data gathered.

# Dedication

First, I would like to dedicate this to all those who through fear and self-doubt felt that they could not achieve that which others so effortlessly seemed to manage.

Secondly, I would like to dedicate this to my mother, who were she still alive would have chuckled at the title of this thesis, but been proud of me nonetheless.

# ACKNOWLEDGMENTS

I would like to first thank my partner and best friend, Jean Parkinson, whose tireless one-on-one instruction for the last 28 years has improved my life substantially.

Secondly, I would like to thank my supervisor and friend, Paul Hobden for his continual patience and belief in me, my colleagues at UKZN and also at WelTec for their support, Robert Morrell and Deevia Bhana for their continued encouragement and support and also to the reviewers of the submitted papers that took the time to provide feedback and help me to improve my writing – whoever you are, thank you.

# DECLARATION

I James Ross Mackay declare that the research reported in this thesis, except where otherwise indicated, is my original work.

(i) This thesis has not been submitted for any degree or examination at any other university.

(ii) This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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Signed: JMackay. Supervisor

20th March 2012

NOTE:

This thesis is a made from a compilation of four papers with different styles of referencing, two of which I am the sole author and two of which are co-authored by a colleague. Where appropriate, reference to the shared work has been made and for the co-authored papers, a breakdown of each author's contribution has been provided.

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# Chapter 1
# Introduction

This thesis is constructed from a compilation of four papers that have a common theme, that of female students learning electrical conceptual knowledge as well as the procedural knowledge to do with constructing real circuits. The four papers are linked together with explanatory text outlining the relationships between each paper as well as the connection of each paper to the fundamental research questions. In this chapter, I have discussed the rationale behind the research, the key research questions as well as given a detailed description of the structure of the thesis. While each paper has a survey of the literature pertinent to its own focus, I have compiled a general literature review in chapter 2 that includes all of these as well as a discussion of the theoretical perspectives I have drawn on in order to understand the findings of each paper.

## Focus and purpose of study

In most countries, technological careers are far more likely to be taken up by men than women. These careers are usually better paid than those in which women predominate. Technological careers are also more likely to be viewed as being more natural to males than to females. The notion that science, mathematics and technology are "male subjects" in school and university appears to be part of a vision of social organisation where men are associated with the active, with reason and with public life while women are associated with the passive, with emotion and with the private sphere (Young, 1990). Cultural beliefs too are permeated with the assumption that technology is male and subtly influences both the way children view themselves as well as the educational choices they make. This is influenced by the home as well as the school, which makes teacher training an important element in building an equitable society. It is because teacher trainees are participants in society and as a consequence reproduce societal cultural assumptions, that they too could view themselves as well as their future learners as being more or less able to understand and engage with technology depending on their gender.

To counter this, in order to improve female teacher trainees' self-confidence in learning electricity, this study seeks to document the development of basic electrical concepts through the context of a kind that female students are said to enjoy such as the design and building of a doll's house. According to Mackay and Parkinson (2010), both Atkinson (2006) and Silverman and Pritchard (1996) have shown that this kind of technological task is favoured by girls learning design and technology. Electro-technology in my experience, appears to be one of the bodies of knowledge least favoured by female students training to be teachers. This is the central issue of the study. The heavily gendered position that learning electricity takes in the curriculum tends to produce female learners who, on average are more passive than their male counterparts in the technology classroom, and likely to be happy to let their male counterparts take the lead in anything to do with learning practical electricity and connecting wires. This is evidenced in the classroom described in this study where over the years I have seen that female learners are unsure of their abilities and are deferential towards their male counterparts who although they don't often have more conceptual knowledge, they have the confidence to try different solutions to practical problems. Female students who come from schools that are disadvantaged in terms of their resources and teaching capacity are even worse off. Not only do they have a gendered approach to things electrical, but they also have to contend with conceptual problems arising from a poor academic background that was a consequence of their impoverished schooling.

**The notions of gender and self-efficacy**

Central to this study is the notion of gender. There are a number of interpretations of gender in the literature and this thesis acknowledges that from a postmodern perspective, third wave feminist theorists have identified multiple feminine and masculine identities present in our interpretation of gender. The consequence of this is that it is simplistic to identify women as one group with a single identity. Gender is considered to be a socially constructed identity that determines how one performs and interacts with others (McPherson, 2000), which according to Haraway (1991), has an impact on why and how females learn and create scientific knowledge. This large difference between women in any single group produces a multiple set of femininities. However, while most of the reference to gender in this thesis reflects the simplistic Male / Female dichotomy, I have alluded to the development of the idea of multiple femininities and masculinities that could have an impact on the way the data collected in this study are interpreted in the final chapter. Since there was no fine measurement of multiple femininities developed, it was not used as a variable in this study since to do so would not have provided me with reliable and valid results. However, this is a possibility for future studies as has been suggested in the final chapter of this thesis.

As with the notion of gender, I would like to define early on the idea of perceived self-efficacy, before a detailed discussion in the literature review. The idea of perceived self-efficacy as being the belief in one's own ability to carry out a particular task, or the belief one has about one's capabilities within a certain sphere of endeavour, is important to this study in that the data suggests that this perceived self-efficacy is central to the way female students appear to learn electro-technology. As will be discussed later in the literature review, people with high perceived self-efficacy try harder, accomplish more and are more persistent than those with low self-efficacy. Changing people's perceived self-efficacy levels is the subject of this research.

In summary, the purpose of this study is to explore and document those factors that affect the learning of electro-technology through the implementation of a contextualized project in which electrical concepts and processes are embedded in a task that female students tend to favour.

## Background to the study

This investigation of South African students learning Technology Education is complicated by the persisting differential in school background in the South African population. This means that to a very great extent the educational disadvantage (facilities, class size, teacher qualification etc.), which was put in place by apartheid policies, continues in schools that were previously set aside for the Black African population (Education and Management Information System, 2006). The extent to which this disadvantage in schools persists 12 years after apartheid ended, is reflected in the 2006 Progress in International Reading Literacy Study (PIRLS) data (Mullis, Martin, Kennedy & Foy, 2007), which show South Africa as the worst country with regard to grade 5 reading, out of 40 countries surveyed (including developing and other African countries). This differential between advantage and disadvantage is the legacy of different funding levels for different race groups under apartheid; despite current attempts to improve this situation, such change is slow; improvement in some aspects, for example teacher qualifications, is likely to take generations. To these factors, that of teacher qualification level can be added. Most South African schools, particularly those originally designed to cater for and still attended largely by Black African students, remain disadvantaged by these measures. Enduring disadvantage in most South African schools combines with many of the gender-related factors touched on above to further disadvantage girls who attend such schools. Other factors, including family background, rural/urban origin, family income, parental occupation, etc. also have potential to blur results.

Gender and population group differentials with respect to education in general and grade 12 Mathematics and Science attainment in particular is also relevant to this study. On one hand, female access to education grew between 1996 and 2002 (Perry & Fleisch, 2006), with a higher proportion of female than male children being retained in the school system. More than 50% of candidates who wrote, passed, and gained grades necessary to attend university in the grade 12 exam between 1996 and 2002, were female, and although the percentage pass rate of male candidates remained higher, this difference declined from 8% to 3% over this period (Perry & Fleisch, 2006). However, in terms of gender differences in mathematics and reading at the grade 6 level, the Southern and Eastern Consortium for Monitoring Education Quality (SACMEQ) study (Saito, 2010) provides us with evidence that the gender difference in achievement between boys and girls in South Africa favours girls, so that while the performance compared to other African countries is poor, there is possibly a greater degree of gender equality in schooling at lower levels. On the other hand, although the pass rates and overall numbers taking mathematics and science was fairly evenly matched with regard to gender in other population groups, participation and success of Black African male candidates was far higher than females'. For example, in 2002 only 23% of Black African female candidates passed Higher Grade Mathematics (20% passed Science) compared to 31% of Black African males (27% passed Science) (Perry & Fleisch, 2006). More recent statistics published by the Department of Education (Department of Education, 2012) do not include data on differences in population group for secondary schools; these differences are only published for tertiary institutions. The data on secondary education provided however, indicates that there is a marked difference in performance in mathematics and physical science based on gender. Of those that sat for National Senior Certificate examinations at the end of 2009, only 18.5% female candidates achieved more than 40% in physical science compared with 22.8% of male candidates. The situation for mathematics is slightly better with 26.3% of female candidates achieving more than 40% as a final grade compared with 33.0% of male candidates (Department of Education, 2012).

Comparisons with other countries worldwide in mathematics and science performance in recent years have shown that South African youth do not perform as well as their international counterparts (Saito, 2010). The kinds of difficulties that are exhibited by South African students are consistent with those recorded elsewhere in the world; however, students entering tertiary study have shown alarmingly low levels of conceptual competence, even amongst high achieving students (Stanton, 1989). International studies such as the Trends in International Mathematics and Science Survey (TIMSS) test has ranked South Africa lowest in terms of learner performance in science of those countries where the survey was conducted (Martin, Mullis, Gonzalez & Chrostowski, 2004). Understanding how simple direct current (DC) electric circuits work is a key curriculum outcome in South Africa, even for those students who do not pursue the study of science to the end of high school (Ministry of Education, 2011) and is addressed in the science curriculum in grade 6, grades 8 and 9 and also later in grades 10, 11 and 12.

## Rationale and contribution to current knowledge

Factors influencing participation and achievement in Technology in school and beyond are of greater interest to science and technology education researchers in

South Africa than ever before, given that the South African Department of Education has in the last few years combined traditionally female and male focused subjects, Domestic Science and Technical Drawing into a new subject, Technology, which has been made compulsory for all pupils up to grade 9. This signals a desire to improve technological understanding and participation in technological careers in the population, for females as well as males. This desire is particularly urgent for demographic groups who, reflecting the apartheid history of South Africa, are underrepresented in this area of the workforce. However, if we fail to examine the gender imbalance in technology-related careers and reasons for this, it is highly likely that the current male dominance in technological professions in historically advantaged sectors of the population will be reproduced in historically disadvantaged groups.

The lack of self-efficacy amongst women in terms of technological careers is in this study key to understanding the problem of underrepresentation of females in specific areas of the workforce. Aronson et al. (2005) defines self-efficacy as the "belief in one's ability to carry out specific actions that produce desired outcomes". Self-efficacy is developed through persistence and effort at a task and, as Bandura (1994) finds, people with high self-efficacy usually experience lower anxiety, and are more likely to view tasks not as difficult but as challenges that can be overcome. One way of developing self-efficacy is through mastery of difficult tasks, and in this intervention a gender-biased task is used to contextualise basic electrical concepts in an attempt to improve the self-efficacy of female students in electro-technology. Improving participation levels in electro technology in tertiary institutions starts not in high school or in the years just prior to entering a polytechnic or university, but much earlier, in the home and in primary school when gendered beliefs of what is and what is not appropriate for women are formed. In this study I scrutinize data that is derived from multiple sources to answer four key questions that are outlined in detail in the next section.

As a contribution to current knowledge, this study provides an insight into the way some female students perceive their learning of electricity. It also provides insight into the pervasive 'clinging to simplistic conceptual patterns of thinking' by students despite many educators considering them trivial and easy to eradicate in the classroom. Evidence presented in chapters 4 and 7 indicates that these patterns simply "hide" themselves well, only to re-emerge later when the student attempts an unfamiliar task. The continual re-emergence of unipolar patterns of thinking as well as indications of transitional thinking where students combine mutually exclusive conceptions, is also a strong contribution that this study makes to current knowledge. From a gender perspective, the issue of lack of perceived self-efficacy as a contributing factor to success amongst female students and the differences in the students' reflections from an emotional point of view are explored in chapter 6.

## Key research questions

At the beginning of the study, I was curious as to why some female students in my basic electro-technology class were opposed to the course in general, in spite of the fact that they were on the whole good students who worked hard and usually achieved high grades. Their reasoning put forward to me on a number of occasions was that while they loved design and technology and were good at it, electro-technology was a body of knowledge that they felt was inappropriate for their studies, simply because they were female. This was stated by one group of students, (who in fact made a formal complaint about the inclusion of electro-technology into their curriculum) in so many words: "We shouldn't have to do this – we're girls!" I was motivated to formally study this and in the end used this statement as the title of the study. The school curriculum (Ministry of Education, 2011) clearly indicates that as design and technology teachers they will have to teach at least basic electricity to primary school children and those who were training to teach higher classes would have to include more than basic electricity.

### Developing a research question

My initial interest was to find out why the female students in my classes did not like learning electricity and this coincided with an attempt to contextualize the learning of basic electricity and electronics by imbedding this learning into projects that the students might like to design and make. Context and gender appeared to be part of a greater web of variables that were interlinked and that had an effect on the attitude and performance of the students. To summarize, there are four key questions this study seeks to answer.

**Overarching question**

*What factors affect the learning of electro-technology by female students?*

In simplifying this question, I have reformulated it into four more direct questions that will be the focus of the four papers that make up this study. The four papers are linked to each other in that two of the papers have been written to answer questions that have arisen from the other two. In this way, the questions that are stated below were not all formulated at one time, but rather were generated over a period of time. My initial interest can be summarized by the question above.

**Question 1**

*What are the differences between male and female students in the way they understand electrical concepts?*

I have attempted to answer question 1 in paper 1 which is described in chapter 4 of this thesis. It arose from observations in class that female students seemed to have a poorer grasp of the conceptual ideas than did their male counterparts, and that this seemed to have an effect on their being able to connect circuits. At first, I put this down simply to differences in schooling; however, it seemed odd to me at the time since female students in my experience in the faculty generally performed better than male students. Question 1 therefore signals the beginning of this study.

**Question 2**

*How was performance on the Doll's House task affected by the perceived self-efficacy of female students?*

I have attempted to answer question 2 in paper 2 after noticing that female students generally lacked confidence with electro-technical tools and processes, but not with tools and processes of other parts of the technology curriculum. It seemed that female students would often be able to use quite sophisticated tools (like a band saw), but developed a fear of specific electro-technical tasks such as soldering. This lack of self-efficacy appeared to be a barrier to their success, along with the perceived lack of conceptual knowledge I had investigated with question 1. Question 2 therefore signals the beginning of the second part of the research project.

**Question 3**

*What were the students' emotional responses to the Doll's House Project?*

After exploring students' levels of self-efficacy, it became evident from the data gathered in written reflections from the students that there was considerable emotion generated around the Doll's House task. In view of this emotional response that seemed to be primarily from the female students, I decided to formulate question 3 to further probe the differences in emotional response between male and female students. Male students appeared to be less emotionally invested in the project and this next question arose out of an interest in probing this difference. The study outlined in paper 3 addresses this question directly.

**Question 4**

*What common errors were made in drawing both circuit and wiring diagrams and in what way do these errors reflect the students' conceptual thinking?*

Finally, something that also triggered curiosity when looking at the data was the way students drew circuit and wiring diagrams. These seemed to reflect the conceptual change that was happening while students were coming to terms with the electrical ideas I had taught them. It was clear from the diagrams that students' misconceptions about electric circuits had resurfaced and that the diagrams appeared to represent transitional ideas they had developed. Question 4 has been addressed in the fourth paper that is outlined in chapter 7.

These four questions I have formulated to encapsulate the entire study. Each question is answered by a different paper; however, there is much more to the study than the answers to these four questions. Earlier, while giving some background to the study, I discussed the persisting differential in education that has resulted from the policies of apartheid in the past. In the four studies, it will become clear that gender is not the only a factor that affects performance; another is relative educational advantage.

However, the overarching question pertains to the effect of gender on learning electro-technology and it is clear that of the four questions that have been developed from this question, the only one that does not pertain to the effect of gender is question 4. This is because question 4 arose from scrutiny of the data collected to answer questions 1, 2 and 3.

## Structure of this thesis

This thesis comprises eight chapters. The first chapter introduces the study and outlines the focus and purpose as well as the key research questions. In chapter 2, I discuss the background literature and theoretical frameworks that will be used to interpret the data collected in the study. In this discussion, two overarching views of learning, that of constructivism and how it relates to the learning of electricity and that of feminist theory and how that relates to the interpretation of the attitudes developed by female students regarding their knowledge of electricity are brought together to form a single pragmatic framework for analysis. Figure 1.1 below shows the structure of the study.

Chapter 3 discusses the research paradigm that I have chosen to use and the related research methodology, which is a pragmatic approach, as well as the design of the study and the techniques I have used to collect and analyze the data. This is an important and pivotal chapter since the research paradigm I have chosen is related to the frameworks I have outlined in chapter 1 on the one hand, but also to the collection of papers that make up chapters 4 to 7 on the other hand.

The four papers that make up chapters 4 to 7 follow a rough chronological order. Chapter 4 is a discussion of diagnostic pretest data collected at the beginning of the study that largely looks at the gender differences in the responses to the pretest questions and since the questions themselves are related to patterns of thinking in electricity, this paper ties the gendered way we think about electrical knowledge to the performance of female students in electro-technology.

In chapter 5, I discuss in much more detail the gendered performance of students on the design and technology tasks that were given to them. Evidence for this is in the scores attained by the students in the final project and examination as well as in the reflections that were gathered at the end of the course and the questionnaires completed by the students.

In a sense, chapter 6 is an extension of chapter 4 in that it has been developed from a closer look at the student reflection data. An APPRAISAL analysis of these reflections is used to further explore the gendered nature of the responses to learning electricity.

The last paper relates back to the first paper which looked at differences in patterns of thinking about electrical ideas between male and female students. These patterns of thinking re-emerge in the discussion of student drawings of wiring and circuit diagrams. While there is some evidence to suggest that there are differences in the way male and female students draw wiring diagrams that is context dependent, this is not alluded to in the paper itself, but has been discussed in the supporting narratives.

These four chapters, two of them already published (chapters 5 and 6), and the other two under review (chapters 4 and 7); provide an insight into the differences in the way male and female students learn electricity as a topic. These differences are discussed in the final chapter which is then related back to the theoretical frameworks discussed in chapter 2 as well as the research paradigm discussed in chapter 3.

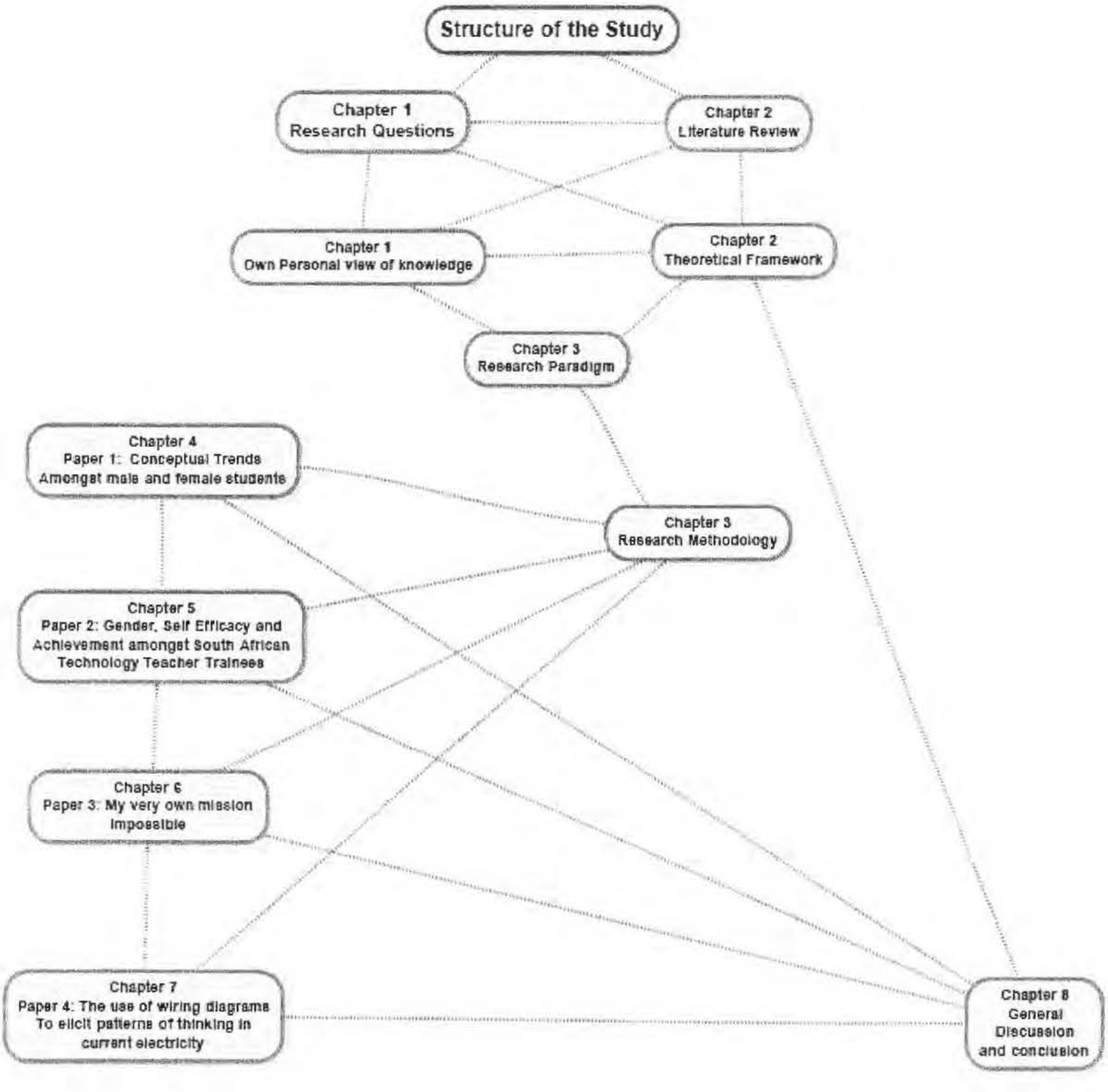


*Figure 1.1* Structure of the study.

The key overarching question is answered in different ways in each of the four papers, but these contributions are brought together in chapter 8 as a final conclusion to the study where I have used selected frameworks for theoretical analysis as tools to formulate an argument based on the one hand on the wealth of knowledge in the literature regarding the learning of electrical concepts and conceptual change while on the other hand the persuasive arguments on the effect of socialization on learning that have emerged in the last six decades from social theorists worldwide.

# Chapter 2
# Literature review

This study is positioned between two main bodies of literature. The first body of literature is the substantial amount of work that has been conducted over the last three decades in the field of alternative conceptions used by students in understanding electricity as well as the development of conceptual change theory in understanding the way students change their ideas about electricity. The second body of work is the literature on gender studies worldwide and the differences in achievement and engagement between male and female students particularly in science and technology. This literature review draws together literature that has been presented in the papers that make up chapters 4 to 7.

## Learning electricity

The use of non-scientific models of current and electric circuits by students and pupils has been the subject of numerous studies over the last four decades. Tiberghien and Delacote (1976) have identified patterns of thinking in basic electricity that students use to inform their actions and decisions when solving electrical problems. These patterns in thinking determine student performance in tasks that they are given and in so doing, lead to errors in answers to test items that are commonly used for assessment. Stanton (1990a) differentiates between errors, preconceptions and misconceptions in the context of learning as being derived from mental models, where errors are explained to be the consequence of preconceptions which lead to particular consequences in data interpretation.

### Accepted alternative conceptions of the way circuits work

Early work by Gilbert and Watts (1983), Tasker and Osborne (1985) and Shipstone (1988) identified several different models that learners use in trying to make sense of electric current and simple DC circuits. Arons (1981) also documents a number of incorrect ideas that persist even after intervention, right until university study. The nature of these mental models that students employ are such that they hinder the conceptual development of any learning of current electricity. These models are outlined in Table 2.1 below which summarises Shipstone's (1988) categorisation of the most common incorrect models of thinking students use in understanding currents and circuits.

Table 2.1. *Elementary Models of current (Shipstone, 1988)*

| Model | Description |
|---|---|
| Unipolar or Sink | Current from only ONE terminal (either positive or negative) No circuit, only a connection from the "power source" to the bulb |
| Clashing Currents | Both a "positive" as well as a "negative" current meet at the bulb and "clash" causing the bulb to light |
| Dissipative or Attenuating | Current is "used up" as charge moves around the circuit. Greater current near the (+) pole, dissipating further away from (+) / If negative charge is predominant, current "comes from" (-) pole |
| Sharing | Current is shared by the different components in a series circuit |
| Scientific | Current is the same everywhere in a series circuit. For the bulb to light, there needs to be a completed circuit. |

**The unipolar or sink model of electric current**

Of these models, the least complex is the *unipolar* or *sink model* of electric current. The *attenuated* or *dissipative* model is a more sophisticated model of thinking in that while it incorporates the idea of a complete circuit, it has a non-scientific idea of current / component relationships within the circuit. It is however, still a model of current that understands current as being "used up" by components in the circuit. Both approaches operate within a non-conservative or consumptive paradigm of electric current and the dissipative model appears to develop naturally from the unipolar approach. In other words, students that used the unipolar approach would have a similar interpretation of circuits as those who used the dissipative approach.

Unipolar thinking has been identified as being the alternative conception least resistant to intervention. This is evidenced by the fact that researchers tracking the dominance of different models over ages ranging from late primary to secondary schools often do not even record it as being sufficiently significant to warrant inclusion into the data (Shipstone, 1988). Tasker and Osborne (1985) in New Zealand found that only around 5% of pupils showed evidence of unipolar thinking and that this was quickly extinguished through directed instruction and the use of focused inquiry tasks. This is however, not supported by Stanton (1990b), who found that in South African students studying physics, the unipolar model survives quite well after initial instruction at school. Reasons for this are unclear and not addressed by Stanton (1990b). McDermott and Shaffer (1992) link the consumptive model to the confusion between energy and current. One would expect the consumptive model of current to naturally lead to drawings of circuits and wiring plans that were peculiar to the models of current informing their ideas about electricity.

**Other common difficulties in electricity**

The main focus of this study from a conceptual development point of view, is the investigation of students unipolar ideas, in their conceptual thinking, however, it is also important to have a wider view of other common difficulties mentioned in the literature that students have encountered in interpreting and building circuits. In this section, I have outlined these other difficulties and mentioned how they may be related to this study. These difficulties are stated below.

McDermott and Shaffer (1992) also identify the lack of concrete experience with real circuits with the failure by students to understand the need for there to be a complete circuit. Related to this is the problem students have in not being able to recognise that the circuit diagram does not necessarily represent physical or spatial relationships and that it is only a schematic representation of connections. This may be of significance to this study as students displayed poor spatial abilities in drawing diagrams as well as interpreting them. In addition, many students had not had any experience connecting circuits before. While she acknowledges the limited generalizability of her study on naïve circuit diagrams drawn by children, Marshall (2008) concludes that the ability to decode circuit diagrams may not reflect an ability to think abstractly about electrical concepts. She does however suggest that alternative coding schemes used by children might be useful in designing instructional programmes.

Other common difficulties outlined by McDermott and Shaffer (1992) include the confusion between potential difference and current, which is related to the common confusion which is between energy and current. This too is related to the unipolar idea, where there is a "one way" flow of energy from the cell to the bulb. Confusing energy and current could well lead to unipolar thinking in drawing circuit and wiring diagrams.

More recent work by Küçüközer and Kocakülah (2007) confirmed in an extensive survey of Turkish students, all of the common difficulties outlined in earlier research summarised by McDermott and Shaffer (1992) and in addition found two alternative conceptual models that were peculiar to Turkish students, which they attributed to language issues and the way electricity was taught in school. This finding is also pertinent to the study as many students are second language speakers of English and so there could be a language issue, although this was not the focus of the study.

Engelhardt and Beichner (2004) developed a useful test for the identification of alternative conceptions in current electricity and used it to compile an extensive list of these conceptions. Much of their work has served to confirm earlier research in this area.

Jaakkola, Nurmi and Veermans (2011) compared students understanding of electric circuits when using simulations only and then using a combination of hands on and simulation exercises and found that the combination of hands-on exercises integrated with simulations provided students with a better understanding of the way circuits work than just simulations alone. This was even true when direct instruction was provided with the simulations. Work done by Tsai, Chen, Chou, and Lain (2007), found that students understood and made sense of different circuits in different ways and that student's conceptions of current were strongly influenced by context. This is particularly relevant to this study, since the circuits and wiring diagrams drawn are context-related.

## Conceptual change theory

In this section, I have discussed conceptual change theory for two reasons. The first is that the intervention given to the students in this study was designed around facilitating conceptual change in the classroom. The second reason is that evidence collected in paper 4 on the way students draw wiring diagrams suggests that these students are in transition from one conceptual framework to another.

Specific to science education has been the more recent work conducted over the last three decades on conceptual change theory. Treagust (2006) describes conceptual change as a process where a restructuring of pre-instructional conceptual structures takes place in order to allow deeper understanding of particular science concepts. Clement and Steinberg (2002) refer to a change that is structural in nature and not one that simply changes the surface features of the conception in question. Baser (2006) describes four teaching techniques that have been discussed in the literature to facilitate conceptual change. The best known of these approaches to dealing with alternative conceptual frameworks in the classroom, initially proposed by Posner, Strike, Hewson and Gertzog (1982) is the idea of providing opportunities for cognitive conflict to take place. In this approach, they suggested that students only change the way they think about a concept if they are first *dissatisfied* by their current conceptual frameworks. If the new conception is *intelligible, plausible* and *fruitful* in solving problems in new situations, it will take root (Posner et al., 1982). For this to happen effectively, a teaching strategy must allow time and opportunity for the student to first become dissatisfied with their current model and then work through the new model that is presented in order to understand it properly and then finally use it in a new situation.

Hewson, Beeth and Thorley (1998) proposed addressing the preconceptions that the learners have through direct intervention using exercises and questioning that exposed these preconceptions and put the learner in a state of *conceptual conflict* (also used by Arons, 1981). The Generative Learning Model (GLM) developed by Osborne and Wittrock (1983) explains learning as a process that focuses on the learner's generation of links between his / her memory store and selected inputs. New meaning is constructed as the learner tries to relate this new idea to experience and new ideas are then accommodated alongside already accepted ideas. Status is then placed on the idea depending on whether it is intelligible, plausible or useful. Problems arise in the implementation of this model by the teacher, when the learner deviates in understanding from what is intended by the teacher.

Niedderer and Goldberg (1994), while studying the conceptual development of an individual student in learning about basic electric circuits, noticed that the student started with common alternative mental models about current and then moved through conceptual development phases using intermediate concepts, prior to developing conceptions that were closer to the scientific view of electricity. This process of integrating prior, everyday ideas about electricity with ideas that were more closely related to the scientific approach they termed *conceptual ecology*, a kind of overall mental model of the process of moving through intermediate developmental phases. Niedderer and Goldberg's idea of intermediate or developmental models is supported by Grayson (2004) who uses the idea of conceptual substitution as a way for teachers to use the intuitively correct ideas of students as a platform to develop scientifically correct concepts. In her study she outlines the complexity of the conceptual change process in addition to the development of intermediate conceptions students have while this change is taking place. Related to this is the use of bridging analogies and forming a link between students' correct conceptions and new knowledge. Clement and Steinberg (2002) reported the use of a strategy that used a cycle of concept generation, evaluation and then modification to teach direct current electricity in a single student case study. Hart (2008) describes the use of appropriate teaching models in developing student conceptions of electricity. She puts forward the idea that conventional physics models are not always good teaching models and that since models play such a significant role in our understanding of microscopic phenomena, these should be selected with care and introduced at times when students need them to facilitate conceptual change.

Borges and Gilbert (1999) describe a conceptual progression of mental models that students go through in developing their ideas about electricity, starting from the idea of electricity as a flow of "stuff" from the energy source to the various components. This then might progress to a model of "electricity as opposing currents" which describes two different types of electricity in a circuit, a notion that still does not conserve current. A development on this is the model of "electricity as moving charges", which Borges and Gilbert (1999) see as a mechanistic view of what happens in a circuit, finally leading to the field model of electricity, which can be used to explain the action of a single charge at a distance from the electrodes. These models of how electricity works in circuits can be closely related to the models of current attributed to researchers like Shipstone (1988) and Tasker and Osborne (1985).

However, not all researchers have viewed conceptual change as the most important idea in learning. Linder (1993) suggests that context, particularly if it is socially determined, has some influence on conceptual appropriateness. Different contexts generate different concepts of the same idea and that what may be more important is conceptual appreciation. This is also supported by Hewson (1996) in his revision of previous work on conceptual change theory. In other words, a student could develop an understanding of a physical concept within a particular context. This would allow for multiple conceptions that are context dependent.

While the development of new knowledge in science has for centuries made use of models and analogies to develop understandings of new phenomena, the use of models and analogies in the learning of science has only recently been acknowledged (Cheng & Brown, 2010). Earlier work on misconceptions sought to relate students' mental models to historically defunct theories in science, leading to descriptions of student thinking as "Aristotelian" or "Galilean" thus connecting this thinking to incorrect misconceptions that had since been abandoned historically through major paradigm shifts. Similarly, those researching the field of conceptual change in the learning of physics have relied on the notion of paradigm shifts to effect conceptual change in the classroom (Hewson, 1996).

More recently however, theorists have preferred to view the origin of these mental models that students' have in terms of "sub-conceptual" intuitive or naïve ideas that are used to construct the preconceived patterns of thinking that are then displayed in student work.(di Sessa, 1993; Vosniadou, Vamvakoussi, & Skopeliti, 2008). Both di Sessa and Vosniadou et al. see conceptual change as being more gradual and both focus on intuitive pre-concepts. In di Sessa's theory, these are called phenomenological primitives or p-prims and in Vosniadou's theory, presuppositions.

The notion of phenomenological primitives (p-prims) as introduced by di Sessa reveal that mental models that students develop can be linked to naïve conceptions that are based on the student's experience of the world. These are more fundamental knowledge structures that form the basis of such "misconceptions" and which are created when the student approaches the problem or situation for the first time. In electricity, such a fundamental knowledge structure would be the sense that electricity is a kind of "matter" that flows from the "producer" to the "consumer". This intuitive conception that "stuff flows" can be applied to heat, water flowing downhill and electricity and as such, could form the basis of the unipolar models that are evident in student thinking. The idea of a pre-concept that is derived from

In Brown's framework for the interpretation of student misconceptions, as outlined by Cheng and Brown (2010), four core elements are discussed; verbal-symbolic knowledge (generalisations that are consciously remembered), explanatory models, implicit models and core intuitions that form the basis of initial preconceived models of thinking about phenomena.

In summary, Shipstone's (1988) categorisation of mental models of current and the way circuits work is a useful framework for the analysis of common errors made by students in developing circuit and wiring diagrams in this study. In particular it is interesting to note that there have been some recordings of the persistence of the unipolar model in other studies (Stanton, 1989) and that the work done by Borges and Gilbert (1999) identifies a progression of mental models of electricity that inform thinking about how circuits work. Issues of context are particularly relevant to this study and the work by Linder (1993) on the effect of social contexts as well as Tsai, Chen, Chou, and Lain. (2007) on the effect of context might explain some of the data that will be presented later.

Duit and Treagust (2003) outline three limitations of the classical conceptual change approaches that were initiated by Posner, Strike, Hewson and Gertzog (1982). The first of these is the narrowness of focus of conceptual change strategies that only looked at the change in science concepts, without considering the changes that need to take place in the student's understanding of science processes and the nature of science. Secondly, Duit and Treagust (2003) maintain that conceptual change strategies took no account of affective factors and thirdly, the learning environment and the socio-cultural factors that affect learning were not considered.

## Gender and technology

At the outset, it is important to note that in this study, the term gender refers not merely to the biological differences between the sexes, but more importantly to the construction of femininity and masculinity in society today. I will return to these issues in greater depth later in this chapter in the discussion on theoretical frameworks. Parts of the following discussion are reproduced from the second paper published emanating from this study (Mackay & Parkinson, 2010, p. 87-88).

According to Mackay and Parkinson (2010, p. 88) much literature exists, based mainly on US and European research, regarding differential performance and participation of boys and girls in technology. This study seeks to extend this research to include the perspective of a developing country, and one whose education system has suffered the disruptive influence of apartheid policies. While no evidence exists for innate difference in ability (AAUW, 1992; Francis, 2000; Silverman & Pritchard, 1996), boys receive more familial encouragement in technological fields (Mammes, 2004), and play games that develop spatial abilities. School technology tasks appear designed to be more interesting to boys than girls (Silverman & Pritchard, 1996; Weber & Custer, 2005). Boys outperform girls in technology, have higher interest levels in it (Schiefele, Krapp & Winteler, 1992), and show interest in different aspects of technology than girls (Atkinson, 2006; Jones & Kirk, 1990; Mammes, 2004;

Silverman & Pritchard, 1996; Weber & Custer, 2005). Female participation in technology decreases in higher grades, combining with parental perception of the inappropriateness of technological careers for girls (McCarthy & Moss, 1990; Woolnough as cited in Davies & Elmer, 2001) to result in low participation of women in technological careers (Brainard & Carlin, 2001; Francis, 2000; Mammes, 2004), incidentally also among the best paid careers (Mackay & Parkinson, 2010, p. 89).

As has been pointed out in Mackay and Parkinson (2010, p. 87), globally, more men than women take up technology-related careers. For males, this technological work is better paid than it is for females and in addition it is widely viewed as more natural to males than to females. The gendering of science, mathematics and technology as male is part of a naturalised vision of social organisation in which men are associated with the active, with reason and with public life while women are associated with the passive, with emotion and with the private sphere (Young, 1990).

The assumption that technology is male permeates cultural beliefs and subtly influences the way children view themselves and the choices they make. Both home and school influence this, making teacher training an important element in building an equitable society. Because teacher trainees participate in and thus reproduce societal cultural assumptions, they too view themselves and their future pupils as more or less able to understand technology depending on their gender. From my experience as a science teacher over the last 25 years in Southern Africa, it is important, especially in South Africa, to counter these assumptions in order to improve the self-efficacy of female teacher trainees so that they can serve as role models for their own pupils. There is also value in tasks that challenge the idea amongst both male and female teacher trainees that technological tasks themselves are gendered (Mackay & Parkinson, 2010, p. 88).

According to Mackay and Parkinson (2010, p. 88), not all design and technology tasks are found by female students and pupils to be unattractive. The literature points to a number of specific design and technology tasks that are seen by female students and school pupils to be attractive. These include design (Atkinson, 2006) and building houses (Silverman & Pritchard, 1996), although, as Lewis (1996) points out, such preferences may be a manifestation of the differential treatment afforded male and female children (including females' primary early socialisation from a parent of the same sex while males are usually socialised by parents of the opposite sex).

Lewis (as cited in Mackay & Parkinson, 2010), distinguishes between a context-driven approach to curriculum design and a content-driven approach in that it takes social, environmental and physical contexts as starting points and uses these to move towards the theories, models and laws that are the starting point of a content-driven curriculum. In this thesis, the task uses the context of building a house to move towards a greater understanding of electrical circuits. Taking students' educational and home background into account, attitudes and levels of self-belief in being able to achieve a technology task are measured before, during and after the task, to see whether doing the task had a positive effect. I also consider achievement on the task and an examination (Mackay & Parkinson, 2010, p. 88).

As outlined in Mackay and Parkinson (2009), this study proceeds from the assumption that differences in participation and achievement of female students in technology and technological careers do not arise from ability differences, but from social attitudes viewing certain fields as less appropriate for women. These attitudes are embedded in the subtly different ways that male and female children are treated (Nicholson, 1984; Smith & Lloyd, 1978) and these attitudes are transmitted through discursive practices (Davies, 1989). The study considers how female and male students express these attitudes, and what effect this has on performance.

Self-efficacy, popularly self-confidence, is the 'belief in one's ability to carry out specific actions that produce desired outcomes' (Aronson et al., 2005, p. 485). One can have generally high self-esteem but lack belief in one's abilities in a certain area. Self-efficacy predicts persistence and effort at a task. People with high self-efficacy experience lower anxiety, and are more likely to view tasks not as difficult but as challenges that can be overcome (Bandura, 1994). Ways of developing self-efficacy include mastery of difficult tasks (indicating importance of practical work) and seeing social models achieve the behaviour (accounting for higher confidence in ability to achieve technological tasks in male compared to female students) (Bandura, 1994).

**Gender and performance in science and technology**

The differential performance and participation of boys and girls in science and technology has been one of the focal points of a number of large studies that are currently underway, for example: Project ROSE (Schreiner, 2006). These studies have in general pointed to the differences in choice made by female pupils and students when it comes to selecting areas to study and they have attempted to explain some of these differences. In these projects and in research conducted over the last few decades, differences in participation and achievement of female students in technology and technological careers have not been seen to have arisen from ability differences, but rather from social attitudes viewing certain fields as less appropriate for women (Nicholson, 1984). These attitudes are embedded in the subtly different ways that male and female children are treated (Nicholson, 1984, Smith & Lloyd, 1978) and transmitted through discursive practices (Davies, 1989). Many school science and technology tasks appear designed to be more interesting to boys than girls (Silverman & Pritchard, 1996; Weber & Custer, 2005).

Mammes (2004) attributed this differential performance between the genders to greater familial encouragement given to boys and the tradition of boys playing games that require spatial abilities. This could be a factor in understanding electrical concepts that require the interpretation of visual representations. Atkinson (2006), as well as Silverman and Pritchard (1996) found that female pupils and students learners preferred some science and technology related tasks over others. An example is the design and construction of model houses (Mackay & Parkinson, 2010).

Acker and Oatley (1998) have pointed to the differences in choice male and female students in Canada make when choosing careers, leading to a general arts / science split. This they say could be due to many factors, including social and psychological, school and other influences. These choices have far reaching consequences. Women in science and technology have a generally lower status with lower salaries and fewer promotional prospects than do their male counterparts (Acker & Oatley, 1998).

The feminist critique of science and technology as being male reaches beyond equity issues that were central to early feminist thinking. Morrell (as cited in Acker & Oatley 1998) has noted that little change has taken place in the development of ownership of many of the sciences as a consequence of the feminist movement. Some sciences remain "male" in character, engineering and physics being good examples of this. Acker and Oatley (1998) point to the feminist critique of science that calls into question the hierarchies and the structure of science itself as being an enterprise that seeks only economic advancement and in so doing has a devaluing effect on humanity. They suggest that a feminist science in contrast would be more caring, non-hierarchical and more environmentally and socially responsible. This is a contrast between the "male" science and technology as an enterprise that seeks to control nature as compared with a feminist agenda that seeks to work with nature.

Haraway (1985) is critical of those who reject technology and has argued that there is a need to embrace the potential that technology has to offer. This is supported by Oakley (1998). While science has been male dominated and alienating, there have been technological advances that, while they may be alienating in practice, have provided benefit to women worldwide. Most of these have been in the field of medical science. Wajcman (2000) argues that the postmodern view of science and technology is one where these are seen as a culture that, like all cultures, changes with time. Haraway's (1985) excitement at the prospect of new technological possibility shifts the feminist debate away from the ecofeminist position of social and environmentally responsible science being the hallmark of feminist science. Several feminist scientists have argued however that a central tenet of "good science" is that it is gender free. Rosser (1998) reacts to this by pointing out that for science to be gender free, society must be gender neutral and until that happens, the development of a feminist science must continue to be assumed.

In summary, the research discussed above points to differences between male and female not in ability, but rather in preference and that society has constructed some science and technology as being inherently "male". This gendered view of science and technology acts as a barrier to participation and learning for female students.

**Gendered attitudes to science and technology in learning**

There has been an awakening worldwide of the necessity to document differences in learning science and technology in relation to various demographic variables, gender being a key variable. Many of these studies have taken place in countries with developing economies and signal an important concern in what actually goes on in the classroom. Several of these studies have shown that in primary school at least, female students show greater interest and have a more positive attitude towards science. Mihladiz, Duran and Dogan (2011) in an extensive study of attitudes to science in Turkey found that $6^{th}$ and $7^{th}$ grade female students from middle income families had a more positive attitude to science than did their male counter parts. This appears to be supported by White's (1999) study that in the UK found that in primary school, males generally have a more positive attitude towards science, but that this shifts to favour females in later years. A study in China by Chuang and Cheng (2002) also supports this finding. A different finding is reported by Akpınara, Yıldıza, Tatarb and Ergina (2009) who in an extensive study in Turkish primary schools found that female students showed a greater interest in science than did their male counterparts. However, they also found that as in most countries, interest in and enjoyment of science tend to tail off the older the students get. They suggest too that there needs to be further work done on the effect of self-efficacy and anxiety in relation with student attitudes and achievement. Similar studies in Pakistan (Iqbal, Shahzad & Sohail, 2010) have shown more positive attitudes towards science from female students, with, however, greater anxiety compared with male students

Osborne (2003) in a comprehensive survey of literature on attitudes to science highlights gender as being a significant influence on the selection of science and technology related careers. In his article, Osborne (2003) cites several studies, (Breakwell & Beardsell, 1992; Erickson & Erickson, 1984; Harding, 1983; Harvey & Edwards, 1980; Hendley, Stables & Stables, 1996; Johnson, 1987; Jovanic & King, 1998; Kahle & Lakes, 1983; Robertson, 1987; Smail & Kelly, 1984) that have shown that girls attitudes to science are significantly less positive than those of boys. This is not to say that tremendous strides have not been made in the development of gender sensitive materials and curricula and the effort to attract more girls into science and technology, but with all the effort that Osborne (2003) describes, in the United Kingdom, there is still a differential in take up of the physical sciences between boys and girls. The numbers quoted by Osborne are more or less equal in chemistry and with 1.6 girls to every boy in Biology, but, disturbingly, 3.4 boys to every girl in physics. This difference in take up within the sciences could, he speculates, be due to the fact that biology and biotechnology are the leading area of innovation in the late $20^{th}$ century. Factors such as the student's perception of the science teacher, self-esteem, motivation, anxiety, attitudes of peers and parents as well as the association of a subject with a specific gender identity are all components of a student's decision to select not only to do science, but to take a specific science subject.

Elwood and Comber (1995) have shown that girls in the United Kingdom are achieving as well as boys, which implies that it is not poor performance that has an effect on girl's attitudes towards the sciences, particularly physics. Whitehead's (1996) research attempts to show that the difference in take up between males and females in science is more to do with boys selecting stereotypically masculine subjects, sometimes in contradiction of their interests, and girls selecting more according to their interest than in order to conform to a feminine stereotype. This, they say, results in boys being overrepresented in some subjects and underrepresented in others.

Reid (2003) looked specifically at attitudes to physics over the age range 10 to 18 and has pointed out that in Scotland; there is a marked decline in attitude from early secondary school, particularly amongst girls. He points to the teaching of physics in lower secondary school as being an area that needs attention, if this decline is to be remedied. However, he reports some reverse in this decline in the later years of his study period particularly amongst girls, Ambrosea and Fennemab (2001) maintain that there is a difference in attitude between males and females toward mathematics and science, which could have been produced from their different classroom experiences. In addition, these differences have not been ameliorated through the gender sensitive curriculum and instruction initiatives that were implemented in the 1980s and 1990s. Finally, with the largely failed attempt to change gendered attitudes towards science and technology, Henriksen (2010) proposes four reasons why seeking a gender balance in science and technology education in important. The reasons given by Henriksen are that science and technology (S&T) need women because S&T needs more people in general, that women bring new perspectives and ways of working to science and technology, that women need S&T so that they can have influence over their own lives as well as the wider community and that everyone, including women should have a real free choice in their education. A key component according to Henriksen is the development of female self-efficacy with respect to science and technology.

**Gender and spatial visualisation**

Gilbert, Boulter and Elmer (2000) have compared modes of representation commonly used in technology with those used in science and while both disciplines use visual representations like diagrams, Design and Technology makes greater use of concrete modes of representation such as physical scale models. The use of such models requires the learner to transition between 2-D and 3-D thinking in Design and technology much more than it does in science. Being able to understand and create visual representations such as 3-D diagrams is a cognitive skill that is fundamental to performing well in both science and technology. While there has been considerable work done comparing spatial reasoning abilities across cultures, gender and class backgrounds, Mitchelmore (1980) maintains that there has never been any concrete evidence to suggest that it is related to innate ability. The differential performance in science and technology between male and female learners has according to Mammes (2004) been attributed to greater familial encouragement given to boys and the tradition of boys playing games that require spatial abilities.

## Frameworks for theoretical analysis

In analysing the data I have collected, I have drawn on several ideas put forward by social theorists over the last six decades. I have divided these ideas into two categories. The first are general theories of learni

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classroom. The second category of ideas that has ir

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free themselves from the need to deal directly with the environment and sta categories. The first are general theories of learning that have provided a foundation to my understanding of the learning that takes place in a science and technology classroom. The second category of ideas that has influenced my thinking and interpretation of data in this study is drawn from social theorists who have influenced our understanding of society in general and the societal influences that create the lasting way in which the female students in this study see themselves in relation to their social worlds, their families and their identities as (female) teachers. Throughout this section, I will try to relate theoretical concepts to my experiences of teaching electricity in a technology class, as a justification in part for the frameworks that I have chosen, but also as a way of setting the scene for the chapters that are to follow.

## General learning theories

### Cognitive learning theories of Jean Piaget and David Ausubel

Cognitive learning theories play a major role in science education, both as theoretical constructs that underpin research and as the basis for the design of learning programmes at all levels of schooling and tertiary education. Central to the development of science education as a field of endeavour has been the theory of constructivism and central to this is the work that was conducted by Jean Piaget. In this research, constructivism underpins not only my interpretation of the data collected, but also the design of the instructional model used to teach electricity and so it is important to retrace the roots of those ideas here.

According to Piaget's theory of cognitive development (Olson & Hergenhahn, 2009), children's understanding of science concepts largely depends on whether or not they have reached the so called "formal operational" stage in their cognitive development. Children start off with a few sensorimotor schemata onto which the build and attach information they glean from the environment as a result of their initial interactions. In his theory, Piaget postulated four stages of cognitive development; the first, as already mentioned is the sensorimotor stage, where children assimilate new information and use these to modify their schemata. This process continues until the child is able to free themselves from the need to deal directly with the environment and start dealing with symbolic manipulations. This is called Interiorization (Olson & Hergenhahn, 2009).

The sensorimotor stage usually takes place in the first two years of development and is followed by the two sub stages of the pre-operational stage, the first being preoperational thinking (two to four years) and the second a period of intuitive thought, from about four to seven years old. The concrete operational stage lasts from around seven to eleven years of age and in it children are able to categorise and conserve concepts. The final, formal operational stage is characterized by abstract thought. All these stages, Piaget linked to biological developmental periods in a child's growing up.

In the Piagetian framework, new knowledge is constructed at the interface between the mind and reality, by a process that combines assimilation, where the mind imposes a structure on reality and accommodation where the mind conforms to reality. This combined process is called equilibration and it represents a dynamic equilibrium between the mind and reality (Olson & Hergenhahn, 2009). When conceptual change occurs, this equilibrium is upset and a new process of assimilation and accommodation occurs. This theory of the building of knowledge in this way is called constructivism and can be seen as a combination of empiricism and nativism.

In contrast to Piaget, David Ausubel's theory of meaningful learning, as outlined by Novak (1977) implies that it is not necessary for a learner to go through the different Piagetian stages. Rather, the greatest factor influencing what the child learns is what the child already knows. This means that as long as the subject matter is presented to the learner in a logical conceptual sequence, any concept can be learned. This explains the ability of some children to reason formally at an early age.

Ausubel places rote learning and meaningful learning on two ends of a continuum. When meaningful learning takes place, new knowledge interacts with existing knowledge and cognitive development takes place, not in stages as Piaget theorized, but as a continuous process of successive differentiation and integration of ideas within a cognitive structure. The ability of a person to recall a relationship between concepts, rather than the specific details, is an indication that meaningful learning has taken place. The idea of progressive differentiation is in direct contrast to Piaget's theory of developmental stages where concepts are acquired depending on the stage of development.

**Lev Vygotsky and social constructivism**

As with Piaget, in Vygotsky's idea of social constructivism (Olson & Hergenhahn, 2009), learners construct their own understandings and meanings from their own experiences. This is done through a process where sense of new information is made by constructing links to prior knowledge, or connecting new knowledge to existing schema. Vygotsky however, emphasises the importance of the social aspect of learning, and the fact that learning is mediated through the interaction with a "more knowledgeable other". This is one of the ways in which he differs from Piaget.

Critical to Vygotsky's (1978) theory of learning is the notion of the Zone of Proximal development or the ZPD, which he describes as being the gap between the actual developmental level of the learner (determined through independent problem solving) and the potential developmental level of the learner (determined through problem solving under the guidance of a more capable other).

This gap between the learner's actual developmental level and their potential developmental level needs to be created if any learning is to happen. One of the purposes of instruction is to create a ZPD within the learner and in social constructivism, it is the learning that takes place as a consequence of this interaction with others that awakens internal developmental processes. Vygotsky (1978) distinguishes between learning and development and insists that development lags learning and that learning and development can never be accomplished in equal measures or in parallel with each other.

The ZPD is useful as an idea to use in designing learning interventions. Group work or getting learners to work together on a task is a common design feature of modern teaching interventions that traces its roots back to the ideas of Vygotsky, the ZPD and Social Constructivism. The ZPD also provides some insight into the meaning of diagnostic tests as measures of a current developmental state based on previous learning. It is not a measure of future performance.

**Albert Bandura and the development of self-efficacy in learning**

In his work on observational learning, Bandura (1994) identifies four processes that he thought influenced learning. These were attentional, retentional, production and motivational processes. Before any learning can happen, the learner has to pay some attention to something that will stimulate the learning. This is an attentional process, linked directly to the observation the learner is making. Retentional processes refer to the retention of useful information gathered from the learning event. Learning is aided by production processes as well where some cognitive representation may take place. The fourth process is that of motivation, which includes acts of self-regulation.

According to Bandura, future behaviour is largely due to acts of self-regulation, resulting from an interaction between the people, the environment they are in and the behaviour they have within that environment. This is referred to as reciprocal determinism, where the behaviour of a person has as much influence on the person and the environment as does the environment and person have on their behaviour. Bandura (1997) distinguishes between extrinsic and intrinsic controls on behaviour, and points out that were there to only be extrinsic controls of behaviour, "people would behave like weathervanes, constantly shifting in different directions" and since this is not the case, most of the regulation that controls our behaviour has to be intrinsic or self-regulated behaviour. This self-regulation is linked to self-evaluation, which Bandura maintains is far more influential than the evaluation by others. This self-evaluation is linked to personal standards of performance, which if too high, can lead to distress and feelings of worthlessness which have a negative effect on performance, mainly due to the fact that these standards of performance are self-imposed.

*Perceived self-efficacy* is the belief one has in being able to carry out a particular task, the belief one has about one's capabilities within a certain sphere of endeavour. Research by Covert, Tangney, Maddux and Heleno (cited in Olson & Hergenhahn, 2009) shows that people with high perceived self-efficacy try harder, accomplish more and are more persistent than those with low self-efficacy. Of course, ones perceived self-efficacy may not correspond to one's real self-efficacy in completing a task. Changing people's perceived self-efficacy levels has also been the subject of some research by Bandura (1994). Ways of developing self-efficacy include mastery of difficult tasks (indicating importance of practical work) and seeing social models achieve the behaviour (accounting for higher confidence in ability to achieve technological tasks in male compared to female students).

## Wider social theories

### The social theories of Michel Foucault and Pierre Bourdieu

A generalised and widely accepted framework for the understanding of identity in the classroom has been outlined by Connolly (1998) in his treatment of race, gender and class and how these categories manifest themselves in schools. Using Foucault's ideas about *discourses* and Bourdieu's ideas of *Habitus*, *Capital* and *Field* he frames differences and perceptions of difference in the school environment. These I have summarised below.

*Discourses*

Foucault sees discourse as a construction of language that takes its form from the way we think and organise our knowledge. This in turn may be determined by the specific community that we identify with and so the language (or discourse) itself acts as a gate which allows through it only those members who have access to the chosen discourse (the discourse community). These are the "us" and those excluded, the "them".

In my study, where the focus is on work conducted within a particular university environment, I have chosen to think of Foucault's idea of discourse as the social construction and organisation of knowledge into oppositional categories. In the

Design and Technology laboratory, where most of the work in this project is located, I have seen these oppositional categories to be primarily "male" and "female", although, as will be discussed later, there are issues of race and class that arise in looking at the data. These oppositions, the "us" and "them" categories and can be thought of as the frames of reference used by students to shape their responses to the environment in which they work and to each other.
The power of these discourses is that they shape, on the one hand, our beliefs in what we are able to do, as well as what we are unable to do. Our identity and the relationship we have with the group(s) that we aspire to be part of is determined by these discourses.

*Habitus, Capital and Field*

I have chosen to use Bourdieu's ideas of *habitus, capital and field* in conjunction with Foucault's idea of *discourses* (Connolly, 1998) to provide me with a deeper insight into why certain behaviours are manifested in the technology laboratory. One can understand *habitus* as the internalised experiences that are the cause of our thoughts and our actions (Connolly, 1998).

*Habitus* is that unconscious act that "happens" without thinking. There is no logical sequence of events that leads to the enactment of the act, much like a child resorting to violence for the simple reason that their parent used the same method in order to achieve the results that they wanted. In the end violence in seen unconsciously as the solution to a certain set of problems. This *habitus* is often what I see in my students' constant reference to prior experience that shapes the gendered discourses that are produced when they are asked to perform tasks that they deem gender inappropriate. It is this experience that also reinforces the male dominance in the technology class. Faced with technical tasks, female students often experience discomfort at being asked to solder, or cut or use tools that they view as meant for their male counterparts.

Male students in the technology class possess forms of social and symbolic capital that enable their confidence and superior performance in tasks that are deemed to be "natural" for them. Even if male students are not particularly adept in the use of tools, they themselves expect good results and the self-efficacy embodied in this expectation in turn enhances their performance.

**Constructing gender - feminist theory**

Oakley (1998) describes feminist theory as having gone through a number of phases in the last 50 or 60 years, resulting in the development of a number of different paradigms of gender. Because in this section, I have drawn on more than one of these paradigms, I have started by describing the changes that have taken place in Feminist theory as related to the general development of social theory from the modernist age of reason to the present day postmodern world and how this relates to both my research design as well as the interpretation of my data.

In developing a framework for analysis of science education projects in Africa, Sinnes (2006) outlines three alternatives to developing gender equity in science education. The first wave of feminism operates from the principle that there is no difference between the way males and females engage with science education. This position focuses on the idea that given same opportunities, females will produce the same scientific knowledge as males. This is often referred to as the liberal feminist position or "first wave" feminism and has as a central tenet, the equality of males and females with the idea that females have simply been kept away from science for political and social reasons (Barton, 1998; Howes, 2002; Keller, 1987).

The idea that either due to the differential way in which girls and boys are brought up or due to genetic differences there is an unmistakable difference between males and females means that girls and boys engage with scientific knowledge differently, is a central tenet of the next wave of feminism. The difference feminists referred to by Sinnes (2006) argue that the differences that make for feminine characteristics are as valid as those that make for masculine characteristics and that while there is a difference, these should be treated equally. In this second wave of feminism, some theorists (e.g. Gilligan, 1982) have claimed that in some cases, female characteristics are superior to males due to females' caring and nurturing ethic compared with males' ethic of rights. Others (e.g. Shiva, 2001) see this as leading to different and more socially and environmentally responsible science. While there is no consensus on these issues, feminists of this wave agree that it is important to acknowledge the differences between males and females, which sets them apart from the liberal feminists of the past who see feminist issues in terms of equality only.

In a postmodern age, a third wave of feminist theorists has identified multiple feminine and masculine identities and asserts that it is simplistic to identify women as one group with a single identity. From a postmodern point of view, gender is a socially constructed identity that determines how one performs and interacts with others (McPherson, 2000). This too has an impact on why and how females learn and create scientific knowledge. Haraway (1991) points out that there are large differences between women in any single group and that this produces a multiple set of femininities.

Young (1997) points to the demise of the feminist agenda of practically making a difference in women's lives as a result of the expansion of the concept of gender and different femininities. The idea of women as a distinct group does not exist in a postmodern world and the effect of this has according to Oakley (1998) been to dilute the efforts of the feminist movement in bringing about real change for women. This theorisation of gender, according to Oakley, needs to be revisited and she argues that in order to reinvigorate the feminist movement, the concept of gender should be rehabilitated. She argues too that while the scientific method "suffers from a contamination through association, because of its siting within the male academy" (p. 142) and that science has been criticised as being exclusionary in practice, underscored by male value systems, this does not mean that sound knowledge gained through scientific study that will make a practical impact on women's lives needs to be rejected as well. In so doing, Oakley calls for a pragmatic use of the term *gender* as well as the knowledge gained from the thousands of scientific studies, particularly conducted on women's health issues. In this study, I have approached the data from a pragmatic point of view , with the main practical focus of the study being the emancipation of female design and technology students from the self-imposed barriers to their own learning of a piece of science that has traditionally been seen to be "male". This I have done in practical ways through the development of female students' self-efficacy.

This brings me to a discussion of knowledge in general, and whether or not it is gender neutral, and what it means to be objective. Lorraine Code (1991) poses the question "Is the sex of the knower epistemologically significant?" By this she points out that in understanding learning it is important to understand the "knower" as one would if one were to distinguish between rural and urban children, or middle and working class children when thinking about how to teach children. The gender of the knower may be important insofar as knowledge brought into the classroom could have an impact on the future learning that takes place. From a pragmatic point of view, considering this question has implications for not only designing appropriate teaching interventions, but also when considering how best to research changes that take place within the learner. The question as to whose knowledge we are learning (Code, 1991) must be seen against the idea of whose knowledge we are creating. If knowledge is gender defined, then the creation of knowledge must be gender defined as well. Most learning theorists have portrayed the learner as an abstraction and not distinguished on the basis of gender. While this is a difficult issue to resolve philosophically, it might be easier to deal with through a pragmatic research paradigm. This will be discussed in chapter 3.

**Performativity and gender identity**

Butler's (1988) notion of performativity has its origins in speech act theory. Examples of speech acts are promises, warnings and orders. In some speech acts, clauses, phrases or sentences are not only statements of representation, but also actions. A good example is the following statement: "I now pronounce you man and wife". This statement not only is a description of what is happening, but in itself is an act (which results in two unmarried people becoming married). According to Butler (1993), "Within speech act theory, a performative is that discursive practice that enacts or produces that which it names (p. 13). In Butler's view, language creates the reality in which we live by endlessly reinforcing our beliefs about what we feel are society's norms. Performatives are speech acts that enact and construct society's conventions.

This act of performing social conventions constructs our own reality. It is the performative act that makes these social conventions real; they are not real on their own. Performatives only produce that which they name by referring to widely accepted norms or societal codes, so a performative act cannot exist without these codes and yet creates them as well. A good example of a performative act is that of "self-talk" where the way we speak to and of ourselves produces the results that reinforce our own ideology about who we are and what we can accomplish. If we think we cannot change a tyre, if we have been brought up to believe that we are somehow incapable of this technological feat either because we are weak or not "technologically inclined" and if because everyone around us says so, and if, as a result, we also say these things, then it becomes reality.

Thus gendered speech acts that reinforce current ideologies about men and women are ways in which we perform gender. Butler (1990, p. 272) writes about gender as being a performative act, a "*a corporeal style*, an 'act,' as it were" in which one performs an act that has been rehearsed throughout history, that was there before we arrived and will be there after we are gone. This performance of gender means that gender is a socially constructed ideology which requires certain speech acts in order to maintain the social norms that are the "reality" of what we see men and women to be.

This performative act of gender has the effect of entrenching society's power relations between the sexes. Women see themselves as being "naturally" technologically incompetent and this ideology is perpetuated through performative speech acts that keep telling both men and women that this way of being is reality and in the end this makes it become the reality. Thousands of these performatives exist, all of which have the effect of adding to the construction of the current reality through reinforcing ideas of difference between men and women.

In this thesis, performatives can be found in the reflections of students on the Doll's House task, where they lay open a gendered reality of what they can and cannot do and also of what they should and should not be expected to do. This act of completing the doll's house project, while making reference to a performative that reinforces current ideology (in other words the use of a gendered stereotype that "making pretty things is better for girls"), shows female students that their reality is not really true. The learned helplessness that is a gendered state of mind constructed around "being a girl" too is a performative that seeks to reinstate social norms regarding the nature of women.

In the same way, the necessity for being technologically competent, for being able to "do electricity" is a performative that seeks to enforce what it means to be male. The association of technology with the male and the idea that being able to do technological things is a natural part of being a man gave comfort to many male students in this study, but at the same time might have provided a source of discomfort for those male students who had not learned to perform the role of the technologically competent male.

Scantlebury and Baker's (2007) description of the creation of supportive communities of learning amongst African American female students provides evidence of the importance of creating a "science identity" perhaps in competition with other identities, but certainly in conjunction with them in order to learn science. Similarly, Tonso (2007) suggests that the formation of an engineering identity that is influenced by general campus life, engineering faculties and culture determines relative success of the individual that can result in male students with fewer competencies getting better jobs than their female counterparts. In "Learning to be Engineers", Tonso (2007) outlines the formation of this gendered engineering identity amongst students, with female engineering students invisible due to the fact that male students could not identify them as "nerds" and with some male students being given undue credit simply because they fitted into a particular masculine stereotype. This gendering of identity within a science class creates a barrier for female students on the one hand, but as Scantlebury and Baker (2007) point out, can also be utilised to develop positive learning patterns in science.

## Summary of key ideas

This chapter draws together rather disparate philosophies of gender on the one hand and learning on the other. In it I have tried to weld and integrate ideas of constructivist learning which I use to try to understand what was happening at the level of conceptual understanding with ideas of identity and self-belief. The first part of this chapter provided a detailed literature review that foregrounded the two main theoretical frameworks I have chosen for the study. In the second part, I have outlined some theoretical ideas that I will use to both develop a research design in chapter 3 as well as a framework in chapter 8 with which to understand the main findings of the four papers that make up the core of this thesis. In this section I will summarise the key theoretical ideas that will form a framework for this analysis. It must be noted that the selection and use of theoretical constructs has been done in a pragmatic way, seeking those constructs which have use in understanding the learning of electrical knowledge that has taken place. This will be discussed later in chapter 3.

### Constructing science knowledge

From a pragmatic point of view, all learning of scientific concepts has to be mediated through a "learning lens". Without such a lens, interpretation of science learning in any form would be meaningless. In this case, I have chosen the lens of constructivism to interpret the data gathered in this study, partly because I use constructivism as an epistemological base from which to design and implement the learning programme on electricity given to the students and partly because it provides us with useful tools for the interpretation of the kinds of data I have collected, namely data on conceptual understanding. For this reason, I will draw quite heavily on conceptual change theory as well as Piagetian ideas of assimilation, accommodation and equilibration, for while I have doubts about the usefulness of the notion of Piagetian stages of development, Piagetian ideas about how concepts are learned form the basis of conceptual change theory. Similarly, I believe that David Ausubel's work on meaningful learning has some resonance with the work done in this thesis in that the contextualisation has provided a gendered meaning for female students which I would argue does help in conceptual development.

Shipstone's (1988) categorisation of mental models of current and the way circuits work is a useful framework for the analysis of common errors made by students in developing circuit and wiring diagrams in this study. In particular it is interesting to note that there have been some recordings of the persistence of the unipolar model in other studies (Stanton, 1989) and that the work done by Borges and Gilbert (1999) identifies a progression of mental models of electricity that inform thinking about how circuits work. Di Sessa's (1993) notion of phenomenological primitives provides a useful platform for the understanding of the origin of preconceived patterns of thinking about electricity. Issues of context are particularly relevant to this study and the work by Linder (1993) on the effect of social contexts as well as Tsai, Chen, Chou and Lain. (2007) on the effect of context help explain some of the data that will be presented later.

**Social constructivism in the classroom**

A central idea in social constructivism is Vygotsky's Zone of Proximal Development (ZPD) (Vygotsky, 1978). The question I have is: How is the ZPD influenced by the gendered environment? Let us take for example a situation where a mixed class of boys and girls is learning electricity in groups that are also mixed gender. Typically, the boys dominate conversation in this "macho" setting, where they have the power. In Vygotsky's idealized situation, learning takes place when a student interacts with a More Knowledgeable Other (MKO), preferably in a group. Knowledge is socially constructed this way. In this case, the MKOs are the boys, or more correctly, there are levels of MKO. Typically the teacher will head this hierarchy and in each group, there will be some students who are more knowledgeable than others. What then happens in the knowledge construction process when girls are isolated in a group and boys "take over". The social aspect of the learning then ceases to be effective at the very least, if not destructive. Perhaps what the girl learns is that this avenue of knowledge is something that "is not for me" as a girl. Alienation takes place in the group and this then increases the distance spanning the ZPD.

**Developing self-efficacy**

Scaffolding learning is another Vygostskian concept which has use in this study and I see scaffolding and Bandura's (1994) development of mastery of processes as having some intersection. While the two concepts are theoretically different, the practical effect in the classroom has been similar. One way to develop self-efficacy amongst students is to provide appropriate scaffolding and the development of relationships between students. This has, I would like to argue, already happened without the intervention of the instructor and in some ways, male students provided some scaffolding for female students. However, as will be argued later, this did not always develop the female students' self-efficacy. Bandura's (1994) ideas of self-regulation and perceived self-efficacy are key concepts in this study. Perceived self-efficacy levels will be probed through questionnaire as well as through student reflections and these provide an insight into how powerful levels of self-efficacy are in determining performance.

**Notions of discourse, habitus and capital**

Levels of self-efficacy in this study are of course linked to gender and gender identity, which brings me to Bourdieu's notions of cultural capital (1991)(in this case, gender capital) and Habitus, which produce lasting ways in which we view ourselves. In this way, we reproduce societal norms. The male students in the class have a form of "gender capital", but only with respect to the tasks they are performing and the particular subject matter. The habitus developed by female students feeds their low levels of self-efficacy and places them in subservient positions in the class where they are powerless and dependent on their male counterparts for academic success.

**Emancipation**

The feminist framework that this project uses has as its central focus, not only the analysis of the gendered learning of electricity that takes place in the classroom, but also the aim of providing through the research and also the developed programme of instruction and emancipatory message for both students and teachers. This brings together the learning of science with its uneasy relationship with feminism and Habermas' ideas of emancipation with ideas of gender identity, performativity and equity. This thesis argues that key to understanding what happens in the learning of electricity, is that it is a different experience for girls than it is for boys. The thesis outlines a framework for understanding gender issues as well as a framework for understanding learning issues. There is a point of connection between these two in this study, which I believe can be seen through the evidence that will be presented in the chapters that follow, of not only a lack of self-belief amongst female participants in learning what is commonly seen to be a "male" topic, i.e. electricity, but also evidence of poorer preparation throughout their schooling in learning electrical concepts. This study uses a pragmatic paradigm to evaluate and ameliorate practical problems encountered in the teaching of electro-technology to female students.

**Developing a useable theoretical framework for this study**

The two frameworks that have been used to inform this study are the broad framework on gender and feminist theory on the one hand and the more specific framework informing the development of electrical knowledge from a cognitive point of view, namely that of constructivism. Each of these frameworks is however insufficient as a tool to both design the investigation of factors affecting the way female students learn electro-technology as well as to interpret the data collected in such an investigation.

The weakness of a constructivist framework is that it simply does not address affective factors, such as the effect of perceived self-efficacy in learning. In addition, it also does not address the effect of gender in relation to this perceived self-efficacy. The sense of learned helplessness has a significant impact on the emotional aspect of learning that is affected mainly by gender in this study. Looking at the learning of electrical concepts without taking cognisance of the cognitive construction of electrical ideas that are related to the students world view, in particular the development of ideas from phenomenological primitives and only looking at the affective factors that have an impact on learning also provides one with an incomplete framework for analysis.

The combination of a sound constructivist framework drawn from the extensive literature on the development of electrical conceptions and conceptual change theory as well as a combination of the ideas of Bandura (1994) about the importance of perceived self-efficacy and the relation this has to gender theory make for a much more pragmatic framework for analysis for this thesis. Table 2.2 below shows how theoretical knowledge has been used to interpret data in each of the four papers.

Table 2.2. *Theoretical perspectives broken down according to paper*

| **Paper** | **Predominant theory used** |
|---|---|
| Paper 1 | This paper draws on constructivism as well as a simplified view of gender as a simple dichotomy. |
| Paper 2 | This paper draws on ideas of gender and science as well as ideas about the impact of self-efficacy on learning. |
| Paper 3 | This paper draws predominantly on the social theorist Bourdieu as well as feminist theory. |
| Paper 4 | This paper draws on Constructivism, conceptual change theory and the wealth of literature on learning electricity. It also draws on aspects of gender theory. |

While there has been no real extension of theoretical knowledge regarding the development of a unified theory to frame this research, the study does open up a need for the development of a comprehensive theory to frame studies that involve gender and conceptual learning.

# Chapter 3

# Overview of the research design and methodology

In this chapter, I provide an overview of the research design that connects the four papers that make up the core of the study to each other as well as to the review of literature and theoretical frameworks that were outlined in chapter 2. This chapter starts with a discussion of research paradigms followed by a detailed description of the context in which the research was conducted. Included in this is a description of the intervention that was used to teach electricity and to research the relationships between gender, self-efficacy and performance on the electrical tasks that students were expected to do. Lastly, I discuss some issues around data collection and ethics.

## Research paradigms

My own stance on investigating issues in education has been based on the scientific method with a largely constructivist philosophy of teaching and learning. The design of this body of research however, includes a mixture of methods that draw from different paradigms of educational research and in so doing also draw from different frameworks of theoretical analysis. What started out as a rather simple empirical study has transformed into a more complex entity where the boundaries between different ways of thinking about data are not as well defined and my attempt to reconcile these different ways of thinking about things has led me to draw not only from two very different theoretical frameworks for analysis, but also from several different methodologies for data collection, each compatible with a way of thinking and each distinct in the way data is collected and handled.

In this section, I start with a description of an empirical study that draws from a constructivist framework (Creswell, 2003) for analyzing the data. The data analysis initially gives a numerical view of a gendered world of learning electrical ideas, but as more qualitative data becomes available, the numerical data takes on new meaning and it becomes more difficult to interpret as I become more engaged with the participants than I was when I planned the study. This apparent lack of objectivity and increased feeling of subjectivity that emanates from critical engagement with the research participants, has meant that I cannot pretend that I am not involved in their (the participants) construction of knowledge and the recognition that I do have an agenda that I am pursuing with regard to the interrogation of a system of education and the emancipation of the participants in the study. This fact places me personally in a subjective role in the design of the study as well as the collection and interpretation of the data. Possibly, the best way to describe my philosophical approach is that I am a pragmatist and as a consequence of this, I select a mixed methods approach (Creswell, 2003) to answering the questions that arise from my studies. In what follows, I outline the main research paradigms and associated methodologies that have been used in educational research and discuss the implications of using these methodologies in my research.

**The normative paradigm (positivist methods)**

Positivism is a philosophical position that uses observation and reason as a way of understanding behavior. While the roots of positivist thought lie in the philosophy of the Ancient Greeks, the beginning of positivism as movement was associated with the French philosopher Auguste Comte, who in the $19^{th}$ century, used the term positivism to describe a position that applies the empirical methods of scientific investigation to the understanding of human and social behavior (Cohen, Manion & Morrison, 2007). From a positivist perspective, the social scientist is seen as an objective observer of social reality, disconnected and able to record data that has been measured, design and use experiments that are carried out on people or groups of people and record the results of these experiments using them as one would in the natural sciences to generate laws and principles that can be tested again and again to see if they are falsifiable.

The scientific method as a method of enquiry for the natural world has been in the last two centuries a powerful way to generate new knowledge. Scientific investigations collect data from designed experiments set up with control groups to test propositions. A key tenet of the scientific method is the idea of reproducibility or falsifiability (Cohen, Manion & Morrison, 2007), where anyone with the correct apparatus can test anyone else's idea or experiment. Only after the results of an experiment have been tested several times do they enter into the realm of "accepted fact". Fact is of course a loaded term, because all knowledge is provisional and accepted only until new or better techniques may unseat that knowledge and replace it with new and different provisional knowledge. These facts form the basis of working theories that are the rules that have been identified that govern the natural world (Olson & Hergenhahn, 2009).

In the normative or positivist model of human behavior, there are two key ideas that distinguish it from other models. The first is that human behavior is rule governed and the second is that investigating the rules that govern human behavior requires the methods of the natural sciences. These methods work well within the confines of a system where variables can be identified and easily controlled. In the social sciences, this is not as easy and for this reason, positivist methods are not universally favored (Johnson & Onwuegbuzie, 2004).

**The interpretive paradigm (anti-positivist methods)**

As alternatives to positivist approaches to investigating social phenomena, methods such as phenomenology, ethnomethodology and symbolic interactionalism reject the idea that generalizable laws can be found that govern human behavior (Cohen, Manion & Morrison, 2007). From an anti-positivist viewpoint, the world can only be interpreted by individuals who share the same frame of reference as those being investigated and the validity of the interpretation is as much to do with the data collection method as it is to do with the alignment between the researchers frame of reference and the frame of reference of those being researched. Investigations begin with individuals and interpret the world around them. Social theories that seek to explain phenomena emerge from the data that is collected by individuals that are imbedded with the social group (Cohen, Manion & Morrison, 2007). Analysis of data in the interpretive paradigm is data that is collected from within the social group and is subjective by nature. Interpretive paradigms seek to interpret the social group through the interactions of the people in the group, analyzing interactions and communications for meaning. From the interpretive standpoint, meaning is paramount, whereas in a positivist or normative view, measurables and patterns determine the form of the data collected and the interpretation is focused on seeking generalizations that can later form the basis of laws.

**Critical theory**

Critical theory (Creswell, 2003) grew out of recognition that both the positivist and interpretive paradigms presented incomplete pictures of social behavior, particularly in the field of education, where political and ideological battles are often fought. Critical educational research has been influenced significantly by Habermas (1972), who suggests that knowledge and research knowledge serve different interests. This is particularly true in realms that are contested such as education. In this study for example, the gendered way in which electrical knowledge is learned could be thought of as having the effect of supporting the status quo, in which women are not expected to deviate from their allotted functions and designated careers. Research then in his view should have an agenda and that agenda is emancipatory.

The idea of emancipation is central to critical theory and hence critical educational research. Critical theory not only admits to the subjectivity that the interpretivists do, but goes further and acknowledges the power relations between individuals within society. Critical theory is emancipatory in that it forces us to take sides and ask "For whom am I doing this research? What will the results be used for?" This places the researcher in a position that she or he needs to make a political decision regarding the research being undertaken. In order to do this, critical theorists argue that positivist and interpretive paradigms are technicist and focus rather on the understanding of a situation than to change it.

**Feminist research**

Leading on from critical theory, Feminist research offers a new paradigm, which sets up gender as a category for analysis and rejects the previous paradigms from the point of view that they were androcentric. While feminist research recognizes that data is subjective and value laden, it is concerned with the issue of power and power relations specifically those that are gender related. Traditional ideas of truth, objectivity and neutrality are deconstructed and analyzed from a feminist perspective. To do this, often multiple research methods are used, partly because of the interdisciplinary nature of the research (Cohen, Manion & Morrison, 2007). In this study, the interdisciplinary nature of the research questions I have asked has meant that I have had to choose multiple ways to collect and analyse my data. This is congruent with a pragmatic philosophy of the nature of knowledge and a mixed methods approach to data collection and analysis as will be discussed in the next section.

**Using a range of methods – a pragmatic (mixed methods) approach**

To return to the methodology chosen for my research, I must also return to the discussion of my own epistemological framework, as was last discussed at the beginning of this chapter. This is necessary because my own interpretation of knowledge has developed from a post-positivist philosophy, due largely to the fact that I have been schooled in the sciences and had in my studies become fascinated with the analytical atomization of knowledge and the development of theories that are used to explain the macroscopic properties of an object through understanding the microscopic basis of that object. To me the most elegant physics was always a microscopic theory that could completely explain a macroscopic phenomenon, such as for example explaining the cooling that takes place when water evaporates. The search for a unified theory or a unified "truth" is a central theme in physics.

As a research paradigm, pragmatism (Creswell, 2003) most easily fits with the nature of the research questions I have asked, that require answers that are drawn from the analysis of both quantitative as well as qualitative data. Pragmatism also fits with my personal philosophies of knowledge and truth. Feilzer (2010) develops a case for the use of pragmatism as a paradigm for educational research that is supported and in turn supports the use of mixed methods. This rehabilitation of pragmatism can be seen as being connected to the rehabilitation of pragmatism as a philosophy. Kuhn (as cited in Feilzer, 2010) describes a paradigm as "an accepted model or pattern". Research paradigms in education; reflect the underlying philosophy of the researcher. In a post-positivist world, interpreting quantitative data in search of a single "truth" is a narrow vision and has an epistemological focus rather than the practical focus of trying to find a solution to a problem. In a similar vein, the relativist sees multiple realities that that require an interpretivist research paradigm to unravel. The difficulty with selecting one or the other paradigm is that the researcher becomes blinded to ideas that spring from the data. The interpretivist while immersed in rich data fails to see the bigger picture provided by the large scale quantitative studies and the post positivist while able to command a view of the data terrain, is often not able to discover the nuanced richness of the data that is excluded from view because it is not quantitative. In a pragmatic world both are possible and the simultaneous collection and interpretation for both qualitative and quantitative data is seen as desirable as it provides not only a broad sweep through the analysis of numerical data, as well as the richness of the detail from the qualitative interpretation of non-numerical data, but by bringing the two together, a further insight is provided the researcher (Creswell, 2003). Pragmatism aims for utility first and truth later.

Consistent with a philosophy of pragmatism is the use of multiple methods of data collection and analysis, more commonly referred to as "mixed methods research". Johnson and Onwuegbuzie (2004) define mixed methods research as a form of research where the researcher combines both quantitative as well as qualitative methods for the collection of data. In this study, I have chosen to use a mixed methods approach that is supported by a practical philosophy of pragmatism (Creswell, 2003). The reason for this lies in the purpose of the research. The initial reason for undertaking this research was to work out why female students had such poor attitudes towards learning electricity, what it was that could be done about it and whether this intervention worked on not.

A normative research paradigm in this context does not work at all because the classroom is a scene of social interaction that requires elements of the interpretivist paradigm and its associated methods as well. If one also considers critical theory with its purpose of emancipation, as well as the fact that the whole study has a feminist focus, it becomes clear that while each of these paradigms and their associated methodologies could be used in trying to find answers to some of my research

questions, no single philosophical standpoint ar
research paradigm. The research questions in thi
multiple methods of data collection within a prag
of this inquiry requires me to be able to use induct
numerical data while at the same time interpret qua
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apartheid South Africa.

While design and technology is not strictly science, there were el
that were/are necessary in my teaching. My teaching approach in
technology was different to the approach used in teaching science
underlying philosophy of the subject was emancipatory. This was a
children could take that would allow them to be both creative as wel
practical physics and in so doing be emancipated both through the cr
enjoyed in designing and making artifacts and through developing de
understandings of physics knowledge that were embedded within the t
curriculum.

questions, no single philosophical standpoint amongst these four is suitable as a research paradigm. The research questions in this study have opened the door for multiple methods of data collection within a pragmatic research paradigm. The logic of this inquiry requires me to be able to use inductive methods when interpreting numerical data while at the same time interpret qualitative data in the light of my knowledge of power relations within the classroom context. This combination of approaches I feel leads to a richer, more inclusive understanding that is I feel free of the dogmas of the past conflicts between the paradigms (Johnson & Onwuegbuzie, 2004).

The pragmatic approach to designing this research is congruent with my approach to teaching and learning in general and consequently the design of the intervention used in this study. Emancipation of the individual has been a feature of my personal philosophy which has fed into my own teaching. This has developed over a number of years into a conflict between my love of the Physics I was teaching and the possibility that this very knowledge in some way oppressed those who were learning it. This conflict has been addressed to some extent through the introduction of a new challenge to science education in the form of design and technology, a subject that was introduced into a "transformational" Outcomes Based Curriculum in post-apartheid South Africa.

While design and technology is not strictly science, there were elements of physics that were/are necessary in my teaching. My teaching approach in design and technology was different to the approach used in teaching science in that the underlying philosophy of the subject was emancipatory. This was a subject that children could take that would allow them to be both creative as well as learn some practical physics and in so doing be emancipated both through the creativity that they enjoyed in designing and making artifacts and through developing deeper understandings of physics knowledge that were embedded within the technology curriculum.

So while my research instincts favoured quantitative methods in the past as a result of my being schooled in the sciences, the emancipatory part of me responded in a different way to the wealth of qualitative data that can be gathered on the way students relate to the material they are being taught. In my teaching as well as instructional design, I have drawn from post-behaviorist paradigms and the theories of learning developed by both Jean Piaget and Albert Bandura, both of which are predominantly cognitive theories of learning. The fact that I also draw from a constructivist perspective when trying to understand the way students think about electrical ideas only reinforces the notion that one needs to have multiple perspectives to fully understand any situation.

I feel that the strength of the overall design is in the wide range of perspectives (and hence mixture of methods) it offers of the same data. Figure 3.1 below shows the interrelatedness of my own ideas of knowledge, the theoretical frameworks that have informed my understanding of what is happening in my classroom, theories of learning, the research paradigms I am using as well as the data I have collected.

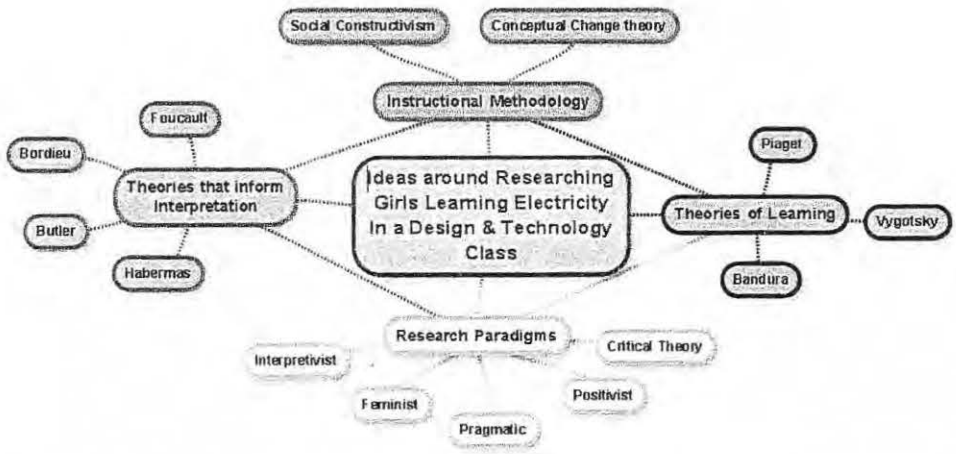



*Figure 3.1* Interrelated ideas of knowledge, theoretical frameworks, theories of learning, research paradigms and data collected

Finally, as discussed above, this research takes a pragmatic approach (Feilzer, 2010) to the analysis of the data, drawing on two canons of thought simultaneously, which I believe strengthens the argument for mixed methods research and the use of pragmatism as a way to frame further studies. The use of only a feminist framework would have lost the compelling discovery in chapter 4 of the differences in conceptual application between male and female students in the diagnostic tests as well the findings in chapter 7 regarding the transitional thinking patterns that emerged from the analysis of wiring diagrams. On the other hand, a narrow focus on electrical conceptions and conceptual change theory would have lost the rich data on emotion and self-efficacy and the effect that this had on female performance in the project.

## Overall structure of the study

This research comprises four papers that were written about data collected in a single five week course that was given at the end of 2006. Since the course was offered every year, there was opportunity to confirm findings and ensure that the data collected was both valid and reliable. Since a mixed methods approach to collecting and analyzing data was adopted, these four papers draw from different kinds of data which are outlined in table 3.1 below. The five week data collection is shown in table 3.2 under the section on data analysis below.

### Implications for data collection and interpretation

In this thesis, a pragmatic approach to collecting and interpreting the data has meant that both qualitative as well as quantitative data are used to try to answer the research questions posed in chapter 1. This is done through a cycle of data collection, initial interpretation and reflection, followed by further data collection and interpretation. The first research question; "*What are the differences between male and female students in the way they understand electrical concepts?*" needed an interpretation of statistical data comparing performance on diagnostic tests by gender and quality of schooling. This data was all gathered mostly on the first day of the project, however, the data analysis and interpretation was done after the analysis of the qualitative data from the reflections as well as the quantitative on gender and self-efficacy. This meant that the second research question on perceived self-efficacy; "*How was performance on the Doll's House task affected by the perceived self-efficacy of female students?*", was actually addressed first. The paper order was arranged not in chronological sequence, but rather in order of what order was necessary to structure an argument.

Table 3.1. *Overall Structure of the study*

| Description of part of the study | Type of data analysed and type of analysis |
|---|---|
| Paper 1: Chapter 4:<br>*Differences in conceptual thinking amongst male and female technology teacher trainees*<br><br>This is a statistical investigation of responses students had to two diagnostic tests designed to elicit different ideas students have about electric circuits. The data was analyzed in terms of gender, level of science taken at school as well as the quality of the school attended. | **Data:** Numerical data, categories in tabular format<br><br>**Analysis:** Statistical analysis of test responses in terms of gender, educational advantage and whether or not science was studied to the end of school |
| Paper 2: Chapter 5<br>*Gender, self-efficacy and achievement in Technology among teacher trainees in South Africa*<br><br>An investigation of performance in the Doll's House Project as well as the final examination in relation to attitudes, gender and quality of schooling. This included both statistical as well as non-statistical data. | **Data:** Numerical data in tabular format, test scores, data on Lickert scales; student reflections<br><br>**Analysis:** Statistical analysis of test responses in terms of gender and educational advantage as well as performance on the final project and examination and whether or not science was studied to the end of school; Interpretation of reflection data |
| Paper 3: Chapter 6<br>*"My very own mission impossible" What an analysis of student language in their reflections can tell us about attitudes to gender and technology*<br><br>An APPRAISAL Analysis of student reflections on the Doll's House Task. This uses systemic functional grammar as an analytical tool to interpret student experiences of the technology project on the basis of gender and school background | **Data:** Student reflections on the project<br><br>**Analysis:** Analysis of student reflections in terms of gender and educational disadvantage using the APPRAISAL framework; Statistical analysis of APPRAISAL categories |
| Paper 4: Chapter 7<br>*Using Wiring Diagrams to identify students' models of thinking about basic electric circuits*<br><br>This study looks at patterns of thinking about circuits that are elicited through the collation and interpretation of student drawings of wiring diagrams. The paper uses a constructivist framework and current literature about conceptual change in learning basic electric circuits, to interpret the drawings. | **Data:** Drawings of circuit and wiring diagrams<br><br>**Analysis:** Error Analysis of student drawings of circuit and wiring diagrams; Some statistical representation of different models of thinking |

Essentially, all data in the five week period was collected before there was any detailed interpretation. This did not mean that I did not look at the data. I glanced at it throughout the five week period and developed a qualitative feeling for the data as it was collected. However, the increased teaching load meant that I mainly left the data to the end to interpret. The initial intention of the project was not to investigate the emotional responses towards doing the project from a linguistic point of view, only

The third question; "*What were the students' emotional responses to the Doll's House Project?*" was one that I had thought would initially be answered by the data that was used for the second paper on Self-efficacy, however, an opportunity arose to look at the data in a more detailed way, by performing an APPRAISAL analysis of the reflection data. The reflection data had proved to be richer than I had initially expected it to be and so it was at this point that I decided to investigate the emotional responses to the project in terms of gender.

The first question and consequently the first paper in the series is a quantitative analysis of test data that explores student understanding of electrical concepts in terms of gender. The framework for interpretation is twofold. First there is the constructivist look at the data and the interpretation of different models of thinking about electrical circuits. This is then linked to gender, so the framework used to interpret the findings from this paper relies on the extensive research conducted over the last few decades

The second paper demonstrated the pragmatic approach of dealing with both qualitative as well as quantitative data as well as the two frames of reference much better than the first paper. In this paper, comparisons on the basis of gender are made of quantitative data such as scores for the project. The findings of these analyses are then interpreted using qualitative data from the reflections as well as semi-numerical data from the Lickert scales. In this paper, as well as the third, a greater reliance on the interpretation of the reflection data takes place, with some triangulation in terms of the numerical data. Taken as a whole, the pulling together of the qualitative data from papers 2 and 3, and the quantitative data from papers 1, 2 and 3, allows for the development of a much richer interpretation of the data, from both a cognitive, constructivist point of view as well as from a gender point of view.

The fourth question "*What common errors were made in drawing both circuit and wiring diagrams and in what way do these errors reflect the students' conceptual thinking?*" was developed after I noticed that there were anomalies in the way students designed wiring diagrams with students commonly reverting back to conceptual models that they knew to be incorrect. In this investigation, for which there was not enough evidence collected, I had initially intended finding out whether or not there was a gender difference in the way these errors were constructed, however, in the end, all I could do was investigate the kinds of error made through an error analysis.

## Research context

### The study site and research participants

The data was collected in an Education Faculty at a South African University. The participants in the study, who constitute a mixed urban and rural group, were 114 Bachelor of Education students, registered for a Design and Technology course. For papers 2 and 3 of the study, 95 of the 114 students who participated were selected to create matched samples where the matched samples were of similar size and where the division was done on the basis of the schools they attended (whether advantaged or disadvantaged) and gender. In this group of 95 students, there were about equal numbers of African male (24) and female students (23), all of whom had attended disadvantaged schools, and white male students (23) and female students (25), who had attended advantaged schools.

The data was collected over five weeks, while students attended an electricity course (taught by the author). The course developed competence in understanding, planning and wiring of a doll's house. This entailed developing understanding of the concept of circuits. Students were divided into six groups with one weekly double period (of 90 minutes) contact time. Students worked on their projects between contact sessions, but had to do this in the classroom.

**Design elements of the instructional model used**

The context of the task was designed to address specifically the interests of female learners. Based on previous experience, female students had a negative view of learning basic electricity and electronics. In choosing a context that was stereotypically female, building a doll's house, it was hoped that female learners would initially enter the intervention with a more positive attitude towards learning electricity. Once the students were interested in the project, the intervention was designed to develop the female students' self–efficacy in electro-technology. The development of skills was scaffolded and supported through activities designed to get female students to a point where they saw themselves performing at a level comparable to the males.

The instructional model consisted of five distinct elements that were implemented over a five week period for the cohort of students that took the course in 2007. The key elements of the intervention were based on literature discussed in chapter 2.

*1. Contextualizing the learning: the doll's house task*

Drawing on the literature around gender, context and learning as described in the preceding sections, the task selected as a focus for this intervention is the individual construction and wiring of a doll's house. Figure 3.2 shows two examples of dolls' houses that were constructed. Further examples of dolls houses can be seen in Appendix A)

*Figure 3.2.* Doll's Houses.

Starting from the assumption that early socialisation is a factor that determines interest in gender stereotypes (Weber & Custer, 2005) the Doll's House task was selected to encourage participation and enjoyment by female students. The electrical knowledge was taught in a way similar to problem based learning where students were presented with what they needed to know, when they needed to know it. This knowledge they had to use to wire the house. The project consisted of four parts:

- *Developing electrical competence.* This involved connecting circuits and designing circuits to perform different functions.
- *Making the house.* This required the use of tools for cutting and joining as well as learning to design basic structures. The decoration of the house was part of this.
- *Wiring the house.* This required being able to plan the wiring, design the circuits and solder.
- *The portfolio.* This involved students keeping a record of their project construction from the initial design to the final submission.

2. *Developing self-efficacy by teaching all students to use the tools and doing all the work in the classroom.*

The course was designed so that by its completion all students would be able to handle tools and perform tasks that were peculiar to electro-technology in addition to being able to design and connect circuits. The work done by students was closely monitored to ensure that each student actually did their own work (something that had not happened in the students' past at school). While effort was made to ensure that all students mastered the skills required to complete the task, there was an emphasis on mastery of core skills amongst female students. To do this, I developed competence by working on small successes, using small groups and one on one tuition to ensure that all students were able to cut, glue and solder by the end of the course.

*3. Using a conceptual change approach to learning electrical concepts*

A conceptual change strategy based on Osborne and Wittrock's (1983) generative Learning Model (GLM) was designed to facilitate conceptual learning of electro-technology. The fundamental concepts of basic current electricity were taught in such a way that the students were made aware of the conceptual frameworks that they themselves used to interpret electrical diagrams. Where their frameworks were unscientific, they were led through a process of Socratic dialogue to confront any misconceptions that they had in order to develop or change their thinking. All conceptual models were tested by the students with their own apparatus. Alternative conceptions were identified and given a name. The conceptual change approach to teaching electricity was based on the phases of the Generative Learning Model (Osborne & Wittrock, 1983) as outlined below:

Phase 1: A preliminary phase where some form of diagnosis occurs. Here students started their study of electro-technology with a diagnostic exercise designed to elicit conceptual models of thinking about basic electric circuits. This was not simply one test or exercise, but a series of tasks that would give me an idea of what commonly held ideas they were using, but also start to lead them to question their beliefs. One such task is shown in Appendix B)

Phase 2: A focus phase where students were expected to focus on a particular problem in a particular context. In this phase, students focused on understanding and designing circuits that would lead them to later understanding of the circuits they needed to construct for their project. Examples of the tasks given in the focus phase are shown in Appendix C)

Phase 3: A challenge phase in which there is a facilitation of an exchange of ideas about what is being learned. In the challenge phase, students were asked to design a circuit suitable for their house with particular specifications. In addition they had to integrate this circuit into the plans of the house, producing a working wiring diagram from which to wire their houses. Figure 3.3 shows a wiring diagram designed by one of the students with quite serious conceptual errors. Further examples of wiring and circuit diagrams are shown in chapter 7.

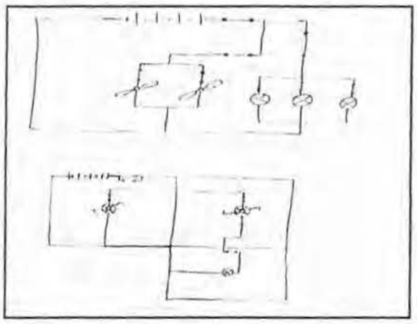


*Figure 3.3*: An erroneous wiring diagram.

Phase 4: An application phase where students use their new found ideas in a real context in order to solve a new problem. In the application phase, students were asked to construct and solder the circuits they had designed and get these to work so that their house was properly electrified to the original specifications given. This requires application of knowledge and skills learned in all the previous phases of the learning model. Lastly, students are required to produce a portfolio of all the things they have done in leading up to the production of the final product (the Doll's House). The summative assessment for the course is an examination.

Table 3.2 shows a detailed breakdown of the relationship between the model I used in this project for teaching electricity and the phases of the generative learning model proposed by Osborne and Wittrock (1983). This modified Generative Learning Model was used to bring students to points where conceptual change was necessary for there to be any progression with the task.

Table 3.2. *Modified Generative Learning Model*

| Key Elements: | Phase equivalence to the GLM |
|---|---|
| **Stage 1: Initial ideas about electricity** | |
| • Pretest MCQ and Prediction exercises<br>• Make the bulb light up<br>• Testing predictions<br>• Summarising predictive responses<br>• Discuss preconceived ideas about circuits and how they work that emerge from the summary | This is equivalent to the diagnosis phase of the GLM. In this phase, students use the tests and responses to first diagnose the problems of the class as a whole and then themselves. This diagnosis will be revisited later. |

| Stage 2: Building basic circuits to get things to work | |
|---|---|
| • Design a circuit to do something simple<br>• Draw the diagram<br>• Connect a circuit from a diagram<br>• Repeat process with more and more complex designs | This stage would be equivalent to a series of focus phases and challenge phases where the students first focus on particular problems and then try to solve them in groups. This requires them to exchange ideas about how circuits actually work, which would be the challenge phase of the GLM. |
| **Stage 3: Understanding what happens in a circuit** | |
| • Develop ideas of charge and current (what is actually happening in the wires when there is a current)<br>• Develop ideas of energy and voltage<br>• Develop ideas of resistance<br>• Calculations if necessary<br>• Revisit preconceived ideas about current and circuits | In stage 3, the students continue to exchange ideas about how circuits work, but they are expected to modify their ideas as a result of expert input from the instructor. This is a continuation of the challenge phase of the process. |
| **Stage 4: Wiring diagrams and Circuit diagrams** | |
| • Design of appropriate circuits for a simple 3 roomed house<br>• Translation of circuit diagrams into wiring diagrams<br>• Circuit and wiring diagrams are drawn on the board for the students<br>• Development of a circuit for their own house<br>• Translation of circuit diagrams into wiring diagrams for own houses<br>• Revisit ideas of circuits in connection with the wiring diagrams to reflect on prior conceptual frameworks | This is the beginning of the application phase of the GLM model, however, there are still elements of the diagnosis phase which are used to pick up preconceptions that have been "hidden" |
| **Stage 5: Wiring the house** | |
| • Students learn to solder, strip wire and make physical, hard wired connections<br>• Students learn to solve problems involving issues of voltage, power and resistance<br>• Students learn to physically place a two dimensional circuit into a three dimensional space. | This is the last part of the application phase of the GLM. However, there is still an element of diagnosis and amelioration that continues throughout this stage, as students often use preconceived ideas to make decisions. The context is real and the problems all new. |
| **Stage 6: Self-evaluation of their work** | |
| • Students reflect on their work and the problems they have had in producing the final product<br>• Students make changes to their final product if necessary | |

*4. Gender specific interventions in the classroom.*

While there has been some debate around using single sex groups in teaching science, with some researchers (Harvey, 1985) finding that separating male and female students does not have an influence on student attainment, Parker and Rennie (2002) have shown in a study conducted in Australia that in their case, separating the sexes allowed for teachers to implement gender inclusive interventions, particularly in developing girl's abilities to carry out hands on activities in class. In this study, arranging the students to work in either male or female groups, but not groups of mixed gender, meant that female students were forced to rely on themselves for task completion. In mixed groups, male students were observed to take a greater role in the activities, thereby not allowing female students to participate as much and not acting upon their suggestions. Interviews with female students indicate that while they did not like the idea initially, they appreciated that without it, many would not have accomplished the tasks themselves. In addition to this, more time was given to ensuring that female students had mastered the core skills needed to complete the project. This was not at the expense of the male students however, who seemed to want less help.

*5. Teaching students to teach the doll's house project in schools*

Part of the reason for this project was to teach students to duplicate the Doll's House Project in schools when they were out on teaching practice later in their studies. This meant that the learning of electrical concepts was conducted in such a way that common misconceptions were made explicit to the students and remedies for these discussed. This allowed me as the instructor to give a running commentary on the teaching I was doing, giving them further learning opportunities in the context of the project. As part of the course on electro-technology, I also integrated lessons on ways to deal with diversity in the classroom as well as issues pertaining to the way people learn about current electricity. This meant not only discussing conceptual ideas and making sure that the students understood how to identify different misconceptions, but also issues of gender in the classroom

## Data analysis

Since the data collected ranged from test scores to interview and written reflections, a range of tools were used for data analysis. In this section, I will elaborate on the kinds of data collected in the study and the tools used for data analysis at each stage in the study.

### The data collected

To control for factors besides gender and take account of the educational inequities, a distinction is made between students who attended schools suffering the disadvantage outlined above, and those who attended relatively advantaged schools. Although this inequity has the potential to invalidate results if not accommodated, ironically it allows a focus on whether conceptual knowledge or gender has greater influence on self-efficacy in approaching a technological task. Because our population is heterogeneous with regard to educational background and thus conceptual understanding, levels of self-efficacy in approaching technological tasks can be compared between male and females students in two groups who have had different educational experiences.

To ensure comparison between students with similar educational, socioeconomic and home backgrounds, I compared attitudes to, and performance in technology amongst two groups: White male compared with White female students (all of whom attended advantaged schools), and Black African male students who have attended disadvantaged schools with female counterparts. For simplicity, I omitted Black African students who attended relatively advantaged schools (36% of the Black African female and 4% of the male students in the group surveyed), as well as South African Indian students (27% of the total sample). Conflating these three population groups would be problematic; having been kept apart by apartheid, it is possible that unmeasured differences in cultural norms would invalidate results. I felt it would be inappropriate to make a comparison of performance between different races, since I had insufficient data on academic background for valid comparison. I did however compare gender-specific trends within the data.

Following a mixed method approach to answering my research questions, I collected both quantitative and qualitative data. To triangulate the study, the variables of gender, performance and self-efficacy in approaching a technology task were investigated quantitatively and qualitatively. Data collection tools that gathered quantitative type data included a personal data questionnaire probing gender, school, and educational level in science and also attitudes to technology using a Lickert scale. The Lickert scale data on levels of self –efficacy and attitude could be summed and averaged to determine differences in attitude and perceived self-efficacy levels between genders. Paper 2 provides a more detailed description of the procedures for the analysis of this data. Another quantitative source of data was performance in the examinations and the Dolls' House Task. A mid-course questionnaire probed self-efficacy concerning specific aspects of the Dolls' House Task. Qualitative data collection includes mid and end of course written reflections, as well as interviews with students. Table 3.3 below shows the different sources of data:

*Paper 1*

This paper analyses quantitative data collected on the patterns of thinking about electricity that students have on entry into the course. The data used in this study is primarily that data that has a numerical value derived from the diagnostic tests as well as the initial questionnaire data which provide information about the students' background. In addition, the scores for the project and examination were also used. This paper addresses the first question discussed in chapter 1, i.e. "*What are the differences between male and female students in the way they understand electrical concepts?"*

*Paper 2*

The focus of this paper is on self-efficacy and achievement in relation to gender. This paper draws from most of the data sources, which include the project assessment, examination, reflection and both the initial as well as the midcourse questionnaire. The main question addressed by this paper is the question relating to the effect of the development of self-efficacy on the students' conceptual development and performance on a practical task. In addition, the paper addresses the relationship between relative educational advantage and gender.

Table 3.3. *Data collected in the study*

| **Point at which data was collected** | **Data Type** | **Applicable to which parts of the study as indicated in table 3.1** |
|---|---|---|
| First day (week 1) | Biographical Questionnaire | 1; 2; 3 |
| | Probe of attitudes to technology | 1; 2 |
| | Pre-test on initial models of electric current | 1; 4 |
| During the course (weeks 2 to 4) | Interviews | 2; 3, 4 |
| | Mid-Course questionnaire probing self- | 2; 3 |
| | efficacy levels | 2; 3 |
| | Brief written reflection | 4 |
| | Designs of circuit and wiring diagrams | |
| When the project was handed in (week 5) | Project assessment | 1; 2; 3; 4 |
| | Student reflection on the project | 2; 3 |
| Two weeks after the Course was completed | Examination (post-test) | 1; 2; 3; 4 |
| Follow up data | Tasks | 4 |
| | Reflections | 1; 2; 3; 4 |
| | Interviews | 1; 2; 3; 4 |

*Paper 3*

The third paper uses the reflection data collected and used in the second paper. In this paper, an APPRAISAL analysis is used to interpret the reflection data in greater depth, focusing on the first two key questions, but also using a methodology from discourse analysis to confirm findings from paper 2.

*Paper 4*

This part of the study has drawn primarily from the drawings produced by the students on circuit and wiring diagrams, both during the course and in the final examination. Reference is made to the data collected in paper 1, on patterns of thinking students have on entry into the course and some interview data is used to support conclusions drawn about context and gender. This paper addresses the issue of conceptual change with some reference to context.

**Description of the data collected**

The data collected took many different forms ranging from quantitative numerical data to student reflections as well as interviews. The quantitative data was recorded centrally on a master spreadsheet that was later used for statistical analyses. In this section of the chapter, I have described the different kinds of data that were collected in the study.

*Student reflections*

Reflecting on their own work is a large part of student teacher education within the faculty that has been developed from the first year of study and so all students were familiar with this genre of communication and knew what was expected from them. This does not mean that they were necessarily good at communication and reflecting on past practices, but rather that they had done this before and so it was not necessary for me to explain to them what a reflection was. However, in order to ensure that students were able to provide good reflective feedback at the end of the project, a midcourse mini-reflection paragraph was required of them as the last part of the midcourse questionnaire (This is shown in Appendix D). This gave some idea of how they felt about the task when they were halfway through it and also when they had completed the task.

The student reflection data was analysed and then entered onto a master spreadsheet that was connected to other data collected for each student, including test scores, project marks, examination scores and biographical details. Student comment in the reflections was divided according to gender and coded for instances where there was the expression of human emotion (Affect), assessment of human behavior (Judgment), and assessments of artifacts, processes, and phenomena (Appreciation). Numbers of each of these instances were recorded and the analysed using the APPRAISAL framework that is discussed in greater detail below and also in the method section of chapter 6.

*Student interviews*

Student interviews were used for clarification and in depth probing of student understanding of concepts as well as their feelings about the various aspects of the doll's house task. Two kinds of interview took place. The first was in larger focus groups of between 10 and 15 students that included both genders. A second, often more focused interview type was held with either individual students or pairs of students. Twelve students were interviewed in this way. A transcript of one such interview is shown in Appendix E. Interview data was insufficient for use as a primary source; however, it was sufficient to triangulate some of the data gathered from test scores, questionnaires or student reflections.

*Responses to questionnaires*

Two questionnaires were given to the students. The first was at the beginning and that consisted of a mixture of biographical detail and questions about learning electricity and school and attitudes towards electricity. This first questionnaire is shown in Appendix F. The second questionnaire was given to the students' midway through then course and was designed to elicit attitudinal responses on a Lickert Scale. This questionnaire can be seen in Appendix D. The data from both questionnaires was recorded on the master spreadsheet for later analysis. These data are discussed in depth in chapters 5 and 6. Questionnaires were refined through a process of peer consultation before they were administered to the students. A colleague was chosen to act as a disinterested observer. In this way, the validity of the data gathered was ensured. Triangulation with other reflection data gathered at the end of the course as well as interview data was also used to ensure validity.

*Performance on the doll's house task*

The performance on the Doll's House task was assessed using a rubric that was developed for the purpose (Appendix G). Individual scores were moderated and recorded on the master spreadsheet. The main focus of the rubric was to assess the electrical wiring part of the project.

*Performance on the diagnostic tests*

At the beginning of the course, students were given two diagnostic tests which were used to describe their conceptual status on entry to the course. These tests were also used as a teaching tool to identify students' preconceived ideas and allow students to deal with them. One of the tests is shown in Appendix B. The results and individual responses to the multiple choice test items were entered onto the master spreadsheet. I recorded observations and reflections as the instructor as notes I made after some of the classes. These reflections were not complete and insufficient to be used as a primary source of data; however, they did provide me with field notes that I could use to confirm trends I had seen in other data.

*Drawings of circuit and wiring diagrams*

One of the tasks given to the students in the middle of the course was for them to design and develop circuit diagrams for their own houses as well as wiring diagrams. In order to teach them this, some hypothetical tasks were given where they had to draw similar circuit and wiring diagrams were given to them before they started designing diagrams for their houses. Two contexts were chosen, one where they had to draw diagrams for a house and the other where they had to repeat the exercise for a car. An example of one of these tasks is given in Appendix H. An error analysis on all drawings done in three contexts, the house, and the car and in the final examination was carried out and this data can be seen in chapter 7.

*Examination data*

There were two kinds of examination data that were used. The first were the students' scores on the electrical part of the examination. (The examination comprised two parts, namely Processing and Electricity). These scores were entered with all the other data on the master spreadsheet that was developed. (The electrical part of the examination is shown in Appendix I). The second kind of data were the drawings of both circuit diagrams as well as wiring diagrams that were student's answers to questions in the examination. Some examples of these can be seen in chapter 7.

**Statistical methods used**

Numerical data collected was analysed statistically using standard t-tests for small samples (<30). In papers 1 and 2, the population of participants was divided according to three criteria, gender, relative advantage of schooling as well as whether or not students had studied physical science to the end of high school. This meant that the sample sizes were on average about 16, giving an average degree of freedom of around 30. In both papers I wanted to compare the mean scores between two samples in order to see if there was a difference between them. For this, a t-value was calculated according to the standard formula (Bless & Kathuria, 2008):

$$t = (x_1 - x_2)\sqrt{\frac{\{(n_1 + n_2 - 2)(n_1 n_2)\}}{\{[(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2][n_1 + n_2]\}}}$$

Where: $(x_1 - x_2)$ is the difference between the means of the two samples and $(n_1 + n_2 - 2)$ is called the degrees of freedom. In order for the t-test to be valid in this study, several assumptions have to be fulfilled (Bless & Kathuria, 2008). These are:

- The sampling of the groups tested must be independent and random
- The groups are independent and unrelated in any way.
- The size of the groups is small (<30)
- The measurements must be made on an interval scale
- The sampling distribution of the difference between the means must be normal
- The population variances are equal

Within the context of this study, these criteria have largely been fulfilled. The sampling has been independent and random in that students have selected to enter the course themselves and this has made them eligible for the study and so the groups of students tested against each other has been predetermined. In addition, the groups themselves are independent and there is no relationship between performance on tests or examinations in any way. This would be different had for example I been testing the same group twice, where the second outcome might be dependent on the first. This was not the case in this study. Sample sizes are all small and below 30, which is why I have selected to use the t-test. In addition, the data falls on an interval scale in all cases as we are comparing scores. However, as far as the sampling distribution of the difference between the means is concerned, this was not tested directly, but it was assumed that since the original distribution was normal, the last two points would be true.

In my statistical analyses of the data I have collected, I have operated from the point of view that the tests are non-directional, since the differences (higher or lower) are evident. This has meant that in all the comparisons between means that I have made, I have selected the two tailed test. This is reflected in the critical values of t that I have used. I have also in a number of comparisons compared means at different levels of confidence, which has provided some insight into how significant the differences are. A table showing critical values of t that are compared to the observed (calculated) values to see if there is a significant difference between means is shown in Appendix K.

Statistical correlations using Pearson's product moment correlation coefficient (r) were calculated in the first paper (chapter 4) to see what relationships existed between the tests. This statistic was calculated according to the formula (Bless & Kathuria, 2008):

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

A number calculated that is close to 1 and positive means that there is a strong positive relationship between the two. Conversely, the close the number calculated is to zero, the less the relationship is between the two sets of data.

**APPRAISAL analysis**

The APPRAISAL framework for analysis as described by Martin (2000) was used as a method to analyze students' attitudes and feelings that were expressed in their written reflections on the doll's house task. The approach was chosen because of its ability to distinguish linguistically between different textual meanings in the written reflections that the students produced at the end of the project. Specifically, this approach was used to enable me to identify different feelings that were being expressed by the students and how these feelings were being framed. The following description of the APPRAISAL framework is essentially reproduced from the first paper (Mackay & Parkinson, 2009, p.735) emanating from this Dolls House project.

The appraisal framework is part of Systemic Functional Linguistics, a semiotic approach to language that must be distinguished from formal grammar, where focus is on word classes within the unit of the clause. In systemic functional grammar, the meaning and the options for making meaning within texts is examined by focusing on both the structure and the lexis of texts. Every utterance may then be analyzed with regard to three metafunctions: ideational, interpersonal, and textual (Halliday, 1994).

In Mackay and Parkinson (2009), the APPRAISAL system focuses specifically on interpersonal meaning considering three kinds of interpersonal meaning used by the writer. These are: the expression of human emotion (Affect), assessment of human behavior (Judgment), and assessments of artifacts, processes, and phenomena (Appreciation). Affect is the primary framework for analysis of interpersonal meaning to encode emotions; however, Martin (2000, p. 145) notes that Judgment and Appreciation can also encode feeling. Judgment can be thought of as emotion that is recontextualized as the evaluation of behavior. Appreciation on the other hand can be thought of as emotion that has been recontextualized as evaluation of things people have made or of natural phenomena.

Affect considers emotions related to both present and future events, which can be either explicitly realized, for example "I love my little dolls house'', ''I'm so proud '', ''an awesome module'', or implicitly realized, for example: ''each time I would get a light to work I would yell and (my mother) would rush in and see what I had managed to do'', thus evoking a sense of pride in accomplishment. In coding the reflections for Affect, it was important to distinguish between negative and positive emotions in addition to the categories of Affect that were coded for. Some examples are: un/happiness, in/security, and dis/satisfaction and emotions such as fear and desire that refer to future events (dis/inclination). Affect also includes on the negative side, misery and antipathy, disquiet, surprise, boredom and displeasure, while on the positive side, cheer and affection, confidence and trust as well as interest and admiration (Mackay & Parkinson, 2009).

Judgment is a framework for meanings that evaluate human behavior. According to Coffin (2000), this is usually through institutionalized norms about how people should and should not behave and often refers to language which criticizes, praises, condemns or applauds behavior (White, 2005). The first category of Judgment refers to judgments involving social sanction of behavior. In this category are included both negative and positive judgments of veracity (truth) and propriety (ethics). A second category of Judgment refers to social esteem, which again involves both negative and positive judgments of normality, capacity, and tenacity (Mackay & Parkinson, 2009, p.736).

Appreciation refers to resources for valuing products, performances, and natural phenomena (Martin, 2000, p. 159). It too has positive and negative dimensions and has three categories, namely: reaction (both impact [noticeability] and quality [likeability]), composition (including balance as well as complexity), and finally, valuation of how worthwhile something is (Mackay & Parkinson, 2009, p.736).

Data from the reflections collected at the end of the course were coded for Affect, Judgment and Appreciation, using the APPRAISAL framework outlined above (for a detailed description as to how this was done, see chapter 7). This provided an insight into the emotions expressed by the students on carrying out the Dolls House Task. The frequency of students expressing different emotions was recorded and then analysed according to gender and level of educational disadvantage. In all cases of Affect, Judgment and Appreciation, comparisons of the frequencies of positive versus negative dimensions were made between groups of students selected for analysis.

**Interviews with students**

Interviews were conducted with selected students and these were conducted in two ways. The first was through broad focus group interviews that were useful for feedback on the processes that took place in the classroom, such as learning to solder, making the house, designing the house and general attitudes about the context of building a doll's house in order to learn electricity.

Individual or sometimes pairs of students were interviewed on specific issues to do with the learning of electricity. These followed the format of an interview about a specific instance that was detected in that students learning of electricity and in particular the transition between designing circuits and designing wiring diagrams. In addition, students were asked to comment on other "instances" of circuit and wiring diagrams that had been developed by other students, suggesting possible problems with the designs as well as ways in which these designs could help them understand their own designs. This technique was loosely based on the 'interview about instances" technique pioneered by Gilbert, Watts and Osborne (1985) and Osborne and Gilbert (1980). Instead of cards showing misconceptions as were used by Osborne and Gilbert (1980), cards showing students own circuit drawings and well as a sample of other drawings from students became the centerpieces of the conversations held in the interviews.

The individual and pair interviews were used to collect data on the "gendered" effect of context on whether or not students felt able to perform a particular task. Interview data was used where appropriate to confirm evidence that context had an effect on performance in designing circuit as well as wiring diagrams, as well as to confirm the existence of different patterns of thinking about circuits. The main focus group interviews were used to confirm other evidence gathered from reflections about the beliefs students had about context, gender and self-efficacy in connection with the design and wiring of the dolls houses. All interviews were recorded and transcribed for use. Interview data in the end was found to be insufficient to support propositions on their own, but was sufficient to provide a confirmation of propositions supported by other data collected.

**Validity and reliability of the collected data**

In view of the fact that different kinds of data have been collected in this study, it is important to discuss issues of validity and reliability. According to Cohen, Manion and Morrison (2007), these terms are often used in connection with testing and evaluation, particularly in quantitative studies, where validity of a test item refers to whether or not that item tests what it says it will test. This is different from the validity of the data analysis which is to do with the selection of an appropriate statistical tool with which to interpret the scores from the already validated test items.

The reliability of a test item then refers to whether or not the item consistently tests the same thing over time, which is important if the study were being repeated over a number of years. In the case of this study, all the data discussed was collected over an initial period of five weeks and so issues of reliability over a long period are not of concern.

Test items in the diagnostic phase of the instruction have been validated over a number of years through constant use and change. Reference to this validation is made in chapter 4 as well as in chapter 7. The examination test items were validated through the faculty examination moderation procedures where the questions were deemed valid through peer evaluation. Finally the assessment tool used to assess the doll's house project was validated through a process where assessment was moderated by another member of staff. This was done while assessing the projects.

Morse, Barrett, Mayan, Olsen and Spiers (2010) have argued that "qualitative researchers should reclaim the responsibility for reliability and validity by implementing verification strategies that are integral and self-correction" (p. 13). In keeping with the notion of verification, the validation of data collected in this study needs to be seen in the light of each paper that was written. Triangulation was used in most instances to validate the data collected. This was done by comparing reflection data, statistical trends as well as questionnaire data. In addition, interview data as well as my own observations were used at times to validate the data collected. In this way, the plausibility of the data collected was consistently checked. On a number of occasions, peer evaluation was used in debriefing sessions to ensure data credibility.

Validity and reliability of the data collected must therefore be seen in the context of the research paradigms used in each part of this study. Golafshani (2003) points to change in the way we view the notions of validity and reliability through the association of a quantitative; positivist paradigm with a qualitative notion of research. This change is echoed in this study, where there is a need to triangulate statistical data with qualitative data. In so doing, this process of verification also seeks to enrich the interpretation of the numerical data collected. Triangulation itself is seen by Creswell and Miller (2000) as a validity procedure culminating in the production of themes or categories as a consequence of a search for commonality and convergence.

The validity and reliability of data on performance on pre-tests relies on both the design of the questions as well as the statistical methods that were used to compare different populations. For attitudinal data collected on a Lickert type scale, the data validity is dependent on the questions asked and whether or not the questionnaire itself has been tested. Reflection and open ended interview data on the other hand requires the form of internal validity as described above. The shift away from positivist mechanisms to ensure validity has in this case ensured that the methodology is indeed mixed and in line with a pragmatic approach to research.

## Ethical issues

Ethical clearance for the project was given by the Faculty of Education ethics committee in 2006. This ensured that not only were the students protected, but also, the research was designed in accordance with standard university policy at the time. The study was centred on a project that was part of a teaching module and as a consequence of this, full participation by students was ensured.

### Informed consent

Participants all agreed to and signed an informed consent form (see appendix J, which includes a copy of the approved ethical clearance application Protocol Reference Number HSS/0083/012D), which outlined what the project was about, ensured their anonymity and confidentiality and provided information about the project. The participants were all students who were training to be teachers and as an additional part of their training, I agreed not only to make available the findings, but in addition provide for them ways in which they could use the results of the study to inform their own teaching. At each stage, acceptance was negotiated by providing explanations as to what each task was looking for and also how they could use similar tasks in their own teaching as diagnostic tools.

All participants were responsible and mature individuals whose competence was not in question since they were registered as students at the university at least in their second year of study. None were younger than 18 years. Furthermore all understood that participation in the project was voluntary and that they could withdraw at any time; however this did not mean that they could stop the instructional part of the study, as this would have meant withdrawing from the course. This was perhaps one of the factors that ensured complete participation. Since many of the data gathering devices were also teaching tasks, it made little sense to withdraw from the study.

**Non-maleficence**

Cohen et al. (2007) discuss the concept of non-maleficence, which involves designing the research so as not to place participants in harm's way of any kind, unless it is unavoidable. This would include emotional as well as physical harm. As far as was possible, the research was designed to do no harm to the students. There were no complaints apart from general complaints about workload that were common every time the course was run. The end of course reflections testify to the fact that the students enjoyed participating in the project and even though the workload was high, it was not more than it would have been had they withdrawn from the non-course related data collecting tasks.

There are however two issues that are central to the study, those of gender and race, that are of particular importance to students, especially in South Africa which has only recently emerged from a devastatingly discriminatory system. Students at the university are particularly sensitive about these two issues and so I have decided to discuss these separately below.

**Beneficence**

At the outset, I decided to use the data gained from this cohort to provide immediate benefit to the students' own development as technology teachers. This was done by explaining the purpose of the diagnostic tests to them and then showing how these tests could be used to teach electricity. This model of transparent engagement with the students was continued throughout the contact period. This process was found to be emancipatory for a number of the students who became interested in their own conceptual development. It may be that this affected the way the students did the project and the way they learned electricity. However, since teaching them electricity was the point of the course, and since explanations of models of thinking were given after the completion of data gathering tasks, I did not consider this to have a significant impact on the quality of the data gathered.

**Issues around gender**

The central issue that was being investigated was the differential learning of electricity by male and female students. This meant that there were times when female students questioned why certain activities were carried out, for example the division of classes into male and female only groups for a short period to ensure the development of female students' self-efficacy. Students appeared to be satisfied by the justification put forward. Generally, the differentiation of participants on the basis of gender was explained in the outline of the project for the purposes of informed consent and in later discussion with students who showed curiosity as to what it was I was trying to find out, there was no negative reaction to the fact that this differentiation had taken place. This was possibly due to the negotiated and ongoing discussions we had had about the tasks. In a sense, female students seemed to "know" that they generally performed poorly at electrical tasks and that this was my area of research seemed interesting to them.

**Issues around race**

The issue of race was a much more sensitive variable to research. I decided after some consultation with colleagues not to differentiate the participants on the basis of race, but rather on the basis of schooling. There were two main reasons for this. The first is that the intention of the research is to help improve what happens in schools, irrespective of the gender of the student and irrespective of the race of the student. The second is that in South Africa, the issue of performance is related to schooling. Those that go to good schools do well and get on in life. Those that go to poor schools are not as lucky. The differential schooling under Apartheid has resulted in a long lasting legacy of poor schooling for the mainly African population of the country. Contrary to this is the quite good schooling that is offered in the formally white schools, known colloquially as "model-C schools". Today, all schools are simply schools with differing models of funding depending on how they are managed, which is also related to the resources they had in the past. This has resulted in two distinct kinds of government school at either end of a continuum. The first is the well run, well resourced, racially integrated school with qualified teachers and on the other end, is a poorly run, poorly resourced school with poorly qualified teachers where there has really been no racial integration.

## Summary

To conclude this chapter, I have used a pragmatic research paradigm that employs a mixed methods approach to collect and analyse data. The reason I have chosen this route is that I believe that none of the other paradigms alone would be able to tell the whole story of a group of students who have struggled to do something they thought they could never do. Selecting a pragmatic paradigm as the most effective way to answer the original research questions I have posed allows me to collect all kinds of data, both of a quantitative as well as qualitative nature that seen together provide me with a much richer picture of the problem I am investigating. In this chapter I have discussed the overriding research paradigms which I have linked to the theoretical frameworks that I have discussed in chapter 2. I have then made a case for the way the data was collected, interpreted and validated, which will be reinforced in the coming chapters.

Finally, the next four chapters will discuss different aspects of each study separately, but in the connecting narratives that link the papers together, I will make further reference to issues discussed in the first three chapters of this thesis.

# Chapter 4

# Gender differences in conceptual thinking in electricity amongst technology teacher trainees

## Introductory remarks

This paper on the differences and similarities in conceptual thinking analyses how students think about basic DC electricity on entry into an introductory Design and Technology course for pre-service school teachers. This is the first of a suite of papers that looks at different aspects of data gathered from the study described in chapter 3. In this paper I focus on answering the first research question: "*What are the differences between male and female students in the way they understand electrical concepts?*"

This paper paints a picture of what students know about connecting basic electric circuits by examining the differences in responses to pre-test items in terms of three factors: gender, whether or not the student selected to study physical science to the end of school and the relative level of educational advantage of the school the student went to. This paper provides a necessary background for understanding the three papers that follow. Much of physics education research on university teaching and learning of electricity examines samples of students that have actively opted to study science in general or physics in particular. This study almost exclusively looks at a sample of students that has specifically moved away from science. Most did not take science to the end of high school and attitudes towards science vary from fearful to angry. They have opted to take Design and Technology not because they are interested in learning about electricity, but because it is the least mathematical and the least scientific course they can select from a compulsory choice. This is a very different sample to the kind of sample that researchers are used to in studying conceptual change amongst students and this can be seen in the data discussed in the following paper.

# Gender differences in conceptual thinking in electricity amongst technology teacher trainees

## Abstract

Our patterns of thinking about electrical concepts are influenced by our prior knowledge. This paper is about the differences in conceptual thinking between students detected on entry into a basic current electricity module that is part of a design and technology course, and the factors that may influence these differences in thinking. Conceptual pre-tests using diagrams of circuits designed to elicit different conceptual models of how circuits work were given to a sample of 114 participants. In addition, data on prior electrical histories, level to which electricity was studied at school, as well as the relative level of educational advantage in terms of school background were gathered via a questionnaire. Responses to the test questions were then compared with these variables using standard statistical tests for significance. The main findings indicate that males performed significantly better than females on the tests, even when school background and prior electrical knowledge were the same. In addition to overall performance, there were significant differences in the way male students responded to particular test items as compared with female students. Performance on the pre-tests was determined to a much lesser extent by educational factors, such as the whether or not the student took Physical Science to the end of school or the relative level of educational advantage of the school they attended. This is interesting in the context of the South African educational system where the quality of schooling is considered to be a major influence on performance.

Keywords: Gender, electricity, models of electric current.

## Introduction

Patterns of thinking about electricity in general and electric current in particular have been the subject of numerous studies over the last four decades. Tiberghien and Delacote, (1976) were among the first to identify the use of non-scientific conceptions in basic electricity that students use to solve electrical problems. These patterns in thinking are deep seated and determine student performance in tasks that they are required to do in the classroom and their summative assessment tasks. While the kinds of alternative conceptions that are exhibited by South African students are consistent with those recorded elsewhere in the world, students entering tertiary study have shown alarmingly low levels of conceptual competence, even amongst high achieving students (Stanton, 1989). International studies such as the TIMMS test have ranked South Africa lowest in terms of learner performance in science of those countries where the survey was conducted. (Martin, Mullis, Gonzalez & Chrostowski, 2004) Understanding how simple DC electric circuits work is a key curriculum outcome in South Africa, even for those students who do not pursue the study of science to the end of high school (Curriculum and Assessment Policy Statement, 2011) and is addressed in the science curriculum from grade 6, grades 8 and 9 and also later in grades 10, 11 and 12. It is also addressed in the technology curriculum in grades 6, 7, 8 and 9. In this paper, I investigate the prevalence of a particular alternative conception of electric circuits held by students embarking on a course on basic electro-technology for teachers in relation to gender and school background.

**Difficulties students have in learning electricity**

Gilbert and Watts (1983), Tasker and Osborne (1985) and Shipstone (1988) have all identified several different models that learners use in trying to make sense of electric current and simple DC circuits. According to these researchers, models of electric current are such that they often hinder the conceptual development of any learning of current electricity. Table 4.1 below summarises the most common incorrect models of thinking students have used in interpreting basic electric circuits. This categorisation of models used by the learners is still relevant and Physics teachers will still find examples of these models of thinking in their classrooms today.

The least complex of these models is the *unipolar* or *sink model* of electric current. The *attenuated* or *dissipative* model is more sophisticated in that while it incorporates the idea of a completed circuit, it also has a non-conservative view of electric current (current is "used up") and in this way, is similar to the unipolar model. The dissipative model appears to develop naturally from the unipolar approach.

Table 4.1. *Elementary Models of current*

| Model | Description |
|---|---|
| Unipolar or Sink | Current from only ONE terminal (either positive or negative) No circuit, only a connection from the "power source" to the bulb |
| Clashing Currents | Both a "positive" as well as a "negative" current meet at the bulb and "clash" causing the bulb to light |
| Dissipative or Attenuating | Current is "used up" as charge moves around the circuit. Greater current near the (+) pole, dissipating further away from (+) / If negative charge is predominant, current "comes from" (-) pole |
| Sharing | Current is shared by the different components in a series circuit |
| Scientific | Current is the same everywhere in a series circuit. For the bulb to light, there needs to be a completed circuit. |

In this paper, I focus on the evidence presented by students in diagnostic tests of extensive Unipolar thinking that has in the past been thought to be a model of current least resistant to intervention. Tasker and Osborne (1985) in New Zealand found that only around 5% of pupils showed evidence of unipolar thinking and that this was quickly extinguished through directed instruction and the use of focused inquiry tasks. Stanton (1989) however, does not support this as he found that with South African students studying physics, the unipolar model survives quite well after initial school instruction. The reasons for this are unclear and not addressed by Stanton (1989). Shipstone (1988) combines the dissipative approach and Tasker and Osborne's (1985) unipolar model into one, based on the fact that both models use a consumptive idea of electric current. According to McDermott and Shaffer (1992), the dissipative model of current has also been linked to confusion between the concepts of energy and current and they maintain that mixing up these ideas is common for students beginning their study of electricity.

McDermott and Shaffer (1992) identify the lack of concrete experience with electric circuits with the failure by students to understand the need for there to be a complete circuit. Related to this is the problem students have in not being able to recognise that the circuit diagram does not necessarily represent physical or spatial relationships and that it is only a schematic representation of connections. Other common difficulties outlined by McDermott and Shaffer (1992), include the confusion between potential difference and current, which can be linked to the common confusion between energy and current. More recent work by Küçüközer and Kocakülah (2007) have confirmed in an extensive survey of Turkish students, all of the common difficulties outlined in earlier research summarised by McDermott and Shaffer (1992) and in addition found two new alternative conceptual models that were peculiar to Turkish students. These they attributed to language issues and the way electricity was taught in schools in Turkey.

The way we learn electricity also has a bearing on the way we understand electrical concepts. Very recent work by Jaakkola, Nurmi and Veermans (2011) found that the combination of hands-on-exercises integrated with simulations provided students with a better understanding of the way circuits work than just simulations alone. Context too is important as found in a study by Tsai, Chen, Chou, and Lain (2007), who found that students understood and made sense of different circuits in different ways and that student's conceptions of current were strongly influenced by context.

Of course, students don't miraculously change from their alternative conceptual framework to a scientific way of thinking about electricity; stages in this change have been identified by several researchers. Borges and Gilbert (1999) describe the conceptual progression of mental models that students go through in developing their ideas. This progression usually starts from the idea of electricity as a flow of "stuff" from the energy source to the various components and then progresses to a model of "electricity as opposing currents" which describes two different types of electricity in a circuit, a notion that still does not conserve current. A development on this is the model of "electricity as moving charges", which Borges and Gilbert (1999) see as a mechanistic view of what happens in a circuit, finally leading to the field model of electricity, which can be used to explain the action of a single charge a distance from the electrodes. This progression of models of how electricity works in circuits can be closely related to the earlier models of current attributed to researchers like Shipstone (1988) and Tasker and Osborne (1985).

This work has been supported by Niedderer and Goldberg (1994), who, while studying the conceptual development of an individual student in learning about basic electric circuits noticed that the students started with common alternative mental models about current and then moved through conceptual development phases using intermediate concepts, prior to developing conceptions that were closer to the scientific view of electricity. This process of integrating prior, everyday ideas about electricity with ideas that were more closely related to the scientific approach they termed *conceptual ecology*, a kind of overall mental model of the process of moving through intermediate developmental phases. Niedderer and Goldberg's (1994) idea of intermediate or developmental models is supported by Grayson (2004) who uses the idea of conceptual substitution as a way for teachers to use the intuitively correct ideas of students as a platform to develop scientifically correct concepts. In her study she outlines the complexity of the conceptual change process in addition to the development of intermediate conceptions students have while this change is taking place. Related to this is the use of bridging analogies and forming a link between students' correct conceptions and new knowledge. Clement and Steinberg (2002) reported the use of a strategy that used a cycle of concept generation, evaluation and then modification to teach direct current electricity in a single student case study.

In this study, I will be looking at evidence that suggests that the unipolar model of thinking is not easily eradicated through school instruction and that in the South African system at least, not only do students come into university courses with this preconceived idea, but that there is a difference between the way male students and female students interpret circuits, with a greater proportion of female students using the unipolar approach than male students. I have used Shipstone's (1988) categorisation of mental models of current and the way circuits work as a framework for the diagnosis of alternative models of thinking about how electric circuits work in this study and have compared the performance of male and female students responses to a set of test items based on this framework.

**Gender and learning science and technology**

The differential performance and participation of boys and girls in science and technology has been one of the focal points of a number of large studies worldwide that have been conducted, for example Project ROSE (Schreiner, 2006). These studies have in general pointed to the differences in choice made by female pupils and students when it comes to selecting areas to study and they have attempted to explain some of these differences in terms of gendered attitudes to careers and work. These attitudes are embedded in the subtly different ways that male and female children are treated (Nicholson, 1984; Smith & Lloyd, 1978) and transmitted through discursive practices (Davies, 1989). As a consequence, many school science and technology tasks, electricity in particular, appear designed to be more interesting to boys than girls (Silverman & Pritchard, 1996; Weber & Custer, 2005), a factor that possibly has an impact on the attitudes of female students to the learning of physical science.

This differential performance between the genders is attributed by Mammes (2004) to greater familial encouragement given to boys and the tradition of boys playing games that require spatial abilities, which could also be a factor in understanding electrical concepts that require the interpretation of visual representations. Atkinson (2006), as well as Silverman and Pritchard (1996) found that female school learners and students preferred some science and technology related tasks over others. (An example given by them is that the design and construction of model houses is preferred by girls over mechanical and electrical tasks). Lewis (1996), however, points out, that such preferences may be a manifestation of the differential treatment afforded male and female children (including females' primary early socialisation from a parent of the same sex while males are usually socialised by parents of the opposite sex). Nicholson (1984) as well as Smith and Lloyd (1978) point to possible differences in the way girls and boys are brought up and the pervasive underlying sexist nature of the way we are conditioned by society as factors that produce a gendered difference in performance in learning science and technology.

With specific reference to learning electricity, Engelhardt and Beichner (2004) found that in analysing data gathered from a diagnostic test they designed to identify alternative conceptions in basic electricity, male participants performed better than female participants. In addition, female participants were found to be less confident in their responses to the questions. They also exhibited the use of more alternative conceptions in the way they approached the questions than did their male counterparts.

In summary, there is no evidence to support the idea that differences in participation and achievement in science and technology are ability related and these must be attributed to other factors such as low self-efficacy levels and negative feelings towards technical knowledge. These factors arise rather from social attitudes that view certain fields of study as less appropriate for women (Young, 1990). Secondly, the evidence that female students exhibit a greater variety of preconceived ideas than do their male counterparts (Engelhardt & Beichner, 2004) suggests that there is a connection between conceptual thinking and gender. This is particularly important in the light of the data collected in this study, as it points to a relationship between gender, attitude and conceptual understanding.

## Research design

Prompted by observations of student difficulties in previous courses I had run, I was interested to see the extent of the use of unipolar thinking on entry into the course and also if there was a difference between male and female participants in their performance on the diagnostic tests. This predominance of unipolar thinking appeared to contradict work reported by other researchers (McDermott & Schaffer, 1992; Tasker & Osborne, 1985). The research design was one of a descriptive case study, where t-tests on diagnostic test data was used to see if there is firstly a predominance of unipolar thinking and secondly if this thinking is gender related. Lastly, I was curious to find out if there was any predictive value to the diagnostic tests and to do this, I generated correlations between different sets of data collected, including the diagnostic tests, the scores for the Doll's house project as well as the final examination.

On entry into the course, two pre-tests that had a focus on common preconceptions (in particular the unipolar model of thinking), were administered along with a questionnaire eliciting biographical as well as data pertaining to educational experience at school. The tests and questionnaire were administered prior to any new instruction and conceptual development. At a later stage, scores of the major project, the wiring of a doll's house and the final assessment for the course, an examination were also recorded. The pre-tests were focused on eliciting patterns of thinking about circuits and were designed to identify these patterns for the purpose of amelioration of alternative conceptions in basic electric circuits as part of the teaching strategy in the course, particularly the unipolar model.

**Who are the participants?**

The participants comprised a sample of 114 students that was selected from a population of 161 students registered for a Design and Technology course as part of a Bachelor of Education degree at a South African University. The sample was selected in order to compare student performance on diagnostic tests based on gender. In order to do this the sample was divided into six distinct groups of students. This module was a single semester module used to prepare students to teach basic electricity to primary school pupils that was project based and used the context of the construction and wiring of a model doll's house to learn electricity.

The division of the sample into six groups was done in order to ensure that gender comparisons that were made were valid, due to the additional complication of the effect of apartheid education. South Africa effectively has a two tier system of education which provides a functional well run school environment with good teachers and sufficient resources to some learners, and a poorly run, ineffective learning environment with poorly qualified teachers and few resources to others. While this purports not to be racially based, in effect it is. In the well run schools that were formally only open to white learners under apartheid, learners of all races mix and enjoy the advantages of a positive learning environment, while the poorly run schools are mostly not integrated and are from the historically African communities (Perry & Fleisch, 2006). In order to distinguish between those students who were disadvantaged by their school education and those who were not, in this study I have decided to use the Education Management Information Systems Report on School Disadvantage Indicators (2006). The distinction in this instance between an advantaged school and a disadvantaged school was made using this government approved data base and ranking system which is determined by the relative wealth of the school itself. The differential education provided under apartheid has resulted in differences in school performance, particularly in mathematics and science, where those students who went to educationally disadvantaged schools perform worse in science and mathematics related disciplines than do those who went to educationally advantaged schools (Perry & Fleisch, 2006).

Table 4.2 gives a breakdown of the student sample based on level of educational advantage and gender. Of the selected students, 61% were female, 67% were advantaged and 72% had not taken science to the end of high school. This table not only divides participants according to gender, which is the primary variable under scrutiny, but also according to level of school advantage / disadvantage and thirdly according to whether or not the participant took science to the end of school or not. In order to see if differences in scores were indeed gender related, it is necessary to account for these other two factors.

**Rationale for the tasks given**

The programme of instruction was based on conceptual change strategies pioneered by Osborne and Wittrock (1983), Posner, Strike, Hewson and Gertzog (1982) and later developed by Kyle, Abel and Shymansky (1989). The design of the programme of instruction started with a *diagnostic phase* (the initial pre-tests), which was followed by a *problem solving phase*, then *challenge phase* and finally an *application phase* where the students were required to use their knowledge to wire an already constructed doll's house. The diagnostic phase is an essential part of the programme of instruction for two reasons. The first is for students to find out and confront their preconceived ideas for the purpose of amelioration and the second is to give them, as student teachers some knowledge of how children think when they are confronted with similar tasks.

Table 4.2. *Statistical Breakdown of the Sample*

| Gender | | Level of Educational Advantage | | Whether or not the student took Physical Science to the end of School | |
|---|---|---|---|---|---|
| Male | Female | Advantaged | Disadvantaged | Science | No Science |
| 44 (39%) | 70 (61%) | 76 (67%) | 38 (33%) | 32 (28%) | 82 (72%) |

The initial diagnostic phase included two tests, one of which required students to predict whether or not a bulb would light up, that was designed to elicit preconceived ideas about circuits and the nature of current. The second test was designed to give further indication about the conceptual models the students used when interpreting circuits and electrical ideas. Examples of items from test 1 are shown in figure 4.1.

In order to ensure that the diagrams in test 1 were understood properly, the light bulb construction was made explicit in a diagram in the students notes and also described on the board prior to the test. This was done to ensure that a lack of understanding of how the bulb was made did not have an effect on the way the students understood the circuits. A similar amendment was made to validate research conducted by Shipstone (1988) and Stanton (1989).

## Data analysis

The data fell into three categories that are listed in table 4.3 below. The first were biographical data about the students themselves, which allowed for the division of the sample into six distinct groups. The groups were divided first according to gender, then according to school (relative advantage of schooling) and then according to whether or not they took physical Science to the end of high school. Lastly, I looked at whether or not the students had ever connected circuits before, but this was not as comprehensively investigated as the other categories, as will be discussed later.

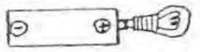
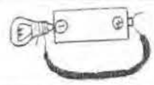
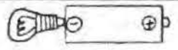
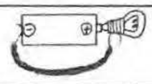
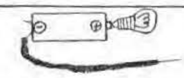
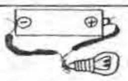
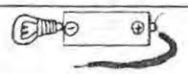
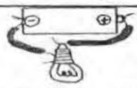
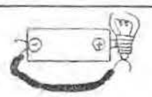
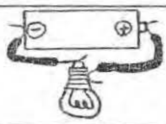
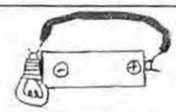
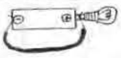
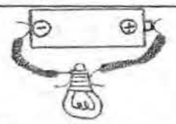
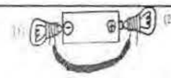
| TEST 1: Does the bulb light up, yes or no? | | | | | |
|---|---|---|---|---|---|
| **Circuit** | **YES** | **NO** | **Circuit** | **YES** | **NO** |
| A  | | | H  | | |
| B  | | | I  | | |
| C  | | | J  | | |
| D  | | | K  | | |
| E  | | | L  | | |
| F  | | | M  | | |
| G  | | | N1  | | |

*Figure 4.1.* Sample test items for the diagnostic phase.

The second set of data was the data from the pre-tests that were given to the students on entry into the course. There were two tests, test 1, which essentially attempted to elicit information about the use of the unipolar model of circuit construction and secondly test 2 which was a multiple choice test used to elicit other models of current used by the students in interpreting electric circuits. The first four questions of test 1 which explicitly elicited patterns of thinking about the unipolar model were investigated separately. This was done in order to investigate contradictory findings in the literature (Stanton, 1989; Tasker & Osborne, 1985).

The third category of data used was that of the scores of the students for their final projects and their examination scores. Both were recorded after completion of instruction. These were correlated with the pre-tests as well as each other for the categories of student identified in the first set of data.

Table 4.3. *Classification of data*

| **Data Category** | **Kind of Data** | **Divisions in the data** | | |
|---|---|---|---|---|
| Category 1 | Gender | Male | Female | |
| | Relative advantage of school attended | Advantaged | Disadvantaged | |
| | Whether or not student took Physical Science to the end of School | No Science | Science | |
| | Whether or not the student connected circuits at school or home | No circuits Connected at school / home | Has connected circuits at school / home | |
| Category 2 | Diagnostic test scores | Pre-test 1(score for whole test) | Pre-test 1(score for 1st four questions) | Pre-test 2 |
| Category 3 | Final Scores for the course | Dolls House Project (out of 100) | Electrical part of Examination (out of 40) | |

**Statistical comparisons that were made**

Two kinds of comparison were made. The first was a comparison between groups to see if there was a statistically significant difference between the means of these groups. Due to the fact that a number of the samples were often below 30, the student's t-test for independent samples was used for this comparison.

A second comparison was made between the four sets of data collected, namely the two pre-test scores and the scores for the final project and examination. I was curious to see if there was any predictive value to the pre-tests and if there was a relationship between the scores in the final project and also examination and the pre-tests. For this Pearson's r was calculated.

## Comments on the data collected

Differences in performance on the initial tests (category 2) between different groups of students in category 1were measured using a comparison of means by calculating the student t score. Initially, broad categories were used as a course measure of where there were differences in performance. There are three category 1 variables (gender, level of advantage and taking science at school). Table 4.4 shows comparisons where there was no control of variables for test 1, table 4.5 shows comparisons where there was a control of one variable and table 4.6, where two variables were controlled for.

**Table 4.4**

The first comparison made between all-males and all-females showed a significant effect for gender, $t\ (112) = 3.08$, $p < 0.05$, with males scoring higher than females. In this instance, the males score significantly higher than the females, with a mean score of 9.77 as compared with a mean female score of 8.09.

Table 4.4. *Statistical Tests on Conceptual pre-test responses; TEST 1 - Focus on unipolar thinking (whole Test)*

| | DF | t-observed | t-Critical at the 95% level of confidence | Significant difference between means? |
|---|---|---|---|---|
| All F vs. All M | 111 | 3.08 | 1.98 | YES |
| All Adv. Vs. All Dadv. | 73 | 1.23 | 2.45 | NO |
| All Sc vs. All No Sc | 111 | 0.04 | 2.05 | NO |

KEY: F – Female; M – Male; Adv. – Advantaged; Dadv. – Disadvantaged; Sc. – Took Physical Science to the end of school. No. Sc. – Did not take Physical Science to the end of school

There was no significant difference in the scores of those students who went to educationally advantaged schools and those who did not and in addition to this; there was no significant difference between those students who took Physical Science all the way to the end of school and those who did not. Both of these outcomes are unexpected, as for a long time, it has been assumed (and indeed it has been shown: Perry & Fleish, 2006) that poor schooling is a significant factor in determining students' performance. In the case of forming mental models and scientific patterns of thinking however, these statistics would appear to contradict conventional wisdom. Data from table 4.4 can be summarised as follows:

- Significant difference between all male and all female students

- No difference between advantaged and disadvantaged students
- No difference between those who took science to the end of school and those who did not

**Table 4.5**

While table 4.4 shows tests for differences between broad categories for test 1 (male/female; advantaged/disadvantaged and science/no-science), table 4.5 shows tests for differences between categories where there two of the three variables were controlled for. This provides a closer look at the same data. Significant differences in performance were also detected in smaller sample sets related to gender (see table 4.5). In those students who had attended advantaged schools, there was a significant difference in performance between males and females $t$ (36) = 2.89, $p < 0.05$, but not, surprisingly between those who attended disadvantaged schools.

Table 4.5. *Statistical Tests on Conceptual pre-test responses; TEST 1 - Focus on unipolar thinking (whole Test)*

| | DF | t-observed | t-Critical at the 95% level of confidence | Significant difference between means? |
|---|---|---|---|---|
| F: Sc. vs. No Sc. | 68 | 0.047 | 2.000 | NO |
| F: Adv vs. Dadv | 41 | 0.675 | 2.120 | NO |
| M: Sc. vs. No Sc. | 41 | 0.315 | 1.980 | NO |
| M: Adv vs. Dadv | 30 | 1.836 | 2.110 | NO |
| **Adv: M vs. F** | **36** | **2.886** | **2.131** | **YES** |
| Dadv M vs. F | 35 | 1.457 | 2.110 | NO |
| Adv.: Sc. Vs. No Sc. | 36 | 0.239 | 2.000 | NO |
| Dadv.: Sc. vs. No Sc. | 35 | 0.667 | 2.042 | NO |
| No Sc: Adv vs. Dadv | 56 | 0.911 | 2.042 | NO |
| Sc.: Adv. vs. Dadv. | 15 | 1.052 | 2.021 | NO |
| Sc.: M vs. F | 29 | 1.295 | 2.042 | NO |
| **No Sc: M vs. F** | **80** | **2.690** | **2.042** | **YES** |

Note: Adv. – Advantaged; Sc. – Took Physical Science to the end of school.
Dadv. – Disadvantaged; No. Sc. – Did not take Physical Science to the end of school

In this comparison, however, there was no control for whether or not students had taken science or not to the end of school. In addition, there were significant differences in performance between males and females who had *not* taken science to the end of school $t$ (80) = 2.69, $p < 0.05$, but not between males and females who *had* taken science to the end of school, suggesting that taking science does have some influence on conceptual development. There was no difference between those who had gone to educationally disadvantaged schools and those who had not, which in the South African context is surprising. The most significant factor in determining performance on the test was again gender. Finally, while there was a significant difference between those who had and had not taken science to the end of school, this was particularly true of female students, while male students appeared to have been unaffected by whether they took science to the end of school or not. This could be due to social differences between boys and girls and the toys that they played with as children; however the fact that the boys did not score significantly higher marks than the girls suggests that there are other factors that influence this conceptual development as well. Supporting this observation is the fact that the performance of students who did not take science to the end of school was divided along gender lines, whereas for those who had taken science to the end of their schooling there was no significant difference between the genders. Data from table 4.5 can be summarised as follows:

- No difference between those female students who took science and those who did not.
- No difference between advantaged and disadvantaged female students.
- No difference between those male students who took science and those who did not .
- No difference between advantaged and disadvantaged male students.
- Significant difference between advantaged male and female students, but not between disadvantaged male and female students.
- No difference between advantage or disadvantaged students scores whether they have science or no science.
- No difference between advantaged and disadvantaged students, even if they have or have not taken science to the end of school.
- Significant difference between male and female students who have not taken science to the end of school, but not for those who have.

**Table 4.6**

The first four questions of test 1 were designed to specifically elicit instances of unipolar thinking. Students, who maintained that these circuits would work, clearly did not see the need for a completed circuit. This in itself is interesting as for some time; researchers have believed that this model of thinking is easily eradicated with instruction (McDermott & Schaffer, 1992). Table 4.6 gives a more definitive picture of differences in the frequency of use of the unipolar model between groups of students where all variables that were tested for were controlled. There were only two significant differences in performance on the first four questions of test 1 (which distinguish between unipolar and non-unipolar thinking) at the 95% level of confidence:

Table 4.6. *TEST 1 - Statistical Tests on Conceptual pre-test responses; Focus on unipolar thinking (first four questions)*

| | DF | t - observed | t-Critical at the 95% level of confidence | Significant difference between means? |
|---|---|---|---|---|
| Disadv M Sc vs No Sc | 17 | 0.663 | 2.110 | NO |
| Disadv F Sc vs No Sc | 16 | 0.994 | 2.120 | NO |
| Sc AdvM vs Adv F | 7 | 0.491 | 2.365 | NO |
| Sc Dadv M vs Dadv F | 6 | 0.455 | 2.447 | NO |
| **No Sc Adv M vs Adv F** | **27** | **4.886** | **2.052** | **YES** |
| No Sc Dis M vs Dis F | 27 | 1.630 | 2.052 | NO |
| SC M: D vs A | 7 | 0.158 | 2.365 | NO |
| Sc F: D vs A | 6 | 0.240 | 2.447 | NO |
| **No Sc M: D vs A** | **25** | **2.814** | **2.060** | **YES** |
| No Sc F: D vs A | 27 | 0.565 | 2.052 | NO |
| Adv M Sc vs No Sc | 15 | 1.955 | 2.131 | NO |
| Adv F Sc vs No Sc | 17 | 1.357 | 2.110 | NO |
| Dadv F: Sc vs. No Sc | 16 | 1.014 | 2.042 | NO |
| Adv M: Sc vs. No Sc | 11 | 1.116 | 2.042 | NO |
| Dadv M: Sc vs. No Sc | 17 | 0.285 | 2.042 | NO |
| Dadv F no Sc vs. AdvF No Sc | 33 | 0.204 | 2.045 | NO |
| DadvFSc vs. AdvF Sc | 6 | 1.306 | 2.000 | NO |
| FA vs. MA (Sc) | 7 | 0.440 | 2.131 | NO |
| MAdv vs. MDadv (Sc) | 7 | 0.136 | 2.010 | NO |

- A significant difference was measured between advantaged and disadvantaged males who had not taken science to the end of school; however, there was no difference between advantaged and disadvantaged females who had not taken science to the end of school.
- There was also a significant difference between males and females from advantaged schools that did not take science to the end of school, but not between males and females from disadvantaged schools.

The comparisons also indicate that there is no significant difference between those that have not done science and those who have when gender and advantage are controlled for. The results from these comparisons could point to the possibility that:

- Poor teaching of science in disadvantaged schools means that conceptually, there is no difference between whether a student takes science to the end of school or not
- For those students who took science to the end of school, there is no difference in performance between male and female students
- For those students who have taken science to the end of school, there is no difference in performance between advantaged and disadvantaged students
- For advantaged students there is no difference for both males and females that took science to the end of school with those who did not.

This tells us that quality of education does seem to have as much an effect on male students as it does on female students. Advantaged males appear to perform better than disadvantaged males and all females, indicating that in electro-technology, advantaged male students might enter university with better conceptual understanding than all other students.

In summary, there were only significant differences between those groups tested on their performance for test 1, but not test 2. Of the seven significant differences detected in test 1, five were related to gender, one were related to whether or not science was taken to the end of school or not and one to the level of relative advantage of the school the student went to.

Test 2 was uniformly poorly done by all students, irrespective of educational background and gender. This may be related to the fact that test 2 assessed for more complex models of thinking that the unipolar model and that for this cohort of students, almost all operated at a unipolar or pre-unipolar level.

There was also no significant difference between the mean scores of those students who had connected circuits at school and those who had not.

To summarise, for test 1, there were significant differences between:

- All Females vs. All Males
- Advantaged males vs. Advantaged Females
- All Males who did not do Science vs. All Females who did not do Science
- Advantaged Males who did not do Science vs. Advantaged Females who did not do Science
- Advantaged and disadvantaged males who have not taken science to the end of school
- All those who took Science vs. All those who did not (first four questions only)
- Females who took Science vs. Females who did not take Science (first four questions only)

**Comment on correlations.**

Table 4.7 shows Pearson's coefficients that were calculated for matched sets of data to see if there was any relationship between the performance on the two pre-tests and the final assessments for the house project and the electrical part of the examination. I decided that since the significance tests of the first part of the study indicated a strong influence of gender and a much weaker influence of level of disadvantage and also taking science to the end of school, I would look at correlations between the diagnostic tests and the final examination and Doll's House Task scores to see if these too were influenced by gender. These calculations yielded unexpected trends.

Generally speaking there was no strong relationship between the various assessments at all. For the class as a whole, the strongest relationship was between the doll's house assessment and the examination, however, this relationship was weak with a coefficient of 0.38. When the data is split into males and females, there is a difference in the strength of the relationship, with a much stronger relationship between the two assessments for male students (r = 0.52) than for the females (r = 0.32). The average female score for the house was 60.58%, the highest of the four groups tested, indicating that perhaps some conceptual change did take place.

Table 4.7: *Mean performance on the four tests with correlation coefficients*

| | **Advantaged Males** | **Advantaged Females** | **Disadvantaged Males** | **Disadvantaged Females** |
|---|---|---|---|---|
| **MEANS** | | | | |
| A: Doll House (%) | 57.96 | 60.58 | 54.62 | 50.89 |
| B: Exam (40) | 27.87 | 24.04 | 17.00 | 16.00 |
| C: Pre-test 1 (15) | 10.17 | 8.24 | 8.46 | 7.78 |
| D: Pre-test 2 (6) | 2.78 | 2.47 | 1.92 | 2.33 |
| **CORRELATIONS** | | | | |
| Doll's House & Examination | **0.663** | 0.159 | -0.236 | 0.340 |
| Doll's House & Pre-test 1 | 0.253 | -0.066 | -0.094 | 0.327 |
| Doll's House & Pre-test 2 | 0.083 | -0.016 | 0.339 | -0.040 |
| Examination & Pre-test 1 | 0.408 | 0.073 | **0.581** | 0.276 |
| Examination & Pre-test 2 | 0.309 | -0.013 | -0.063 | 0.128 |
| Pre-test 1 & Pre-test 2 | 0.488 | 0.129 | -0.070 | 0.254 |

## Discussion and conclusion

The literature provides evidence of two aspects of conceptual development that are of interest to this study. The first is the *lack* of prevalence of the unipolar model in studies that have been conducted in various parts of the world. Tasker and Osborne (1985), Shipstone (1988) and McDermott and Schaffer (1992) all point to low incidences of reported unipolar models of thinking and in addition, explain that this model is easily eradicated. This study finds evidence to the contrary in South Africa. Now it may be that the type of student that undertakes a design and technology course in an education degree is not one who has much interest in science, but Stanton (1989) has provided evidence of the unipolar model of thinking present in answers given by engineering students at another South African university, which confirm the evidence gathered on the prevalence of unipolar thinking in this study.

The second aspect of conceptual development that is present in the literature is the finding by Engelhardt and Beichner (2004) that female students who took their diagnostic test showed results that had a greater number and more varied set of alternative conceptions. This finding is I feel supported by the findings of this study that the unipolar model of thinking is more prevalent amongst female students that it is amongst male students.

The literature also points to the level of educational advantage as being a significant factor affecting performance. This is confirmed by Perry and Fleisch (2006) in their analysis of matric results. However, whether or not a student used the unipolar model of thinking in responding to the diagnostic test items does not seem to be markedly influenced by level of educational disadvantage in this study. Similarly, taking science to the end of school appears not to have any marked influence on the model of electric current used for the students in this cohort.

In summary, it seems from this sample of students, that those coming into this design and technology course had varied experiences in learning about basic electric circuits prior to starting the course. Factors that seemed to influence their selection and use of the unipolar model of thinking were gender, whether or not they had attended an advantaged or disadvantaged school and also whether or not they had done science to the end of school. A fourth factor, whether or not they had actually connected any circuits in their pre-university education did not seem to play a role in the mental models that they developed. Of the three factors that did seem to influence whether they used a unipolar model of thinking, gender was by far the biggest influence. This seemed to be followed by whether or not the students did science to the end of school or not (which may in turn be influenced by gender). The level of educational disadvantage in terms of the quality of the school they attended did not influence the performance on the tests at the 5% level of significance, which given the history of schooling in South Africa is surprising.

Correlations between the initial pre-tests and the final assessments in terms of gender reveal further interesting results. The coefficients calculated are low ($< 0.5$) indicating that the pre-tests do not have substantial predictive powers for the examination score and the Project mark. This is not surprising and in fact is somewhat encouraging as it shows that the students' destinies are not pre-determined on entry into the course, no matter how they think about electricity. This is borne out by the fact that the advantaged females managed to perform as well as advantaged males on the house project.

Finally, the data paints a picture of a major influence of gender on patterns of thinking when interpreting simple circuit diagrams. This has implications for instructional design as well as for further research. It is suggested that due to the continuing differential in performance in science in general and in learning electricity in particular, programmes of instruction be designed to ameliorate these gender related patterns of thinking. Further research also needs to be conducted into the reasons why differences in patterns of thinking exist between male and female students, as well as to why there is such a prevalence of unipolar thinking amongst South African students.

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## Concluding remarks

### Addressing the combined use of two theoretical frameworks

This first paper in the series draws heavily on a constructivist approach to learning science in general and on research on conceptual change theory in particular. As will be seen in chapter 7, this is particularly relevant to understanding the conceptual change that takes place when the students in this cohort come to drawing the design diagrams for the wiring of the doll's house and actually wiring their circuits. In this way, chapter 4 is connected quite explicitly to chapter 7. The patterns of thinking that are discussed in both papers are related to the way students understand electric circuits and also to the way these patterns change. As a second framework for interpreting the data, this paper makes reference to issues of gender and in so doing, draws on feminist theory. This is particularly important in order to understand the factors that might contribute to female student's low levels of self-efficacy when it comes to engaging with the task of wiring the doll's house, an issue that is discussed more fully in chapter 5. In this way, chapter 4 combines two distinctly different ways of thinking about intellectual processes in order to interpret data that has both elements of the specific construction of scientific knowledge as well as the wider societal influences that affect the way we learn things.

### Addressing the research questions

This paper addresses the overarching research question: "*What factors affect the learning of electro-technology by female students?*" by outlining the effect of gender on performance on diagnostic test items as well as the lesser importance of school background, be it advantaged or disadvantaged and with or without science to the end of school. The first research question: "*What are the differences between male and female students in the way they understand electrical concepts?*" is also addressed as the study data paints a picture of a major influence of gender on patterns of thinking when interpreting simple circuit diagrams. The other research questions are not addressed in this paper.

# Chapter 5

# Gender, self-efficacy and achievement among South African technology teacher trainees

## Introductory remarks

The initial purpose of the overall study was to look at the effect of context on learning electricity, specifically, placing a design and make project in a context that was familiar and perhaps attractive to girls, in this case a doll's house. Similar projects had been tried in the past, for example designing and making bubble blowing machines for parties, "flashing lights" Alice bands, make up tables and electrified jewelry cabinets with alarms. The idea that the "girly-ness" of the projects might be attractive for the predominantly female class admittedly pandered to a gender stereotype, but was found through informal discussion with the class to be something that the female students liked and were excited by. Generally, most design and technology projects that were available in school text books in South Africa at the time were ones that were appealing to boys and the efforts to promote gender equity by the publishers were not so much a selection of the projects, but more to do with the depiction of both boys and girls doing projects in the books that traditionally were "boys projects".

Gender differences in the selection of and participation in particular careers and fields of study at university has been the subject of a number of studies worldwide (Example: The ROSE Project as outlined in Schreiner, 2006). These differences we assume are not due to differences in ability, but rather due to differences in the expectations from society for girls and boys. This chapter expands on the effect of these expectations on the development of self-efficacy in technological tasks amongst male and female students and the effect that development has on performance.

Chapter 4 examined the patterns of thinking about basic electrical concepts developed by students entering a design and technology course. This chapter shifts the emphasis to examining the relationship between gender and self-efficacy in the teacher trainees engaged in constructing and wiring a Doll's House and addresses the following research questions:

**Overarching question**

*What factors affect the learning of electro-technology by female students?*

**Question 2**

*How was performance on the Doll's House task affected by the perceived self-efficacy of female students?*

**Question 3**

*What were the students' emotional responses to the Doll's House Project?*

In order to do this, this part of the study interprets quantitative data that included examination scores, task assessments, and data from questionnaires as well as qualitative data that included interviews and written student reflections that were collected. These data were interpreted in the light of current literature on gender and science and technology and were compared to similar data that has been collected worldwide, that indicate that issues of gender, context and relative levels of self-efficacy are widespread. The data collected in this study, point to a gender bias in student teachers entering university with more male than female students having done science to the end of school. In addition, there is a continuing differential in standards of education in South African schools that has necessitated distinguishing those who had attended educationally advantaged from those who had attended educationally disadvantaged schools.

**The contribution of the second author in the production of the paper: Gender, self-efficacy and achievement among South African technology teacher trainees**

This paper was the first research output submitted for publication from the Doll's House Project. I asked the second author to help me prepare the research for publication, since I had never published in a journal before. She played a supervisory role in guiding me in learning to write for publication. The paper was subsequently submitted to the journal Gender and Education and accepted. All paperwork pertaining to the project was developed by myself (applications for ethical approval, faculty approval etc.). The project conceptualization, data collection, data capture and most data analysis was done by me. My co-author had some input into the interpretation of the data through discussion and gave me extensive guidance in how to redraft what I'd written for publication. I wrote the methodology as well as the findings section and some of the literature review. My co-author made suggestions for reading some of the literature and again gave guidance in redrafting it. We shared the writing of the discussion / conclusion in the same way. In so doing, she taught me how to write for publication and the real benefit to me, from my perspective, was the way she dealt with the reviewers comments. This taught me that a systematic unemotional response to the reviewers' comments gets results. This paper would not have been published, had it not been for the way the document was reworked.

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# Gender, self-efficacy and achievement among South African Technology teacher trainees

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This article considers the relationship between gender and self-efficacy in teacher trainees engaged in an electricity-related design and construction task. Quantitative data (examination scores, task assessment, and questionnaire) and qualitative data (interviews and written student reflections) were collected. There is a gender bias in student teachers entering the University with more male than female students having done Science to grade 12 level. In addition, the continuing differential in standards of education in South African schools necessitated distinguishing those who had attended educationally advantaged from those who had attended educationally disadvantaged schools. In the examination, a test of theoretical knowledge, male students in each group outperformed female students. This we explain in terms of school background, gender responses from family members who regarded Science as a male domain, and the resulting lower self-efficacy of female students. However, female students achieved as well as male students in the design and construction task. We argue that although males had better self-efficacy levels than females at the outset, the hands-on, individual nature of a task in a domain usually constructed as male led to female students developing increased levels of self-efficacy, which ensured task performance matching that of the more knowledgeable male students.

**Keywords:** technology education; gender; self-efficacy

## Introduction

Worldwide, far more men than women take up technology-related careers. Technological work, better paid than the areas in which women predominate (such as clerical work) is widely viewed as more natural to males than to females. This gendering of Science, Mathematics and Technology as male is part of a naturalised vision of social organisation in which men are associated with the active, with reason and with public life while women are associated with the passive, with emotion and with the private sphere (Young 1990). The assumption that technology is male permeates cultural beliefs and subtly influences the way children view themselves and the choices they make. Both home and school influence this, making teacher training an important element in building an equitable society. Because teacher trainees participate in and thus reproduce societal cultural assumptions, they too view themselves and their future pupils as more or less able to understand technology depending on their gender.

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Equity, including gender equity, is an important aim of education in South Africa, and it is thus important to counter these assumptions and improve the self-efficacy of female teacher trainees so that they can serve as role models for their own pupils. There is similar value in tasks that challenge the notion amongst both male and female teacher trainees that tasks themselves are gendered.

In order to improve female teacher trainees' self-confidence in learning electricity, this article documents the contextualisation of basic electrical concepts in a task of a kind that female students are said to enjoy. These include design (Atkinson 2006) and building houses (Silverman and Pritchard 1996), although, as Lewis (1996) points out, such preferences may be a manifestation of the differential treatment afforded male and female children (including females' primary early socialisation from a parent of the same sex while males are usually socialised by parents of the opposite sex).

According to Lewis (1996), a context-driven approach to curriculum design is distinguished from a content-driven approach in that it takes social, environmental and physical contexts as starting points and uses these to move towards the theories, models and laws that are the starting point of a content-driven curriculum. This task uses the context of building a house to move towards a greater understanding of electrical circuits. Taking students' educational and home background into account, attitudes and levels of self-belief in being able to achieve a Technology task are measured before, during and after the task, to see whether doing the task had a positive effect. We also consider achievement on the task and an examination.

The study proceeds from the assumption that differences in participation and achievement of female students in technology and technological careers do not arise from ability differences, but from social attitudes viewing certain fields as less appropriate for women. These attitudes are embedded in the subtly different ways that male and female children are treated (Nicholson 1984; Smith and Lloyd 1978); such attitudes are transmitted through discursive practices (Davies 1989). The study considers how female and male students express these attitudes, and what effect this has on performance.

Self-efficacy, popularly self-confidence, is the 'belief in one's ability to carry out specific actions that produce desired outcomes' (Aronson, Wilson, and Akert 2005, 485). One can have generally high self-esteem but lack belief in one's abilities in a certain area. Self-efficacy predicts persistence and effort at a task. People with high self-efficacy experience lower anxiety, and are more likely to view tasks not as difficult but as challenges that can be overcome (Bandura 1994). Ways of developing self-efficacy include mastery of difficult tasks (indicating importance of practical work) and seeing social models achieve the behaviour (accounting for higher confidence in ability to achieve technological tasks in male compared to female students) (Bandura 1994). This study reflects an interesting dynamic between educational background and gender, indicating that self-efficacy in technology is related to gender rather than to conceptual knowledge.

## Gender and technology

Much literature exists, based on US and European research, regarding differential performance and participation of boys and girls in Technology. This study seeks to extend this research to include the perspective of a developing country, and one whose education system has suffered the disruptive influence of apartheid policies. While no evidence exists for innate difference in ability (Silverman and Pritchard 1996; Francis 2000; American Association of University Women 1992), boys receive more familial encouragement in technological fields (Mammes 2004), and play games that develop spatial abilities. School Technology tasks appear designed to be more interesting to boys than girls (Silverman and Pritchard 1996; Weber and Custer 2005). Boys outperform girls in Technology, have higher interest levels in it (Schiefele, Krapp, and Winteler 1992), and show interest in different aspects of Technology than girls (Silverman and Pritchard 1996; Mammes 2004; Atkinson 2006; Weber and Custer 2005; Jones and Kirk 1990). Female participation in Technology decreases in higher grades, combining with parental perception of the inappropriacy of technological careers for girls (Woolnough 1990, quoted in Davies and Elmer 2001; McCarthy and Moss 1992) to result in low participation of women in technological careers (Mammes 2004; Francis 2000; Brainard and Carlin 2001), incidentally also among the best paid careers.

Our investigation of the situation amongst South African Technology Education students was complicated by the persisting differential in school background in the South African population, which means that to a very great extent the educational disadvantage (facilities, class size, teacher qualification etc.), which was put in place by apartheid policies, continues in schools that were previously set aside for the Black African population. The extent to which this disadvantage in schools persists 14 years after apartheid ended is reflected, for example, in the 2006 PIRLS data (Mullis et al. 2007), which show South Africa as the worst country with regard to grade 5 reading, out of 40 countries surveyed (including developing and other African countries). This disadvantage is the legacy of different funding levels for different race groups under apartheid; despite current attempts to improve this situation, such change is slow; improvement in some aspects, for example teacher qualifications, is likely to take generations. A Department of Education-sponsored survey (Education Management Information Systems 2006), which assessed schools in terms of facilities such as electricity and water provision, road access, building maintenance, and laboratory and library provision, allows us to distinguish educationally disadvantaged schools. To these factors, that of teacher qualification level can be added. Most South African schools, particularly those originally designed to cater for and still attended largely by Black African students, remain disadvantaged by these measures. Enduring disadvantage in most South African schools combines with many of the gender-related factors above to further disadvantage girls who attend such schools. Other variables, including family background, rural/urban origin, family income, parental occupation, etc. also have potential to blur results.

Relevant data for South Africa include gender and population group differentials with respect to education in general and grade 12 Mathematics and Science attainment in particular. On one hand, female access to education grew between 1996 and 2002 (Perry and Fleisch 2006), with a higher proportion of female than male children being retained in the school system. More than 50% of candidates who wrote, passed, and gained grades necessary to attend university in the grade 12 exam between 1996 and 2002 were female, and although the percentage pass rate of male candidates remained higher, this difference declined from 8% to 3% over this period (Perry and Fleisch 2006). On the other hand, although the pass rates and overall numbers taking Mathematics and Science was fairly evenly matched with regard to gender in other population groups, participation and success of Black African male candidates was far higher than females'. For example, in 2002 only 23% of Black African female candidates passed Higher Grade Mathematics (20% passed Science) compared to 31% of Black African males (27% passed Science) (Perry and Fleisch 2006).

This study concerns gender and the accessibility of technological knowledge. To control for factors besides gender and take account of the educational inequities outlined above, a distinction is made between students who attended schools suffering the disadvantage outlined above, and those who attended relatively advantaged schools. Although this inequity has the potential to invalidate results if not accommodated, ironically it allows a focus on whether conceptual knowledge or gender socialisation has greater influence on self-efficacy in approaching a technological task. Because our population is heterogeneous with regard to educational background and thus conceptual understanding, levels of self-efficacy in approaching technological tasks can be compared between male and female students in two groups who have had different educational experiences.

To control for extraneous variables, and to ensure similar educational, socioeconomic and home background among the students compared, we compare attitudes to, and performance in, Technology amongst two groups: white male compared with white female students (all of whom attended advantaged schools), and Black African male students who have attended disadvantaged schools with female counterparts. For simplicity, we omit Black African students who attended relatively advantaged schools (36% of the Black African female and 4% of the male students in the group surveyed), as well as South African Indian students (27% of the total sample). Conflating these three population groups would be problematic; having been kept apart by apartheid, it is possible that unmeasured differences in cultural norms would invalidate results. It would be inappropriate to make a comparison of performance between different races, since we have insufficient data on academic background for valid comparison. We will, however, compare gender-specific trends within the data.

### The design and construction task

The task that is the focus of this study was the individual construction and wiring of a three-roomed dolls' house. To avoid students getting friends or family to do the task, students constructed and wired the dolls' house in the Technology laboratory. The Dolls' House task was chosen to appeal to female students as Silverman and Pritchard (1996) found that girls responded well to tasks such as building houses.

### Methodology

To triangulate our study, the variables of gender, performance and self-efficacy in approaching a technology task were investigated quantitatively and qualitatively. Quantitative methods include a personal data questionnaire probing gender, school, and educational level in Science and also attitudes to Technology using a Likert scale. Another quantitative source of data was performance in the examinations and the Dolls' House task. A mid-course questionnaire probed self-efficacy concerning specific aspects of the Dolls' House task. Qualitative data collection included mid and end of course written reflections, as well as interviews with students. The data shown in Table 1 were collected.

### Methods of data collection

The data were collected in an Education Faculty at a South African University in the city of Durban in the South Eastern KwaZulu-Natal province. The subjects of the study, who constitute a mixed urban and rural group, were about 100 Bachelor of Education students. The task described in what follows was assigned by the first

Table 1. Data collected in the study.

| Point at which data was collected | Data type |
|---|---|
| First day (week 1) | • Biographical questionnaire<br>• Probe of attitudes to technology |
| During the course (weeks 2–4) | • Interviews<br>• Mid-course questionnaire probing self-efficacy levels<br>• Brief written reflection |
| When the project was handed in (week 5) | • Project assessment<br>• Student reflection on the project |
| Two weeks after the course was completed | • Examination (post-test) |

author as part of the coursework in Technology. In total there were 95 students in the study, about equal numbers of African male (24) and female students (23), all of whom had attended disadvantaged schools and white male students (23) and female students (25), who had attended advantaged schools.

The data were collected over five weeks, while students attended an electricity course. The course developed competence in understanding, planning and wiring of a dolls' house. This entailed developing understanding of the concept of circuits. Students were divided into six groups with one weekly double-period contact time. Students worked on their projects between contact sessions, but had to do this in the classroom.

The course started with conceptual pre-tests to help students face preconceptions about electrical concepts. A series of hands-on activities on building various circuits and to learn the use of different circuit components and other background information necessary to connect and wire the dolls' house followed. Students wired their own dolls' house, but group tasks helped them understand basic principles and develop skills. Observation showed female student reticence in solving problems, allowing male students to 'take over' the tasks and dominate the groups. Students then had to learn to convert a circuit diagram to a wiring diagram of the plan of their house. This was followed by lessons in soldering and using tools to make and wire the house.

## Results and discussion

This section examines some quantitative data showing students' achievement in both the electricity section of the end of year examination (i.e. students' end-of-course theoretical understanding of electricity) and in the Dolls' House task. Where relevant, to test for significance in differences of measurements, we used a *t*-test which shows differences between sample means for small samples such as ours (Caulcott 1973). Using a range of qualitative and quantitative methods, we then consider students' initial, mid and end of course attitudes and self-efficacy, attempting to plot how these change, and how they relate to achievement levels.

### *Students' achievement in the end of course examination and in the Dolls' House task*

For both advantaged and disadvantaged groups, the spread of marks for the electricity section of the examination (maximum marks 50) shifted to the lower end of

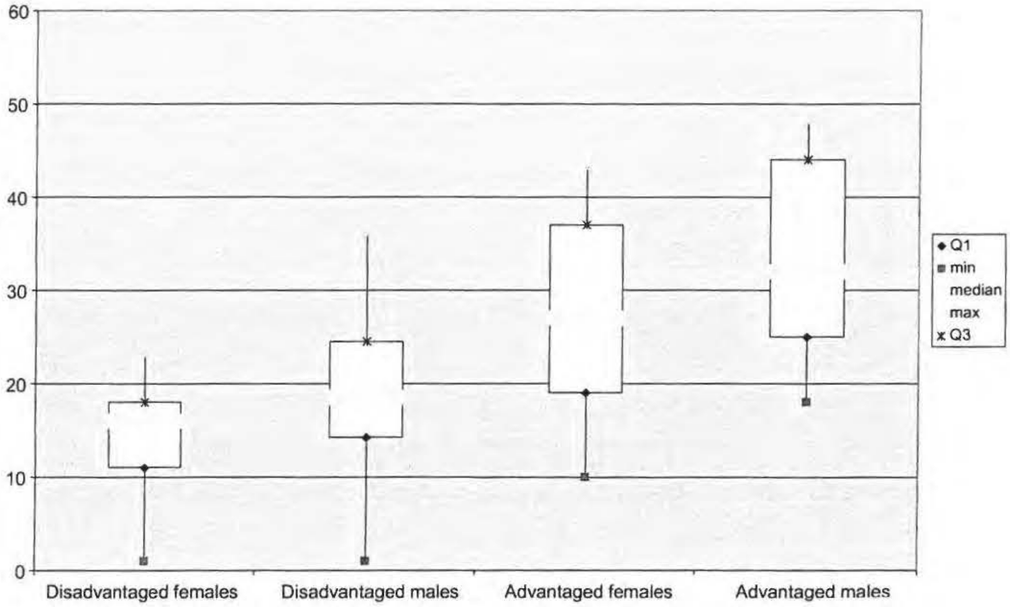


Figure 1. Box plot comparing results in the electricity section of the Technology exam.

the scale for female compared with male students, and fewer female students achieved marks in the higher mark intervals (Figure 1). Both advantaged and disadvantaged males outperformed female counterparts (difference significant at 95% level using a *t*-test) in the year-end examination. A question requiring design of a circuit for a house was significantly better performed by males amongst both educationally advantaged and disadvantaged students.

By contrast, the educationally advantaged female students marginally out-performed male counterparts in the overall dolls' house mark (not significant at 95% level; Figure 2), and although male students from disadvantaged schools out-performed

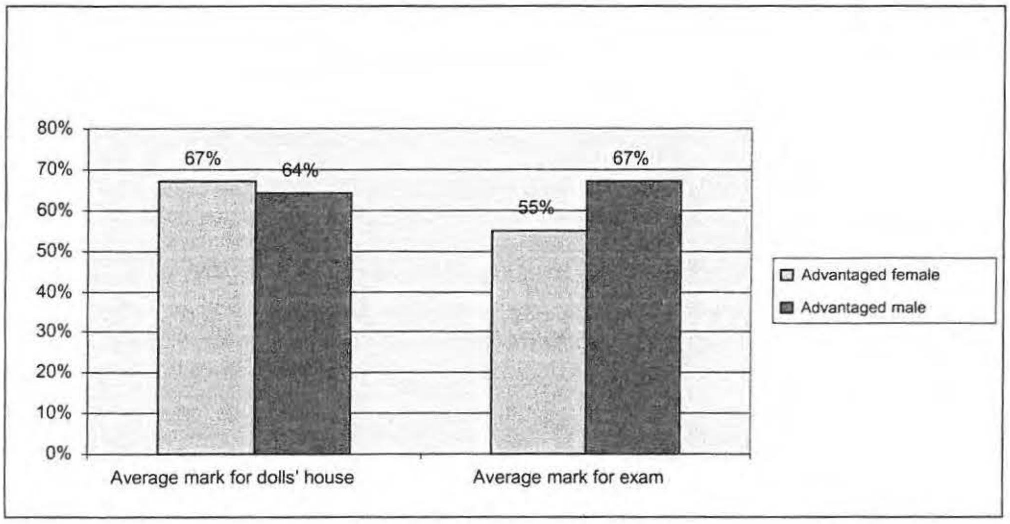


Figure 2. Educationally advantaged male and female students: marks for Dolls' House task and exam.

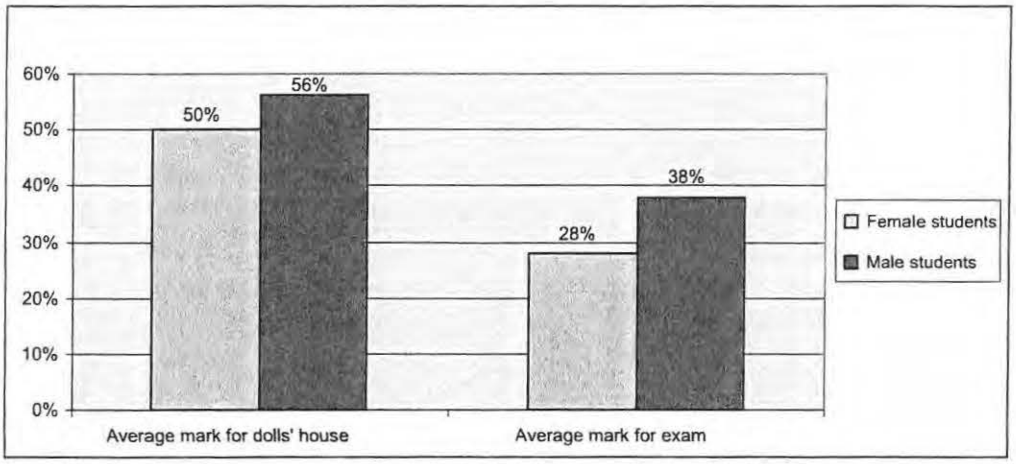


Figure 3. Educationally disadvantaged male and female students' marks for Dolls' House task and exam.

female counterparts (significant at 95% level), the difference is less marked than for the examination (Figure 3).

At first we speculated that this greater equivalence reflected aspects besides electricity, such as construction and design of the dolls' house. Silverman and Pritchard (1996) found that girls respond better to some tasks (e.g. building houses) than to others, and Atkinson (2006) found that they do best in Design and worst in technical aspects such as Electronics. However, Figure 4 compares disadvantaged male and female students' achievement in different aspects of the Dolls' House task. Although a gender difference exists for the wiring diagram (significant at 95% level), gender differences in achievement for most aspects of the Dolls' House task are small.

For advantaged students the same situation can be seen in Figure 5, with no statistically significant difference in performance between males and females in any subtask associated with making the dolls' house.

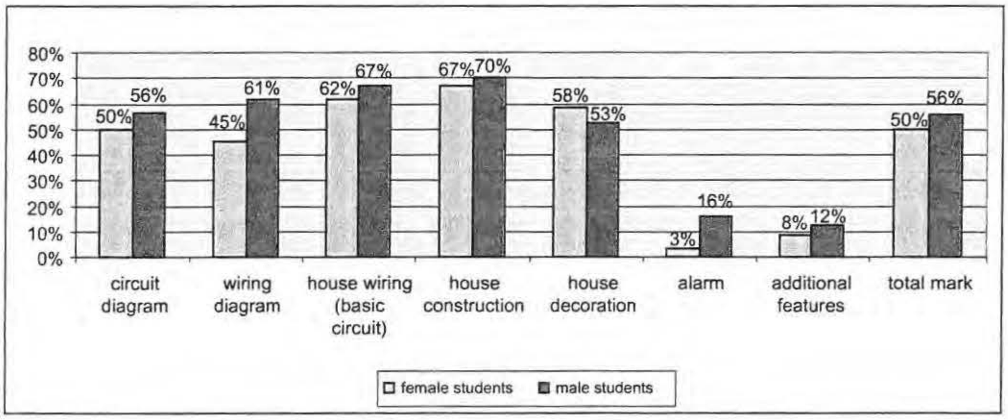


Figure 4. Performance in different aspects of the Dolls' House task: educationally disadvantaged male compared to female students.

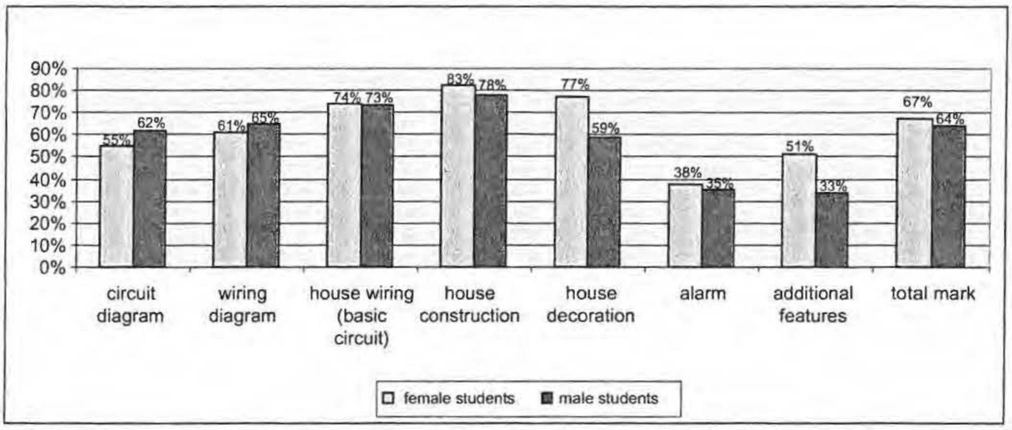


Figure 5. Performance in different aspects of the Dolls' House task: educationally advantaged male compared to female students.

### *Initial questionnaire probing background in Science and Technology*

For both disadvantaged schools and advantaged schools few female students took Science to grade 12 (Figure 6). By comparison, almost half the disadvantaged male students and half the educationally advantaged male students did so. (A *z*-test indicates that this difference is significant.)

If school Science reliably predicted examination achievement in electricity, we would expect disadvantaged males to outperform advantaged females. However, school (dis)advantage is a stronger predictor for achievement in the electricity part of the examination. Taking a subject to a certain level ignores how well the student did or the standard of teaching at the school. For the most part, advantaged female students took Science until grade 9/10 only, but the teaching they received may have been good, perhaps accounting for an average examination mark above 50%.

Educationally disadvantaged males were more likely than disadvantaged females to take Science to grade 12, and they did better in the electricity part of the examination (38% average compared to 28% for female students). Nevertheless, both groups still got less than 50% on average, indicating that this section is taught particularly badly in disadvantaged schools. Another factor besides school teaching which may

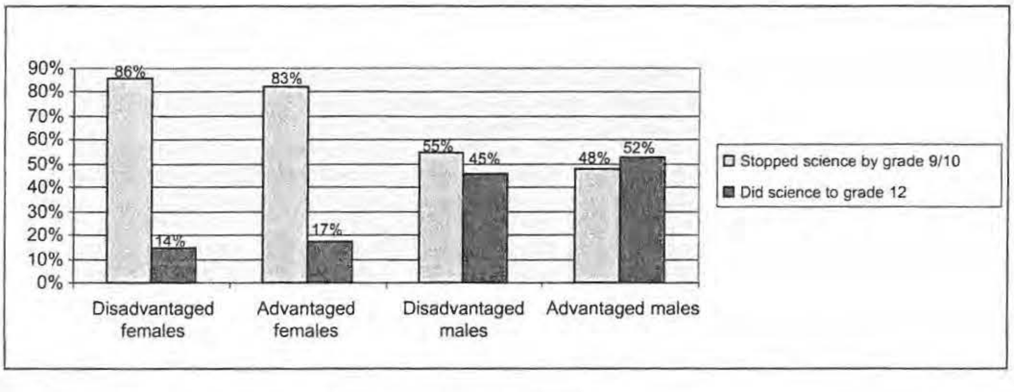


Figure 6. Grade to which students did school Science.

contribute to low examination marks in students from disadvantaged schools is knowledge about the topic amongst other members of the community, for example parents. In fact, as we report below, fewer than 10% of the parents of students from disadvantaged schools have knowledge of electricity.

Mammes (2004, 91) and Weber and Custer (2005, 55) note gender differences in socialisation, with boys given more electronic toys. Mammes (2004) found this gave girls less experience with tools than boys. Boys received more such toys in both our groups (see Table 2), but, probably for socio-economic reasons, far more educationally advantaged students received them, and most reported receiving many such toys.

### Initial questionnaire probing attitudes to electricity and technology

Although achievement is predicted by (dis)advantage of school attended, attitudes and self-efficacy are gender-related. Around 70% of female students in both educationally advantaged and disadvantaged groups regarded electricity as hard to understand before starting the course. Only around 30% of male students felt this way. (A $z$-test indicates that this difference is significant.)

Of the students from disadvantaged schools, 73% of males and 82% of females report fear of electricity, reflecting possible lack of familiarity with electricity, as some students commented in reflections that electricity was installed at home recently. As expected, fewer students from an advantaged educational background, (33% of female and 43% of male students) viewed electricity as frightening, reflecting greater familiarity. (A $z$-test indicates that the quoted male–female differences are not significant for either advantaged or disadvantaged group.)

Encouragingly, students in all categories were confident they could learn to connect electrical circuits, but greater male confidence persisted, with 79% of disadvantaged male students compared to 17% of female students agreeing strongly with this statement.

The questionnaire probed students' gender bias regarding technology using three statements: 'Technology is a boys' subject', 'Boys are better at connecting circuits than girls' and 'Boys are better suited to technical jobs than girls'. Encouragingly, between 87 and 100% of students disagreed that 'Technology is a boys' subject'. However, when probed on whether boys are better at connecting circuits, as many as 39% of female students from disadvantaged schools felt that boys are better.

Disadvantaged females' perception of gender difference rose further in the workplace, where 43% either agreed or strongly agreed that boys as better suited to technical jobs (Figure 7). In our data, this group, with lowest achievement in this subject, is more likely to view low achievement as reflecting gender than are male counterparts. This supports other elements in our data indicating that low self-efficacy blocks female students' achievement. As Bandura (1994) notes, low self-efficacy is accom-

Table 2. Number and kinds of electrically operated toys received as children.

| | $N$ | Received toys | Kinds of toys received |
|---|---|---|---|
| Disadvantaged male students | 24 | 7 (29%) | Cars, electric motor |
| Disadvantaged female students | 23 | 3 (13%) | Car, bear, hair dryer |
| Advantaged male students | 23 | 19 (83%) | Cars, trains, planes, radios |
| Advantaged female students | 25 | 15 (60%) | Walking dolls, cars, trains, animals, radios |

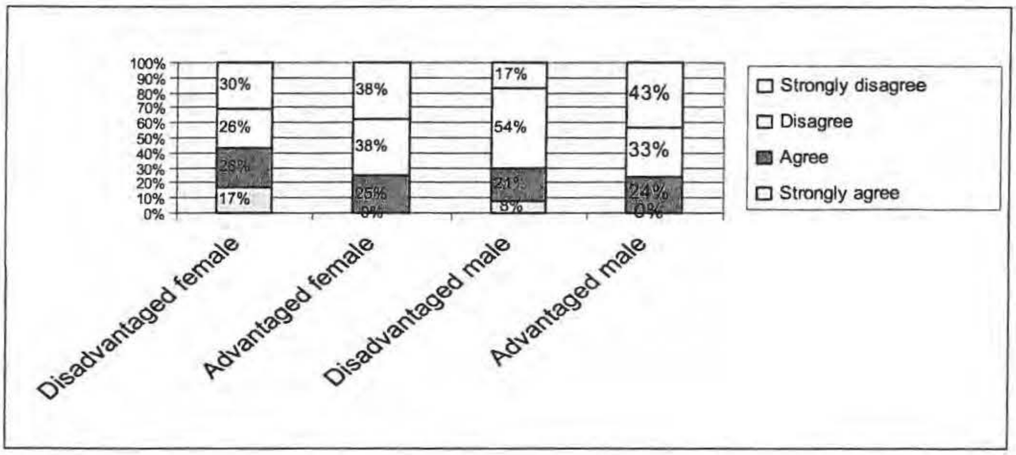


Figure 7. Boys are better suited to technical jobs than girls.

panied by a tendency to dwell on one's own shortcomings. This group's particularly low self-efficacy in this area may help to explain Perry and Fleisch's (2006) finding that in the subjects of Mathematics and Science only, are female Black African grade 12 candidates greatly outperformed by male counterparts.

Reasons for gender bias were probed in questions concerning Science teachers and parental encouragement in technological tasks. Encouragingly, few students reported gender bias in teachers, with female students marginally less likely than male students to report gender bias in Science teachers. Apparently it was not perceived lack of encouragement from school teachers that led only 16% of female students to take grade 12 Science compared to 49% of male students.

The group from disadvantaged schools report little parental bias in encouragement by parents in the technical area, although male respondents were more likely to agree strongly that parents encouraged them than were female respondents (Figure 8). Advantaged male respondents (70%) were more likely than females (44%) to have felt their parents encouraged them in the technical area. Significantly, 60% of advantaged students' parents were in a position to pass on technical knowledge to their children (below), but fewer chose to pass it on to female than male children. The lower parental

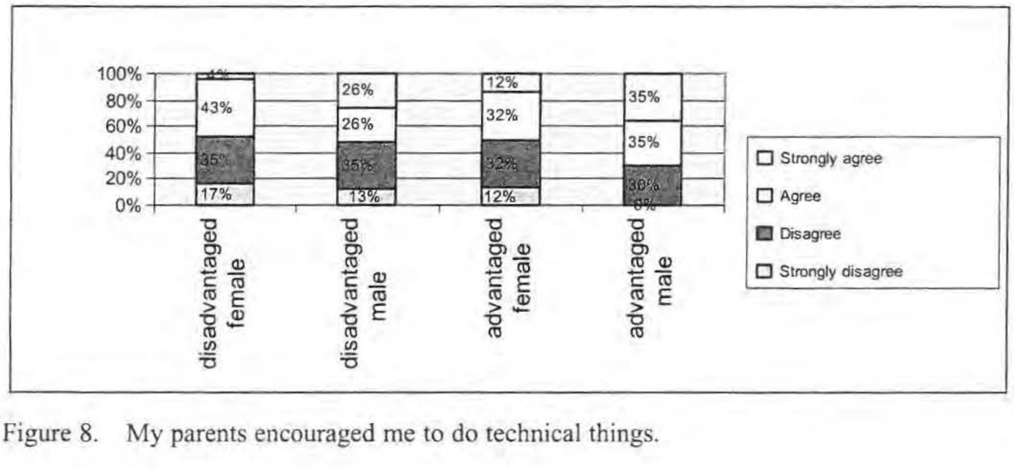


Figure 8. My parents encouraged me to do technical things.

encouragement in Technology afforded to females reflects findings elsewhere (Mammes 2004; American Association of University Women 1992), and is likely to contribute to the gender imbalance in technological careers. Interestingly, more than 60% of educationally advantaged students report that one parent has a technical background. By contrast, fewer than 10% of students from disadvantaged schools have parents with technical knowledge. This is one of the measures indicating lack of comparability of the two groups, and confirms the inappropriateness of comparing academic achievement of the groups.

### Mid-course questionnaire which probed self-efficacy

Although achievement was more closely related to (dis)advantage of school attended than to gender, self-efficacy was dictated by gender, as the literature predicted. Male students of both groups are more confident than female students in their responses to 11 questions. Significantly, nine of these questions relate to technical aspects of the dolls' house (marked with an asterisk in Table 3).

Soldering, which most students had mastered at the time of this questionnaire, reflects higher self-efficacy amongst female students than aspects of the task not yet attempted (supporting Bandura's 1994 suggestion that self-efficacy is built by mastery). Also, there was little difference in confidence between male and female students in dolls' house construction, probably because most students had already made their dolls' house.

Table 3. Student mid-course confidence of achieving aspects of the Dolls' House task (%).

| | Disadvantaged female students | Advantaged female students | Disadvantaged male students | Advantaged male students |
|---|---|---|---|---|
| Making a bulb light up* | 42 | 80 | 86 | 94 |
| Connect circuit to switch on bulb* | 29 | 70 | 78 | 88 |
| Connecting a circuit that makes an upstairs/ downstairs bulb work* | 14 | 35 | 52 | 59 |
| Explain how electric circuits work | 36 | 30 | 64 | 82 |
| Circuit to change the direction of electric motor with switch* | 18 | 0 | 50 | 65 |
| Planning circuit for dolls' house* | 50 | 50 | 65 | 76 |
| Wiring plan for dolls' house* | 48 | 50 | 76 | 76 |
| Soldering* | 58 | 79 | 90 | 94 |
| Connect wiring and components* | 22 | 21 | 67 | 94 |
| Use dolls' house in own teaching | 54 | 35 | 77 | 76 |
| Making the dolls' house | 81 | 100 | 66 | 94 |

*Technical aspects.

Interestingly, male students reported higher confidence than female students about using the dolls' house in their own teaching, showing they do not dismiss it as a female task.

### *Self-efficacy at the end of the Dolls' House task*

After submitting their dolls' houses, students reflected on the task in writing, outlining positive and negative feelings on the experience of making and wiring the dolls' house. Recurring themes in the responses are fear, experience of difficulty or frustration, comments on gender, increase in self-efficacy, feelings of pride, expressions of fun or enjoyment, and comments on applying what was learnt in wiring their own home.

It was difficult to interpret students' reflections on the task because of difficulty in judging the role of norms making it less acceptable for men than women to express emotions. That the task is situated in an area in which men are expected to be competent and knowledgeable exacerbates this. Expressing fear, lack of confidence or difficulty probably feels less acceptable to male than female students for whom competence with technology is not a cultural expectation. Our difficulty arose from inability to judge if the lack of male comments on these themes was the result of being competent enough not to have these feelings, or from being unprepared to express the feelings.

We found that male students expressed fear, lack of confidence and difficulty far less than did female students. Female students were more likely to reflect on fear of not being able to do the task. Students commented on their 'anxiety and frustration' at the task, described as 'a huge problem', 'my very own mission impossible' and 'a nightmare'. For another the task contributed to 'a stressful and depressing period' because of 'the thought that if the lights would not work I would fail'. Others described how they were 'shocked', 'petrified', 'apprehensive', 'hopelessly lost', 'absolutely dreaded doing it', 'didn't have a clue' and some 'wanted to drop out of Technology because I felt this was something out of my league'.

A number of female students mentioned fear of physical dangers believed to be inherent in the task: 'afraid of blowing things up!' and 'so nervous if that solder falls over my fingers and burns me'. One 'did give up at times when I got shocked'. This erroneous belief she has been shocked by a 1.5 or 9 V battery several times must hinder achieving the task. One, however, commented that 'I also learn that electricity cannot just burn a person', suggesting improved confidence as a result of improved knowledge.

Female students were more likely than male students to reflect on the difficulty and frustration they experienced, commenting that: 'I can say with definite certainty that this was one frustrating task' and 'It has given me a new view of the term patience'. Some compared making the house which, in line with the literature, they found easier, to the more difficult task of wiring the house: 'Building a dolls' house was not tough and I did enjoy it. But things changed when I had to wire my house. It took me two weeks because I had to undo the wiring several times'; 'It was easy to make the dolls' house … Wiring was not easy; I had to make several trials before getting it right'; 'I was excited because I love design … but then the nightmare came; we were to put electricity in the house'. The few male students who mentioned difficulty downplayed it: 'I found the circuitry a tad complicated to construct but my goal was met'.

Other, mainly male, students expressed the difficulty in terms of 'a good challenge'; 'a fun but challenging experience'; 'both a challenge and a great experience'; 'What I like about the project is that it demand critical thinking … It was very helpful'; 'I found the wiring extremely time consuming but the reward of seeing the lights illuminate surpasses the anguish'; 'making mistakes is what make me learn more than anything'. As Bandura (1994, 71) notes: 'People with high assurance in their capabilities approach difficult tasks as challenges to be mastered, rather than threats to be avoided'. The higher expectation on male students to be capable of technological tasks is likely to build self-efficacy as they believe it is something they can do and not 'out of my league' or 'impossible'.

Interestingly, however, although female students claim to have found the Dolls' House task more difficult than male students did, they achieved about as well in the task as the male students. This indicates that the task went some way towards helping students overcome negative attitudes to electricity. This is partly the value of a hands-on task, but also that because the task was individually assessed, female students were not able to hang back and allow male students to do the wiring, as was observed happening in group work. The following comments confirm this: 'I found myself in difficult position because it is individual work'; 'I am not an electrical person … I can't really remember how to wire a circuit board because I never did the circuit on my own'.

Not surprisingly, female students were more likely than male students to comment on their attitude to electricity as a gendered area and how this changed while making the dolls' house: 'I found wiring confusing. When I started I thought: it's easy! I was surprised that I can do it, being a girl – I was think that it was a boys thing to create and wiring a dolls house'; 'Thanks very much for your module it helpfully [sic] and I am a proud South African as a woman'; 'I enjoyed this experience because it showed me that as a woman I do need to know about electricity'; 'I learnt that you don't have to be male to be hardy with electricity. Wiring this house empowered me as a woman. I am happy with the end result … as a woman have accomplished this on my own'; 'I'm so proud I can be able to connect electricity; all those year I thought that boys are the only one who know how to do wiring'. The lack of self-efficacy that accompanies believing something is beyond one contributes to the task being difficult.

A number of female student comments imply that their attitude that electricity is a male preserve lowered their confidence in achieving the task, at least initially: 'When we have to design a dolls' house with electricity it became another story because I thought that was meant for boys only'; 'I thought it was going to be hard since I have it in my mind that electricity its men's job. But when I was face with the challenge I had to stand up for myself and do it … I felt proud I am capable doing such work being a woman'. These reflections suggest lack of confidence in being able to perform a task viewed as a male domain. The following student focuses on the perceived shortcomings of her entire gender: 'technology is likely passed by boys as they are strong and thoughtful. By this I mean as we are girls, we need enough time when doing project because this type of work, we are not used to it'.

Others commented on how they liked doing a task that was designed to appeal to female students: 'I liked the idea of a dolls' house because in the last project we had to make a car – gender equity!' Two male students picked up on this with one joking that he had 'reworked my house into a he-man towers' and another claiming it 'was exciting to do the house from a girl's perspective. I got in touch with my feminine side'.

A number of female students reported relying on male relatives or friends of either sex for help: 'I asked a friend if he'd be willing to do it for me ... my friend and I wired it together. She knows more than I did so I learnt a lot'; 'when the wiring was not working I needed my dad's help'; 'I went to a classmate and asked him how do you connect a mains switch and he explained to me'; 'Its one of my peer who help me but he didn't connect it he only tell me what I need to do'. Some were helped by 'my uncle'; 'a Physical Science major'; 'the person at the hardware' or 'my landlord'. A male student commented: 'a lot of people battled and once I helped them they got the hang of it'.

Experiencing improved confidence as a result of doing the task was remarked on by a large number of female students, which suggests that the task did build self-efficacy. This is clear in: 'This experience changed my mental attitude towards electricity as it is thrilling to be able to light a light bulb!'; 'I thought it's impossible for me; how on earth can I do that! Now I can say I can!'; 'the project opened my mind to what I am capable of''; 'I realised that I didn't hate wiring my dolls' house as much as I thought'.

One characterised herself as having 'travelled from a person inexperienced in electrical work to a person confident in building circuits'. Another also maps the journey: 'I was so negative. I told myself that I can't do this ... I felt positive attitude that I can and I must do this thing ... I couldn't believe it when it works. I felt the love of doing it again'.

Some female students, however, reflected that they still view electricity as something they cannot do. 'For me it was hard to start, I felt I could not do it. I felt that it is hard and there is just no way I can make a house with a main and three light bulbs. I thought about it and saw that it was beyond my ability'. Some students had very negative feelings to overcome and became only a little more confident from doing the task: 'I've always hated it and had a block from high school. I thought I would never be able to make a dolls' house, definitely not by myself ... but I proved myself wrong! I did get help and advice from others but I did the wiring all by myself. Overall I feel a little better about electricity; I feel more confident but I still find it frustrating!'

Female students were also more likely to express pride, characterising what they had done as 'a great achievement', 'a great accomplishment', 'the most exciting and relieving moment of my life', 'very rewarding', and themselves as 'glad', 'very happy', 'really proud', 'proud that I accomplished this on my own', 'proud and amazed', and 'so proud of myself I feel I can do anything'. One student's pride extended to family members: 'Even my mother said she was proud as each time I got a light to work, I would yell and she would rush in and see what I had managed to do'. This pride is evidence of female students' increased confidence because of doing the task themselves, confirming that mastery of difficult tasks improves self-efficacy (Bandura 1994).

One theme expressed more frequently by male than female students was that of interest and enjoyment. Students commented that 'wiring was the most fun and exciting part'; the dolls' house was 'an amazing project', 'very interesting', 'really fun to make', 'extremely fun', 'challenging yet enjoyable', 'interesting yet very relaxed' and 'the best practical and most rewarding project that I have done' (at university). One female student reported intending 'to redo the whole project. I didn't know I'd find a new hobby – electricity'. Male students on the whole found the task fun and interesting. Possibly fear, low self-efficacy and experience of difficulty of many female students lessened enjoyment. As Bandura (1994) notes, anxiety accompanies low self-efficacy.

A slightly concerning feature of the reflections came from the eight students who claimed they would apply skills they had learnt at home. One female student commented that 'if they have problem at home about electricity I'm going to help them. It is easy for me now'. Although this carries its own dangers, students' willingness to apply their skills at home does reflect improved self-efficacy.

## Conclusion

In this study male Technology teacher trainees from both educationally advantaged and disadvantaged schools were more likely than female counterparts to have taken Science to grade 12. In each group around 50% of male students had taken grade 12 Science, true for fewer than 20% of female students in each category. We can thus conclude that on average male students had better theoretical understanding of electricity than female counterparts. Unsurprisingly, male students outperformed female counterparts in theoretical knowledge of electricity tested in the examination. It was also clear, however, that educationally advantaged female students had better theoretical understanding of the concepts tested in the examination than did male students from disadvantaged schools. This is an indication of the problematic nature of educationally disadvantaged schools. However, this anomalous situation does show that gender expectation is more important than is theoretical knowledge in building confidence in the ability to perform tasks.

The different societal expectations and pressures experienced by male and female students are evidenced in answers to a questionnaire indicating that male students received more encouragement from families to do technology-related careers. Female students also reported receiving fewer electrically operated toys. Students reported, however, that their Science teachers encouraged male and female students equally.

Our study showed that students themselves believe in the greater fitness of males than females for technological careers. Although all students strongly disagreed that 'technology is a boy's subject', there was greater tendency to agree that 'boys are better suited to technical jobs than girls'. This attitude was most marked in female students from disadvantaged schools, the group doubly disadvantaged by education and gender.

Data from two questionnaires, interviews and written reflections indicated that female students were less confident in their abilities in electricity-related subtasks embedded in the course project: making and wiring a dolls' house. In mid-course questionnaires female students showed low self-efficacy relative to male counterparts in their ability to do a range of subtasks including connecting the wiring and components and drawing a wiring plan. End of course reflections indicate female students experienced more anxiety, frustration and difficulty. Correspondingly, female students were also more likely to reflect on increased levels of confidence and to express pride in their achievement than were male students. By contrast, male students were more likely than female students to reflect on their interest and enjoyment in the project.

Societal expectations of males being better at technological tasks benefit male students because success is more likely at tasks at which we and others expect us to succeed (Aronson, Wilson, and Akert 2005, 485). By extension, tasks where there is no societal or personal expectation of success are more difficult. Female students recorded the doubt and anxiety accompanying their efforts to wire their house. They noted their expectation that as girls they would not succeed in the task and the anxiety this engendered.

Significantly, by contrast with examination performance, female students performed as well as male counterparts in making and wiring a dolls' house. The literature leads us to expect female students to be good at and enjoy designing and making houses, but not wiring circuits. However, even when the task was broken down into subtasks, there is no significant gender difference between subtask performance, with one exception: female students from disadvantaged schools achieved significantly worse wiring diagram marks than male counterparts. Thus, in spite of lower confidence, worse school background and lower theoretical understanding, female students performed as well as their male counterparts in a practical task.

It is clear that doing the task successfully built confidence and pride in most female students, although some females lacked confidence to the end. Performance in the Dolls' House task equalled that of male students but theoretical knowledge continued to lag. It cannot be expected that knowledge missed in three years at school can be quickly gained.

Contextualising an area (electricity) of which most female students had little theoretical background in a task which the literature leads us to expect female students will enjoy (design and make a house) does appear to have been successful in developing a positive attitude to electricity in particular and Technology in general. However, the hands-on nature of the task as well as the need to do a task individually and to master the skills required were equally important in developing female students' self-efficacy. More research on the contribution of context to the development of self-efficacy, attitude and performance is needed. What this research has shown is that providing contexts that assist students in mastering difficult tasks on their own builds self-efficacy and may contribute to improving participation of female learners in the Technology classroom.


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## Concluding remarks

These first two papers revealed gender differences in the way students see electrical circuits from both a conceptual perspective as well as in terms of their self-efficacy in performing tasks of an electrical nature. The fact that in the examination, a test of theoretical knowledge, male students in each group outperformed female students can be explained in terms of the combined effect of poor conceptual knowledge and low self-efficacy amongst female students that has more to do with the way society's expectations that ability, since the development of their self-efficacy when it comes to learning electricity has appeared to have a positive effect on female students perceptions of themselves and their own electrical abilities, which could possibly account for improved performance in the doll's house task. Since female students achieved as well as male students in the design and construction task, I would like to argue that although males had better self-efficacy levels than females at the outset, the hands-on, individual nature of a task in a domain usually constructed as male, led to female students developing increased levels of self-efficacy, which ensured task performance matching that of the more knowledgeable male students.

### Addressing the use of the theoretical frameworks

In this paper, the predominant framework used for interpretation was that of gender theory, even though there was a simple dichotomous interpretation of the term gender that was used in classifying the data. Constructivism was used in the design of the course only and as such is not referred to explicitly in this paper.

### Addressing the research questions

The second research question and the overarching question are both addressed in this article, as well as to a certain extent, question 3, pertaining to the emotional responses of the students to the project itself. In this case, data showed that providing contexts that assist students in mastering difficult tasks on their own, builds self-efficacy and may contribute to improving participation of female learners in the technology classroom.

# Chapter 6

# "My very own mission impossible": an APPRAISAL analysis of student teacher reflections on a design and technology project

## Introductory remarks

This article takes a closer look at the emotion and anxiety felt by female students in completing an electrical design and technology task and attempts to answer the third research question shown below:

*What were the students' emotional responses to the Doll's House Project?*

It follows on from chapters 4 and 5 which had a look at gender differences in conceptual thinking and levels of self-efficacy respectively and the impact that these differences have on performance. In this part of the study, an APPRAISAL analysis is used to compare the end of course reflections on the design and make process for the doll's house task and the course in general. While the methodology used in interpreting the student reflections is a linguistic framework for interpreting interpersonal meaning from text, the interpretation of the results of the analysis is from a post-structuralist perspective that connects our social context to the way we view the world. This allows us to see a design and technology class that is fractured along gender lines and one where it is naturally assumed that being male means being competent at electro-technology.

### The contribution of the second author in the production of this paper

This paper came about as a consequence of the first paper submitted for publication. In the analysis of student reflections, my co-author noticed that there were linguistic trends that could be analysed using a framework taken from Systemic Functional Grammar, namely the APPRAISAL framework for analysis. Linguistics is outside my field of expertise and in the case of this paper, I was led by my co-author, who has significant expertise in this regard. For this area, in which neither I nor my supervisor had expertise, my co-author acted as a secondary supervisor. Thus she played a supervisory role in guiding my reading and understanding of the literature. From working with her, I learned how to implement the APPRAISAL framework in the interpretation of the reflection data, as well as develop some understanding of the categories used for analysis. While the interpretation of the data was guided by my co-author, I had the following input. I designed the study and collected the data; after I learned how to do it, we shared in the task of categorizing and interpreting the writing produced by students. I had input through the leadership of the second author into the analysis of the data and the subsequent discussion. She had some input into the writing and redrafting of the paper, but this was mostly written by me.

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# "My very own mission impossible": an APPRAISAL analysis of student teacher reflections on a design and technology project*

JAMES MACKAY AND JEAN PARKINSON

*Abstract*

*A post-structuralist perspective suggests that our social context will lead to lasting ways of viewing the world, which will be reflected in what we think, say, and write. This study aims to test whether gendered expectations of success in a technological task are reflected grammatically in reflections on the task. Eighty-seven teacher trainees built and electrically wired a doll house as a class assignment. Their written reflections on this experience were analyzed using the APPRAISAL framework, which allows analysis of expression of emotion (AFFECT), assessment of behavior (JUDGMENT), and assessment of artifacts (APPRECIATION). The grammar of male students' writing reflects a comparatively positive experience of the task. A greater proportion of the interpersonal content of the male students' compared to the female students' reflections was devoted to a positive assessment of the doll's house and the course (APPRECIATION). Female students' reflections gave more attention to negative appraisal of their own emotions (AFFECT) and actions (JUDGMENT), indicating that gendered experience is indeed encoded in the grammar of the reflections. We interpret our findings as reflecting the anxiety and difficulty of achieving a task when we ourselves and others in our social context expect us not to be able to achieve that task.*

*Keywords:* *APPRAISAL; technology education; gender; reflections; ideology.*

## 1. Introduction

From a post-structuralist perspective, our personal history and social context lead to lasting ways of viewing the world and acting in it (Bourdieu 2000). Our prior experiences influence our attitudes and values, and our

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"conscious and unconscious thoughts and emotions," our sense of ourselves and our relationship with the world is "constantly being reconstituted in discourse each time we think or speak" (Weedon 1987: 32). This implies that our attitudes and values are unconsciously encoded in and perhaps recoverable from what we say and how we say it. In Bourdieu's (1991: 2) words: "every linguistic interaction, however personal and insignificant . . . , bears the traces of the social structure that it both expresses and helps to reproduce."

With this as a starting point, we examine the written reflections on a design and technology assignment of male and female pre-service education students. The reflection genre encourages students to integrate learning with their own emotions and beliefs. We hypothesize that the emotions expressed in these reflections will show gender differences. Our study assumes that differences in participation and achievement of female students in technology and technological careers arise not from innate differences, but from social attitudes viewing certain fields as less appropriate for women. These attitudes are embedded in the subtly gendered ways that children are treated (Nicholson 1984; Smith and Lloyd 1978), and result in different experiences of technology and other areas of life for men and women. Our prior experiences constitute our personal and social history, and are reflected in and create what Bourdieu (2000) calls *habitus*. Habitus is "durable dispositions" or "schemes of perception, appreciation and action" that allow us to "generate appropriate and endlessly renewed strategies" (2000: 138). Our habitus influences our vision of the world in a certain way and our actions in it. Our experience of the social world, including its inequalities, is internalized and reflected in what we say and how we express ourselves.

For Gumperz and Cook-Gumperz (1982: 1), gender and class "are communicatively produced." Similarly, "gender ideologies" are "socialised and sustained by talk" (Ochs 1992: 336) and transmitted through discursive practices (Davies 1989). Butler's (1988) idea of performativity and gender as a process of repeated acts guided by a script that is already determined suggests that people are regulated by a framework within which they are able to select a gender style from a restricted repertoire (Salih 2002). Individuals perform masculinity or femininity in what they read, write, and say, and in Blackburn's (2002) research, repeatedly perform the same gender identity. In our research, we have not gathered sufficient data to enable us to distinguish fine differences in gender styles.

Reflection on an educational experience aims to encourage pre-service teachers to reflect on a practical experience, connect with the experience emotionally, and integrate the learning with present knowledge and beliefs. For Boud, Keogh, and Walker (1985: 19), reflection involves returning to, connecting with, and evaluating an experience, before integrating learning into one's conceptual framework; thus the student teacher is able to "recapture their experience, think about it, and evaluate it." Reflection, the "interaction of experiences with analysis of beliefs about those experiences" (Newell 1996: 568), allows student teachers to analyze why they do something and to access their own beliefs and feelings about it.

The data were collected in an education faculty at a South African university in the city of Durban. The doll's house project, involving designing, making, and wiring a doll house, was assigned as coursework in a first-year technology course for teacher trainees. The course, whose purpose was to improve student teachers' understanding of practical electrical technology, was taught by the first author (male). Data sources included an end-of-project written student reflection. Initial content analysis indicated that many students experienced the assignment, particularly the house wiring, as comprehending abilities more natural to males than to females, and that, perhaps as a result, many female students experienced stress in doing the project. Female students spoke of the task as being "a nightmare," and its accomplishment as being "the proudest moment of my life"; explicit statements on gender appropriacy included: "I was surprised that I could do it being a girl" and "all those year I thought boys are the only one who know how to do wiring".

Before describing our analysis of the student reflections, we summarize our analysis of other data, already described in Mackay and Parkinson (forthcoming), including biographical information such as school background and subjects, doll house assessment, examination performance, student interviews, and the written student reflections that are the focus of this article.[1]

Mackay and Parkinson (forthcoming) considered self-efficacy in building and wiring a doll house, and compared students' attitudes toward the task, assessed achievement in the task and in examination questions. Self-efficacy is "belief in one's ability to carry out actions that produce desired outcomes" (Aronson et al. 2005: 485). People with high self-efficacy experience lower anxiety, and are more likely to see tasks as challenges to be overcome rather than as difficult (Bandura 1994). Ways of developing self-efficacy include mastery of difficult tasks and seeing social models achieve the behavior (Bandura 1994).

Our original study involved 100 male and female students in equal proportions; 87 of these wrote reflections, analyzed in this article. Taking account of the importance of the context of learning, the continuing differential in standards of South African education also necessitates distinguishing those who attended educationally advantaged schools from those who attended educationally disadvantaged schools. Disadvantaged schools, a legacy of apartheid, continue to be found in areas occupied almost exclusively by black African people: townships and rural areas. The demographic profile of educationally advantaged schools, now ethnically mixed, has, by contrast, changed greatly since the apartheid years. To ensure similar educational, socioeconomic, and home background among the students compared, the study analyzed the reflections of white male and white female students (all from advantaged schools) and black African male and female students (from disadvantaged schools). For simplicity, we omit black African students who attended relatively advantaged schools (36% of the black African female and 4% of the male students in the group surveyed), as well as South African Indian students (27% of total sample). Conflating these groups might invalidate results because of unmeasured differences in cultural norms. About half of the male and half of the female students fell into each group (educationally advantaged/disadvantaged). Relative educational advantage of schools was measured by a government sponsored survey (EMIS 2006) using a range of indicators such as laboratory and library provision, utilities (running water, electricity, tarred roads), as well as teacher training. Relative dis/advantage is scored from least to most advantaged (deciles 1 to 10). We use school background, data to which we have ready access, as an indication of socioeconomic background, although factors in the student teachers' home socialization may be as relevant to their response to the doll house task as the degree of dis/advantage of their schools.

Our wider study revealed that female students had lower self-efficacy in their ability to build and wire the doll house. Half the male students in both groups had taken science to grade 12 level, compared with fewer than 20% of the female students; not surprisingly both advantaged and disadvantaged female students achieved significantly lower marks in the electricity examination questions than did their male counterparts (see Figure 1).

However, the examination performance showed that educationally advantaged female students had better theoretical understanding of electricity than educationally disadvantaged male students. Despite this, their self-confidence (in interviews and pre- and mid-course questionnaires) was lower than that of the disadvantaged male group (Table 1). This engendered our suspicion that differing gendered expectations might play a role in building confidence in ability to perform this task.

A pre-course questionnaire provided evidence of a gendered prior experience: male students got more encouragement from families to enter technology-related careers, and received more electrically operated toys as children. Also, students believe that males are better fitted for techno-

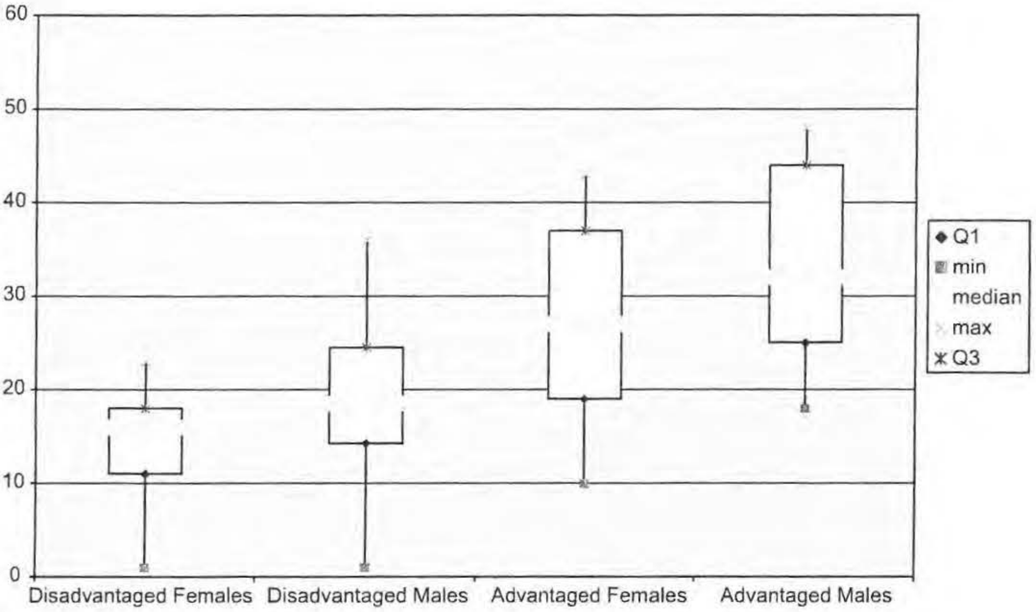


Figure 1. *Box plot comparing results in the Electricity section of the Technology exam*

Table 1. *Student mid-course confidence of achieving aspects of the doll house task*

| | Disadvantaged ♀ students | Advantaged ♀ students | Disadvantaged ♂ students | Advantaged ♂ students |
|---|---|---|---|---|
| Making a bulb light up | 42% | 80% | 86% | 94% |
| Connect circuit to switch on bulb | 29% | 70% | 78% | 88% |
| Upstairs/downstairs bulb | 14% | 35% | 52% | 59% |
| Explain how electric circuits work | 36% | 30% | 64% | 82% |
| Switch to change motor direction | 18% | 0% | 50% | 65% |
| Planning circuit for doll house | 50% | 50% | 65% | 76% |
| Wiring plan for doll house | 48% | 50% | 76% | 76% |
| Soldering | 58% | 79% | 90% | 94% |
| Connect wiring & components | 22% | 21% | 67% | 94% |
| Use doll house in own teaching | 54% | 35% | 77% | 76% |
| Making the doll house | 81% | 100% | 66% | 94% |

logical careers: most disagreed that "technology is a boy's subject", but agreed that "boys are better suited to technical jobs than girls". This was most marked in female students from disadvantaged schools. Expectations that they will be better at technological tasks benefit males because

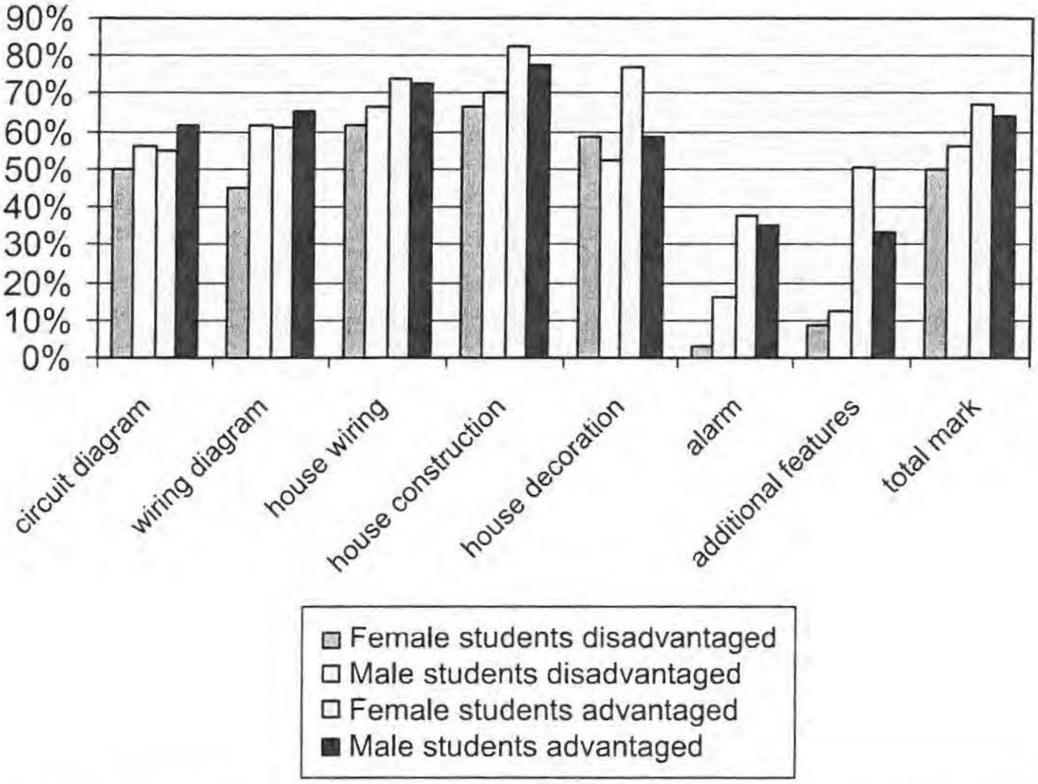


Figure 2. *Performance in different aspects of the doll house by students in the four groups*

success is more likely to be achieved with tasks where we and others in our social context expect us to succeed (Aronson et al. 2005: 485). Tasks where there is no societal or personal expectation of success are more difficult. Female students recorded the doubt and anxiety accompanying their efforts to wire their house. They expected, as girls, not to succeed in the task and this engendered anxiety.

In contrast with examination performance, mean performance of female students was as good as that of male counterparts in all aspects of making and wiring the house.[2] This comparison is reflected in Figure 2. The literature (Atkinson 2006; Silverman and Pritchard 1996) leads us to expect female students to succeed at and enjoy designing and making houses, but not wiring circuits. However, there was no statistically significant gender difference in performance in either the advantaged or disadvantaged group. Thus, in spite of lower confidence, worse school background, and lower prior theoretical understanding, female students performed as well as male counterparts in the practical task. In the next section, we turn our attention to our method of analyzing the reflections.

## 2. Method of analysis: the APPRAISAL system

To analyze students' attitudes and feelings as expressed in their written reflections on the doll's house task, we sought an approach that would enable us to analyze what feelings were being expressed and how these were being framed. To do this we rely on the APPRAISAL framework, part of systemic functional linguistics, a semiotic approach to language. In distinction to formal grammar, where focus is on word classes within the unit of the clause, systemic functional grammar examines meaning, and the options for making meaning within texts by focusing on "lexicogrammar," which includes both the structure and the lexis of texts. Every utterance may be analyzed with regard to three metafunctions: ideational, interpersonal, and textual.

APPRAISAL, a framework for analysis of interpersonal meaning in text, considers three kinds of interpersonal meaning used by a writer or speaker: expression of human emotion (AFFECT), assessment of human behavior (JUDGMENT), and assessments of artifacts, processes, and phenomena (APPRECIATION). Although AFFECT is the primary framework for analysis of interpersonal meaning to encode emotions, Martin (2000: 145) notes that JUDGMENT and APPRECIATION also encode feeling. JUDGMENT is emotion recontextualized as evaluation of behavior, while APPRECIATION is emotion recontextualized as evaluation of things people have made or of natural phenomena. For the most part these meanings are explicitly realized (or "inscribed") through evaluative lexis and syntax (Macken-Horarik 2003: 298) such as "I *love* my little dolls house", "I'm so *proud*", "an *awesome* module", etc. Such meanings may also be implicit or "evoked" through use of linguistic units more variable in type and length (Adendorff and De Klerk 2005: 74). Interpersonal meanings are evoked through use of ideational meanings which act as "tokens" of attitude. These evoked meanings are sensitive to co-text (Martin and White 2005: 66) and may have been cued earlier in the text by use of inscribed meanings (Coffin 2003: 230). Evoked expressions depend on the reader's reading position for interpretation (Martin and White 2005: 66) and rely on shared cultural norms and a shared cultural and ideological standpoint of reader and writer (Coffin 2003: 231). Examples are "the lecture seemed to fly past", evoking enjoyment, and "each time I would get a light to work I would yell and (my mother) would rush in and see what I had managed to do", evoking a sense of pride in accomplishment.

AFFECT, the central system for expressing emotions, considers both emotions about present events (distinguished in Martin's APPRAISAL system [2000: 151] as un/happiness, in/security, and dis/satisfaction) and emotions such as fear and desire that refer to future events (dis/inclination).

Martin (2000: 150) notes that emotions of un/happiness involve "affairs of the heart," including, on the negative side, misery and antipathy, and on the positive side, cheer and affection. Emotions expressing in/security are concerned with what Martin (2000: 150) calls "ecosocial well-being." Negative aspects include disquiet and surprise, while positive aspects are confidence and trust. Emotions of dis/satisfaction involve the pursuit of goals (2000: 150), negative emotions being ennui and displeasure and positive emotions, interest and admiration.

JUDGMENT is a framework for meanings that "appraise human behaviour by reference to a set of institutionalised norms about how people should and should not behave" (Coffin 2000: 274). It refers to language which "criticises or praises, which condemns or applauds the behaviour —the actions, deeds, sayings, beliefs, motivation etc.—of humans or groups" (White 2005). The first category of JUDGMENT refers to judgments involving social sanction of behavior that is explicitly culturally codified: il/legality and im/morality. In this category are included both negative and positive judgments of veracity (truth) and propriety (ethics). A second category of judgment refers to social esteem, which again involves both negative and positive judgments of normality, capacity, and tenacity.

APPRECIATION refers to resources for valuing products, performances, and natural phenomena (Martin 2000: 159). It too has positive and negative dimensions and has three categories. These are reaction (both impact [noticeability] and quality [likeability]), composition (including balance as well as complexity), and finally, valuation of how worthwhile something is.

## 3. APPRAISAL analysis of the doll's house reflections

The reflection genre is the writer's appraisal of an educational experience, as well as being the students' appraisal of their own reaction to this experience. This makes a reflection a fruitful source of insight into students' feelings about the experience.

We begin this account with four extracts from the reflections of a representative from each of the four groups of students: Ntombifuthi (a female student who had attended a rural decile 7 school; schools below decile 9 are regarded as disadvantaged by the university);[3] Michelle (a female student who had attended an advantaged urban decile 10 school); Sizwe (a male student from a disadvantaged decile 7 school in a rural area); and finally Gareth (a male student from an advantaged urban decile 10 school).

| | | |
|---|---|---|
| 1 | + tenacity | JUDGMENT |
| 2 | – capacity | JUDGMENT |
| 3 | – capacity | JUDGMENT |
| 4 | – security | AFFECT |
| 5 | + tenacity | JUDGMENT |
| 6 | – capacity | JUDGMENT |
| 7 | + tenacity | JUDGMENT |
| 8 | + satisfaction | AFFECT |
| 9 | + capacity | JUDGMENT |

Figure 3. *Appraisal resources in Nthombifuthi's reflection*

(1) (An extract from Nthombifuthi's reflection)
It was very difficult to make a doll house. *I tried my best* [1] to know how to do wiring *but I got lost.* [2]

*The first thing I was struggling with* [3] was the plan for my house, but at last I manage to do it. It took me three weeks to do wiring. The first day I tried but the bulb did not light. *It was the stress day for me* [4] *but I did not give up* [5] and I came for next day. I connected everything in order but the light didn't turn on. Ask help from other people but *they did fail to do my house wiring.* [6] But *at last I put more effort* [7] I changed everything and start from scratch like I never did it before finally my doll house work.

I can say I learnt a lot from this course. *I'm so proud* [8] that I can be able to connect electricity, *all those year I thought that boys are the only one who know how to do wiring.* [9]

Figure 3 shows that in a way that our data found to be typical of female students from a disadvantaged educational background, Nthombifuthi judged herself as lacking in capacity for the task (particularly when compared with male students) but as a person who perseveres, trying repeatedly until she was successful. In Figure 3 we code the way we analyzed each instance of APPRAISAL in Nthombifuthi's reflection. The + and – signs refer to whether in each instance of APPRAISAL the writer appraises the experience positively or negatively.

(2) (An extract from Michelle's reflection)
*I must say that this was one of the hardest and most challenging assignments I ever had to do*! [1] It was a lot of hard work and *it was incredibly time consuming and finicky.* [2] Nevertheless, *it was very interesting to see how electricity works.* [3]

| | | |
|---|---|---|
| 1 | – composition: complexity | APPRECIATION |
| 2 | – composition: complexity | APPRECIATION |
| 3 | + reaction: impact | APPRECIATION |
| 4 | + satisfaction | AFFECT |
| 5 | – composition: complexity | APPRECIATION |
| 6 | T* + tenacity | JUDGMENT |
| 7 | + reaction: impact | APPRECIATION |
| 8 | – disinclination | AFFECT |
| 9 | T – insecurity | AFFECT |
| 10 | – disinclination | AFFECT |
| 11 | + tenacity | JUDGMENT |
| 12 | – dissatisfaction | AFFECT |
| 13 | – unhappiness | AFFECT |
| 14 | + satisfaction | AFFECT |
| 15 | + happiness | AFFECT |
| 16 | + satisfaction | AFFECT |

*T stands for "token" of attitude, or evoked instance of APPRAISAL

Figure 4. *APPRAISAL resources in Michelle's reflection*

> Firstly I built the dolls house out of balsa wood *which was lots of fun.* [4] *Gluing the house together was a bit tricky,* [5] I needed 4 arms to hold everything in place. But *I made a plan* [6] and *it turned out great.* [7][4] Then came *the most daunting part of the whole assignment* [8] ... *I was getting grey hairs over the wiring* [9] because I thought to myself, *I can't even wire a plug, how the hell am I going to wire a dolls house with lights and an alarm system...?!* [10] But after getting some much needed guidance, *I sat down at my desk and began to figure this thing out.* [11] After wiring every room, I finally got the chance to connect the wiring to the battery to see if it worked. *And wallah ... only 2 of the 4 room lights were working.* [12] *What a bummer!* [13] So I sorted that problem out and then tried again. All the lights came on this time and *the main switch was working perfectly.* [14] *I think that was the most exciting and relieving moment of my life.* [15] *I'd done it!* [16]

As was characteristic in our data among female students from an advantaged educational background, Michelle uses a good deal of AFFECT, both positive and negative, and expresses herself strongly for academic writing including exclamation marks, expressions such as "what a bummer!", strong epithets as in "incredibly finicky" and apparent exaggerations such as "most exciting and relieving moment of my life". In Figure 4 we indicate how we analyzed Michelle's reflection.

| | | |
|---|---|---|
| 1 | + Composition: balance | APPRECIATION |
| 2 | + capacity | JUDGMENT |
| 3 | + reaction: impact | APPRECIATION |
| 4 | + satisfaction | AFFECT |
| 5 | + satisfaction | AFFECT |
| 6 | + propriety | JUDGMENT |
| 7 | + capacity | JUDGMENT |
| 8 | + capacity/satisfaction: admiration | JUDGMENT/AFFECT |
| 9 | + Composition: balance | APPRECIATION |
| 10 | + valuation | APPRECIATION |
| 11 | + capacity | JUDGMENT |

Figure 5. *APPRAISAL resources in Sizwe's reflection*

(3) (Sizwe's reflection)
*The course is well planned and it is interesting* [1] because of the lecturer. *He explained everything in such a way that he opened our mind and made things easy for us.* [2]

*But what was interesting is that we did a practical work* [3] *that makes us feel comfortable with the course* [4] and when I had a problem my lecturer help me to solve that problem and I learn a lot about electricity and *I enjoy the course.* [5]

I would like to thank *my lecturer for being patient* [6] because for the first time I experience some few problems because *it was the first time to me to do electricity but I found it easier during the course.* [7] The problem I had is to differentiate positive and negative and how to connect it. So *now I can say I can do better.* [8]

The course should be continue and *it is relevant to the life situation* [9] and *it is helpful.* [10] *To be a teacher does not mean that you cannot understand about electricity.* [11]

Text (3) (analyzed in Figure 5) shows that Sizwe's reflection is interpersonally positive, as characteristic of the reflections of male students from a disadvantaged educational background. Positive APPRAISAL resources include AFFECT, JUDGMENT, and APPRECIATION equally. In his reflection Sizwe praises the course and the lecturer. Such solidarity with the lecturer was distinctive in the reflections of this group, and combined with the final sentence of his reflection implies that the lecturer is a positive model for Sizwe, who is building a new identity for himself as a knowledgeable, competent teacher.

| | | |
|---|---|---|
| 1 | + satisfaction | AFFECT |
| 2 | T + inclination | AFFECT |
| 3 | + valuation | APPRECIATION |
| 4 | – Composition: complexity | APPRECIATION |
| 5 | + reaction: quality | APPRECIATION |
| 6 | + satisfaction | AFFECT |
| 7 | – capacity | JUDGMENT |
| 8 | + inclination | AFFECT |
| 9 | + valuation | APPRECIATION |

Figure 6. *APPRAISAL resources used in Gareth's reflection*

(4) (Gareth's reflection)
When I was young *I was always fascinated by electricity*; [1] I remember my uncle making a Dolls house for his daughter, and *I never thought I would have the opportunity to make one myself.* [2]

*Truly this was an amazing project*; [3] from the outlook *when you look at a circuit diagram it looks complicated.* [4] But once you get down to making it, *it is extremely fun.* [5] *I really enjoyed using the soldering iron and the glue gun.* [6] I guess because you see instant results using them.

*The thing that I found the most challenging was the alarm system* [7] as I forgot to put it into the house instantly and so everything was painted and set up and then I had to try and figure out how I was going to put in a buzzer. *The project has encouraged me to make an even bigger house and add to it a lot more accessories.* [8]

*I really feel this project was appropriate* [9] and I learnt a lot that I can take into the exam to help me get better marks. Thanx.

Characteristic of the reflections of male students from an advantaged educational background is the positive AFFECT and APPRECIATION that predominated. Text (4) (analyzed in Figure 6) reflects Gareth's positive assessment of the project ("amazing", "extremely fun") and his enjoyment in doing it, which extends to repeating the project on his own with "a lot more accessories". Interestingly, the reflection contains evidence of a social model achieving similar behavior ("I remember my uncle making a Dolls house").

It will be noted from the above discussion that almost all instances of APPRAISAL are inscribed rather than evoked. In the whole corpus only 14 instances out of 551 in total were evoked rather than inscribed. This may be because expression of feelings is expected in the reflection genre and, familiar with this genre because it is commonly used in their studies, students felt comfortable with explicit expression of emotion. Another factor is the relative shortness of the reflections (mean length 185 words), so that evoked meanings cannot easily have been cued by explicit lexis earlier in the text.

## 4. APPRAISAL resources used by four groups: quantitative and statistical analysis

Before analyzing the APPRAISAL resources used in the data, we considered reflection length and mean number of instances of APPRAISAL included in the reflections.

### 4.1. *Number of instances of APPRAISAL expressed by the different groups*

Whether students were from an advantaged or disadvantaged school background made no difference on average to the reflection length.[5] However, mean number of words written by males (153 words) was significantly lower than by females (217 words).[6]

In addition, because our study had been sparked by an initial impression that female students imbued their reflections with more emotion, we tested this, and found that the mean number of instances of APPRAISAL used by female students (7.6) was significantly higher ($t = -3.401$) than the mean number of instances used by the male students (4.9). Could the greater length of female students' reflections have been the cause of the higher mean number of uses of APPRAISAL by female students? We compared the number of instances of APPRAISAL used per 100 words by male (3.4) and female students (3.9). Here we found that the difference was not significant ($t = -1.26$). Thus there is not significantly more APPRAISAL per 100 words in the female students' reflections compared to the male students'; however, the female students chose to write reflections that were, on average, 42% longer, and in doing so expressed more emotion. This discrepancy in the number of words written by male and female students led us to take account of both the absolute number of instances of the different types of APPRAISAL in the reflections of these four different groups, as well as the proportion of APPRAISAL used by each group that fell into each APPRAISAL category. We were interested in what students in the four different groups chose to appraise in their reflections: was it their emotions, their actions or those of others, or artifacts such as the doll house, or the course?

In our analysis we found that with regard to AFFECT, students appraised their own emotions. With regard to JUDGMENT, students assessed their own actions and behavior. AFFECT and JUDGMENT are thus useful in gaining insight into students' own feelings and what they felt about their behavior.

### 4.2. *AFFECT*

In this analysis we found that fear and disquiet are related, fear being the anticipation, and disquiet the present experience of insecurity while doing an activity. Interest and cheer are also hard to distinguish in this analysis. Students speak of enjoying the task, which at first was tempting to code as happiness. However, in the context of completing an academic project, satisfaction seemed more appropriate, and statements like "I enjoyed constructing the house" were coded as satisfaction (interest) rather than happiness (cheer). The following kinds of expressions were coded by us as falling into each category:

| Happiness (cheer) | Satisfaction (interest) |
|---|---|
| *Fun, happy, couldn't believe it, glad, excited, feel better, didn't hate it, thrilling, looked forward, reward, fascinated* | *Interesting, involved, enjoy* |

It is clear from Table 2 that female students were more likely than male students to use AFFECT. Prominent categories (highlighted in Table 2) were disinclination (fear), insecurity (disquiet), happiness (cheer), satisfaction (admiration), and satisfaction (interest), with only the last of these expressed very much by male students. This indicates that female students represent themselves as experiencing more positive and negative emotions as a result of the project, than male students do.

Female students were just as likely to express satisfaction (interest), but far more likely to express happiness (cheer) and satisfaction (admiration) with their own performance, indicating perhaps that female students experienced successful completion of the task as more of an accomplishment than did male students. Female students also were more likely to express negative emotions (fear and disquiet: both present and anticipated insecurity while making and wiring the house). It is clear from this that female students experienced anxiety in building and wiring the house, a finding we relate to lower initial expectation in the female students that they would be able to achieve the task because the woodwork and in particular the wiring associated with the assignment are not tasks that they expect women to be able to do. Explicit statements include: "Technology

Table 2. *AFFECT: comparison by gender and educational dis/advantage (after Martin 2000: 150–151)*

| | | | | 24 ♀ disad | 20 ♀ advan | 25 ♂ disad | 18 ♂ advan | Tot 87 | Example |
|---|---|---|---|---|---|---|---|---|---|
| AFFECT | AFFECT (present events) | unhappiness | misery | 2 | 4 | 1 | 1 | 8 | "Looking back on the project that started off in tears" |
| | | | antipathy | 0 | 3 | 1 | 0 | 4 | "I hate electricity" |
| | | happiness | cheer | 10 | 11 | 3 | 3 | 27 | "its thrilling to be able to light up a light bulb" |
| | | | affection | 1 | 2 | 3 | 0 | 6 | "because I love design" |
| | | insecurity | disquiet | 19 | 9 | 3 | 0 | 31 | "First I battle to build up a house" |
| | | | surprise | 0 | 1 | 0 | 0 | 1 | "much to his surprise" |
| | | security | confidence | 2 | 5 | 2 | 3 | 12 | "the harder I worked the more confident I felt about my house" |
| | | | trust | 0 | 0 | 0 | 0 | 0 | |
| | | dissatisfaction | ennui | 0 | 0 | 2 | 0 | 2 | "you end up losing interest" |
| | | | displeasure | 3 | 1 | 1 | 1 | 6 | "I get cross because I didn't finish my project" |
| | | satisfaction | interest | 11 | 14 | 15 | 15 | 55 | "I truly enjoyed the making of the house" |
| | | | admiration | 14 | 13 | 5 | 3 | 35 | "I did the wiring by myself which I am very proud of" |
| | AFFECT (future events) | disinclination | fear | 17 | 17 | 4 | 4 | 42 | "because I had a phobia" |
| | | inclination | desire | 4 | | 0 | 4 | 8 | "hopefully a little girl will get pleasure playing it as I did building it" |
| | | | Total | 83 | 80 | 40 | 34 | 237 | |

Table 3. *JUDGMENT in the reflections*

| | Positive | Who is judged, and by whom? | +− | Negative | Who is judged? |
|---|---|---|---|---|---|
| *Social esteem* | | | | | |
| normality | 2 "lucky I have a science background" | | | 0 | |
| capacity | 35 "I feel like someone who knows about electricity from now on" | student judges self, boys, other students, the lecturer | | 74 "I could not grasp what we had to do" | student judges self |
| tenacity | 24 "But I struggled and struggled until it get done" | student judges self | 2 | 4 "I was so negative. I told myself that I can't do this" | student judges self |
| *Social sanction* | | | | | |
| veracity | 0 | | | 0 | |
| propriety | 17 "He has patience to give guidance" | Student judges the lecturer | | 1 "I thought it was unfair" | |

is likely passed by boys as they are strong and thoughtful" and "I was surprised that I could do it being a girl".

### 4.3. *JUDGMENT*

There were 159 uses of JUDGMENT in the data. In a small number of cases, students assess the lecturer as kind and patient because he helped them. Far more frequently, students' judgments are of their own behavior. They judge themselves to be capable or, more frequently, not capable; they judge themselves to be persevering, often structuring their reflection as eventual triumph after repeated struggles.

Table 3 shows that most frequently it is the student who judges him/herself. A negative appraisal of capacity, a feeling of being unable to do the task, was a prominent category. As we discuss below relating to APPRECIATION, we did not analyze as APPRAISAL bald statements such as "it was a hard task". However, when students chose explicitly to attach the experience of ease/difficulty to themselves (e.g., "I found it extremely dif-

Table 4. *JUDGMENT: analysis by gender and educational advantage*

| | *Positive* | | | | *Negative* | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 24 ♀ disad | 20 ♀ advan | 25 ♂ disad | 18 ♂ advan | 24 ♀ disad | 20 ♀ advan | 25 ♂ disad | 18 ♂ advan | |
| *Social esteem* | | | | | | | | | |
| normality | | 2 | | | | | | | 2 |
| capacity | 6 | 9 | 18 | 2 | 31 | 26 | 9 | 8 | 109 |
| tenacity | 12 | 5 | 5 | 2 | 3 | 1 | | | 27 |
| *Social sanction* | | | | | | | | | |
| propriety | 6 | 3 | 7 | 1 | | | | 1 | 18 |
| Total | 24 | 19 | 29 | 5 | 34 | 27 | 9 | 9 | 156 |

ficult to understand circuits"), we viewed this as a judgment on themselves and this is analyzed in our data as CAPACITY. Analyzing the data by gender and educational dis/advantage yields further interesting results shown in Table 4.

A first interesting feature of our analysis of JUDGMENT shows that a positive appraisal of their own CAPACITY is the most frequent use of JUDGMENT by disadvantaged male students. Female students in both groups appraise their CAPACITY negatively. CAPACITY assesses whether a person is competent or capable (Coffin 2000: 275) and in our data was typically instanced in expressions such as "but it challenging me a lot to get electricity to work" and "Even after I was showed the basic steps I was still hopelessly lost". A second noticeable feature is a tendency of educationally disadvantaged female students to positively appraise themselves for TENACITY. TENACITY is a person's dependability or resolve and in our data was typically instanced in expressions such as "but then when I was faced with the challenge I had to stand up for myself and do it". Finally, educationally disadvantaged students of both genders were more likely to appraise positively the lecturer's willingness to assist them (PROPRIETY) in statements such as "The lecturer have been kind enough to assist me wherever I encountered the problems".

### 4.4. *APPRECIATION*

For Martin (2003: 173; original emphasis), APPRECIATION

> construes attitudes about texts, performances and natural phenomena, and fits into frames such as *I consider it 'x'*: I consider it *innovative/unimaginative*

Table 5. *APPRECIATION in the data*

| | Positive | Student assesses | Negative | Student assesses |
|---|---|---|---|---|
| Reaction: impact | 36 "an awesome module" | Course, assignment | 1 "All the years electricity had been very boring for me" | |
| Reaction: quality | 29 "It is extremely fun" | Project, designing, making, wiring the house | 5 "the most irritating task ever" | |
| Composition: balance | 8 "The module was well structured" | course | 8 "it did not go as planned" | |
| Composition: complexity | 10 "Doing wiring really gave me no sweat" | wiring, circuit | 28 "I can say with definite certainty that this was one frustrating task" | Assignment, wiring, circuit |
| Valuation | 37 "This kind of project is very useful to us" | Module, project | 2 "What is not really good about it is I spent a lot of time" | |

In this analysis we look upon the doll house as being in the nature of an artwork/artifact. The APPRAISAL system (Hunston and Thompson 2000: 142) expresses writer opinion on the good/bad parameter. In the context of student reflections on this task, the easy/difficult distinction was salient in the data. Students assessed "difficult" as bad and "easy" as good. This is clear in Table 5, where complexity is a prominent negative category. The emotional/interpersonal content of whether the task is easy or difficult is clear in statements such as "The wiring was a mission at first", "I must say that this was one of the hardest and most challenging assignments I've ever had to do", "I honestly found making the doll's house pretty easy". However, the emotional/interpersonal content in "It was easy making the house", and "It was also difficult to solder together" is less clear, although it could be regarded as evoked APPRECIATION in this context where almost all students regarded ease/difficulty as important enough to mention in their reaction to the task. Nevertheless, as students chose factual expression for expressions of ease/difficulty in cases such as "It was easy/difficult making the house", we regarded such statements as

Table 6. *APPRECIATION: analysis by gender and educational advantage*

| | Positive | | | | Negative | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 24 ♀ disad | 20 ♀ advan | 25 ♂ disad | 18 ♂ advan | 24 ♀ disad | 20 ♀ advan | 25 ♂ disad | 18 ♂ advan | |
| Reaction: impact | 6 | 7 | 8 | 14 | | 1 | | | 36 |
| Reaction: quality | 3 | 6 | 5 | 14 | 2 | 2 | 1 | | 33 |
| Composition: balance | 1 | 2 | 5 | | 1 | 6 | | 1 | 16 |
| Composition: complexity | 4 | 4 | | 3 | 2 | 13 | 9 | 4 | 39 |
| Valuation | 4 | 6 | 16 | 10 | | 1 | 1 | | 38 |
| | 18 | 25 | 34 | 41 | 5 | 23 | 11 | 5 | 162 |

factual, and not as examples of APPRECIATION. We counted 169 instances of appreciation in the data.

Figure 6 indicates that students appraised the course, assignment, and various aspects of their own doll house such as the building and the wiring. The most negatively appraised aspect of the project was the electricity/circuit/wiring of the doll's house. It was said to be "tricky", "exasperating", "a mission", and by contrast, "rewarding", and "extremely fun".

Table 6 indicates that APPRECIATION was a favored resource for male students, and for this group was most likely to be positive.

## 5. Discussion: the APPRAISAL resources used by the four groups in the study

What is clear from the above analysis, and confirmed by the summary in Table 7, is that positive appreciation is the APPRAISAL resource of choice for the advantaged male students. They prefer APPRECIATION as an APPRAISAL resource, and their mean use of APPRECIATION per 100 words is significantly higher than for any of the other three groups of students.[7] The course, the assignment, and the learning experience are very positively evaluated as "extremely fun", "awesome", and "a real and life applying way of letting us learn". Their use of AFFECT is almost entirely positive and they avoid JUDGMENT,[8] locating emotional response to the assignment as external to their own behavior. Using APPRECIATION, they construe the emotional response to a greater extent than the other groups

Table 7. *Summary of the* APPRAISAL *resources used by students in the four categories*

| | ♀ disad | ♀ advan | ♂ disad | ♂ advan |
|---|---|---|---|---|
| Number of students | 24 | 20 | 25 | 18 |
| Instances of use of APPRAISAL resources | 166 | 173 | 124 | 94 |
| Mean instances of use of APPRAISAL resources per student | 6.9 | 8.7 | 5.0 | 5.2 |
| Instances of AFFECT as a proportion of APPRAISAL resources | 50% | 46% | 32% | 36% |
| Positive AFFECT as proportion of APPRAISAL resources | 26% | 26% | 23% | 30% |
| Negative AFFECT as a proportion of APPRAISAL resources | 25% | 20% | 10% | 6% |
| Positive JUDGMENT as a proportion of APPRAISAL resources | 14% | 11% | 24% | 5% |
| Negative JUDGMENT as a proportion of APPRAISAL resources | 20% | 16% | 7% | 10% |
| Positive APPRECIATION as a proportion of APPRAISAL resources | 11% | 14% | 27% | 44% |
| Negative APPRECIATION as a proportion of APPRAISAL resources | 3% | 13% | 9% | 5% |

as attached to or characteristic of the doll house itself. The group's expression of their own emotional reactions to the assignment is almost entirely positive, with 79% of APPRAISAL used by this group being positive.

Like the advantaged male group, male students from disadvantaged schools are positive in their appraisal of the assignment, with 74% of instances of APPRAISAL being positive. Unlike the advantaged male students, this group uses AFFECT, JUDGMENT, and APPRECIATION equally. Comments about their own emotions are on the whole positive ("I really enjoyed this experience"). As a proportion of the APPRAISAL resources they use, the group uses positive JUDGMENT as a resource significantly more than the other three groups (e.g., compared to advantaged male students, $z = 3.808$); they comment positively on their own capacity to do the task ("It made me think I am capable") and tenacity in persevering ("and I overcome all problems"). They are also the group that made most positive judgments on the lecturer's willingness and ability to help them ("My lecturer was so helpful, although he is strict on his work, no playing time, man of work"). APPRECIATION, mostly positive, is directed at the course and assignment ("This project is fun to do").

As a proportion of the APPRAISAL resources they use, disadvantaged female students choose to use JUDGMENT significantly more than any other group (compared to disadvantaged males, $z = 3.116$) and AFFECT, particularly negative AFFECT, significantly more than disadvantaged male counterparts ($z = 3.259$). For this group, emotions and attitudes about the doll house task are experienced as internal to themselves, and their mean use of APPRECIATION is significantly less than the other groups (compared to disadvantaged male students, $t = 2.112$). The doll house evokes the negative emotions of disquiet ("At times I felt like not submitting") and fear ("I was so nervous if that liquid falls over my fingers and burns me") as well as more positive emotions of admiration of their own achievement ("I felt proud that I am capable of doing such work being a woman"), interest, and cheer. Disadvantaged female students use JUDGMENT resources to judge themselves as lacking in capacity to achieve the task (e.g., "I could not grasp what we had to do"), but willing to persevere until they manage ("But I struggled and struggled until my dolls house get done"). They appraise the overall experience significantly less positively than the male students (51% of APPRAISAL items were positive, compared with 79% for advantaged and 74% for disadvantaged male students), with a high level of negative AFFECT and JUDGMENT. Mean use of APPRAISAL resources by this group is significantly higher than for their disadvantaged male counterparts.

As can be seen from Table 7, the profile for advantaged female students is similar to that of disadvantaged female students, with advantaged females less likely than disadvantaged females to construe the experience using JUDGMENT resources and more likely to use APPRECIATION. As with disadvantaged counterparts, advantaged females construe the experience in terms of emotion they felt about building the doll's house. This includes fear ("After I was given the instructions my first thought was 'I am going to fail'"), disquiet ("The other lights became dimmer. This worried me"), admiration ("I've done things I never thought I could achieve"), and interest ("But I sure enjoyed the experience towards the end"). JUDGMENT is used to indicate feelings of not being competent ("By now I would sure have been able to confidently explain a circuit and connect electricity but instead I am found wanting"). APPRECIATION is equally divided between positive ("The once frustrating task turned to a more fulfilling fun-filled one") and negative ("incredibly time consuming and finicky") assessments of making and wiring the house. As with disadvantaged female students, this group uses JUDGMENT and AFFECT significantly more and APPRECIATION significantly less ($z = -5.439$), as a proportion of the APPRAISAL they use, than do their male counterparts.

## 6. Conclusion

A picture emerges from this analysis of a class that separated along gender lines rather than according to educational background. Female students in both groups chose to use more AFFECT and JUDGMENT than did their male students, while for male students the balance shifted toward APPRECIATION as a resource. Only half of the APPRAISAL items used by female students in both groups were positive, compared to three-quarters of the items for male students. The significance of this becomes greater considering that students used AFFECT and JUDGMENT to appraise their own emotions and behavior, and APPRECIATION to appraise the assignment or course. To generalize, female students appraised their own emotions and actions negatively, while male students appraised the task and the course positively. This difference is particularly marked for disadvantaged females who avoided APPRECIATION (i.e., appraisal of the task) and focused almost entirely on their own emotions and behavior, construing them relatively negatively. It is interesting to note that the female students did not achieve worse in the doll house task than did their male counterparts (Figure 2). Yet, as this analysis shows, they experienced the task far more negatively than did male students, passing harsher judgments on their own performance and experiencing more negative emotions.

Our analysis has confirmed, at a grammatical level of APPRAISAL, Weedon's (1987) contention that our thoughts and emotions (such as fear, pride, concern about competence) may be reconstituted in our utterances, and that beliefs about whether a task is more or less appropriate to our gender does influence us emotionally, and has real consequences for how easy or difficult we will experience the task as being.

Notions of gender appropriacy pervade society and are learned firstly in the family and later encountered on a daily basis in public texts, behaviors, and activities, making them difficult to change. The South African Department of Education, in line with education authorities in other countries, has changed the way that technology is taught in schools: there is now a single subject for male and female learners, rather than Domestic Science for girls and Woodwork for boys. Although unlikely rapidly to do away with gendered beliefs altogether, this is likely to impact on beliefs about gender appropriacy. Expressions of pride in accomplishment by female students in our study are an indication that accomplishment of "male" tasks in technology classrooms makes gradual inroads into such attitudes, in the same way that the opening up of science and maths to females has done in classrooms in many countries.

The existence of different femininities and masculinities and the related production of different gendered performances could have been interesting to look at in the context of the wide diversity of the class. This is a limitation of the study and would indeed be a fruitful avenue for further investigation.

## Notes

* We are grateful for assistance with an earlier version of this article from Alison Crouch, Caroline Goodier, and three anonymous reviewers of the article.

1. Consent was gained from the students to analyze reflections and other written course output. The option of refusing consent without negative consequences was stressed.
2. $t$-statistic for exam and aspects of doll house:

| | House mark | Exam mark | Circuit diagram | Wiring diagram | House construction | House wiring |
|---|---|---|---|---|---|---|
| Disadvantaged ♂ compared to ♀ | −2.766 | −2.552 | −0.846 | −2.406 | −1.494 | −1.784 |
| Advantaged ♂ compared to ♀ | 0.734 | −2.093 | −0.902 | −0.718 | −0.884 | 0.159 |

*Italicized* means reject the hypothesis that means are equal (reject if $t \geq \pm 2.021$ at 5% probability level)

3. Names have been changed.
4. "to make a plan" is a South African expression implying creativity despite inadequate resources.
5. $t = 0.617$; at the 5% significance level we reject the hypothesis that means are equal if $t \geq \pm 2.021$; thus means are equal, so no difference in length.
6. $t = -3.121$; $t \geq \pm 2.021$, so number of words is significantly different.
7. $t = 2.19$ when this group is compared to advantaged female students.
8. Mean use was significantly lower ($t = -2.94$ when group is compared to advantaged females).

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## Concluding remarks

This paper on the analysis of student reflections provides us with a different perspective of differences in the way male and female students approached and electro-technology based design and technology course. While there is perhaps not sufficient data to connect the three papers, a pattern of poor conceptual development, low levels of self-efficacy as well as evidence of high anxiety levels in connection with the doll's house project. This may be coupled with a gendered perspective of what are naturally assumed to be tasks that are male, compared with tasks that are naturally assumed to be female, however, not data was collected that provided evidence of perspectives of femininity and masculinity in relation to this task. This may be a weakness in the research design. The next chapter will return to the issue of conceptual development and look again at patterns of thinking about electric circuits and evidence of the persistence unipolar beliefs.

### Addressing the use of the theoretical frameworks

In this article, the overriding framework for analysis is that of gender theory. It is through this lens that we interpret theoretically, the effect of this project on the lives of female students participating in the project. As a tool for analysis, we have used APPRAISAL theory in order to unravel the discourse that forms the data. Constructivism as a theory of learning presents itself only in terms of its use in the design of the learning task.

### Addressing the research questions

This article addresses research questions 2 and 3 (RQ 2 & 3)
*"How was performance on the Doll's House task affected by the perceived self-efficacy of female students?"* and *"What were the students' emotional responses to the Doll's House Project?"*
The APPRAISAL analysis of the student reflections provides us with evidence that, at a grammatical level our thoughts and emotions influence our beliefs about whether or not a task is more or less appropriate to our gender, and that these have real consequences for how easy or difficult we experience that task as being.

# Chapter 7

# Using circuit and wiring Diagrams to identify students' mental models of basic electric circuits

## Introductory remarks

While this paper shifts quite significantly away from gender issues in learning electricity, it does deal with another important issue that has arisen in the course of this study and that is the persistence of the unipolar model of thinking. As part of the project, students were expected to design wiring diagrams and in this paper, I have identified through the use of this device, the persistence of models of thinking that I had thought would have been eradicated.

Wiring diagrams are interesting for science teachers, since they are not part of the usual armoury of exercises that are brought out to try to find out the way students think. In this paper, the issue of gender and performance is not addressed as in the other three papers, simply because there is not enough data to support any findings that are hinted at by anecdotal evidence. For this reason, I have chosen to discuss this anecdotal evidence in the concluding remarks, because I feel that it is an avenue that could be useful to research.

In this chapter I address the last research question:

*What common errors were made in drawing both circuit and wiring diagrams and in what way do these errors reflect the students' conceptual thinking?*

The focus of this paper is on the conceptual models used by students to design wiring diagrams. While this paper does not speak directly to the issue of gender and learning electricity, it does highlight some of the conceptual difficulties that students, including female students have had in completing this project. This in itself is in line with the aim of the project to investigate factors that affect the learning of electro-technology by female students. This study has insufficient data to determine whether the drawing of wiring diagrams is different for male and female students, although, there is interview evidence to suggest that choosing a gendered context, to embed the wiring activity might have an effect on the perceived self-efficacy of female students. This is discussed further in the discussion section on the limitations of the study in chapter 8.

In addition, this data was collected as part of the broader project and as such, sheds light on how the class as a whole learned electrical concepts. The possible differences in the drawing of these diagrams as a consequence of gender, be it by using a simple male / female dichotomy or an interpretation based on multiple masculinities and femininities, is an area that would be a worthwhile avenue for further investigation.

# Using circuit and wiring Diagrams to identify students' mental models of basic electric circuits


**Abstract**

This paper reflects on the use of wiring and circuit diagrams as a tool to diagnose student problems in understanding basic electric circuits. Prior to wiring a model house, a sample of 114 primary school teacher trainees were taken through a programme of instruction in current electricity based on fostering conceptual change through cognitive conflict. As part of the project, students were asked to design both circuit as well as wiring diagrams for a doll's house. The wiring diagrams were then compared to the circuit designs. Common errors in the circuit diagrams, the wiring diagrams as well as subsequent examination responses to related questions were recorded and categorised according to alternative models of electric current identified in the literature. An analysis of the catalogue of common errors in developing the circuit and wiring diagrams, suggests that students not only revert to earlier, non-scientific models of electricity when confronted with the rather more difficult task of spatially organising the components that need to be connected to fit in with the design of the house, but that they also exhibit interesting "transitional" diagrams that incorporate conflicting ideas about circuits. These instances of transitional thinking as manifested in the students' wiring and circuit diagrams might reflect instances of intermediate developmental models used by students, or perhaps the re-emergence of phenomenological primitives. This conceptual ecology that is manifested through a process of designing wiring diagrams could be a useful way to track and facilitate conceptual change in students.


Keywords: Context, conceptual change, diagnostic tool, electricity

## 1. Introduction

The use of non-scientific models of current and electric circuits by students and pupils has been the subject of numerous studies over the last decades. Tiberghien and Delacote (1976) identified patterns of thinking in basic electricity that students use to inform their actions and decisions when solving electrical problems. These patterns in thinking determine student performance in tasks that they are given and in so doing, lead to errors in answers to test items that are commonly used for assessment. Stanton (1990a) differentiates between errors, preconceptions and misconceptions in the context of learning as being derived from mental models. In this context, errors are explained to be the consequence of preconceptions which lead to particular consequences in data interpretation. This paper is about the influence and tenacity of preconceived ideas of electricity and circuits in the development of students' performance in being able to interpret, draw and construct simple circuits. In this paper I provide a more detailed analysis of the diagrams that were drawn than was the case in an earlier paper (Mackay, 2009) which had as its focus the effect of gender on drawing circuit and wiring diagrams. The main question being addressed in this study is the investigation of the extent and nature of the common errors that are made by students in drawing circuit and wiring diagrams. I am also interested to find out the extent to which these errors can be mapped onto our existing knowledge of students' naïve ideas about electricity.

*Alternative conceptions of the way circuits work*

Early work by Gilbert and Watts (1983), Tasker and Osborne (1985) as well as Shipstone (1988) identified several different models that learners use in trying to make sense of electric current and simple DC circuits. Arons (1981) also documents a number of preconceived ideas that persist even after intervention, right until university study. The nature of many of these (incorrect) mental models that students employ are such that they hinder conceptual development in the learning of current electricity. A summary of Shipstone's (1988) categorisation of the most common incorrect models of thinking students use in understanding current and circuits is outlined in table 7.1 below.

Table 7.1 *Preconceived Ideas of Current (Shipstone, 1988)*

| Model | Description |
|---|---|
| Unipolar or Sink | There is current from only ONE terminal (either positive or negative) or no circuit is drawn with only a single connection from the "power source" to the bulb. |
| Clashing Currents | Both a "positive" as well as a "negative" current meet at the bulb and "clash" causing the bulb to light. |
| Dissipative or Attenuating | Current is "used up" as charge moves around the circuit. Greater current near the (+) pole, dissipating further away from (+) / If negative charge is predominant, current "comes from" (-) pole |
| Sharing | Current is shared by the different components in a series circuit |
| Scientific | Current is the same everywhere in a series circuit. For the bulb to light, there needs to be a completed circuit. |

Of these models, the least complex is the *unipolar* or *sink model* of electric current. The *attenuated* or *dissipative* model is a more sophisticated model of thinking that while it incorporates the idea of a complete circuit, it has a non-scientific idea of current / component relationships within the circuit. It is however, still a model of current that understands current as being "used up" by components in the circuit. Both models operate within a non-conservative or consumptive paradigm of electric current and the dissipative model appears to develop naturally from the unipolar model. It is possible therefore that students who used the unipolar model might have a similar interpretation of circuits as those who used the dissipative approach.

Unipolar thinking has been identified as being the alternative conception least resistant to intervention. This is evidenced by the fact that researchers tracking the dominance of different models over ages ranging from late primary to secondary schools often do not even record it as being sufficiently significant to warrant inclusion into the data (Shipstone, 1988). Tasker and Osborne (1985) in New Zealand found that only around 5% of secondary school pupils showed evidence of unipolar thinking and that this was quickly extinguished through directed instruction and the use of focused inquiry tasks. This is however, not supported by Stanton (1990b), who found that with South African students studying physics, the unipolar model survives quite well after initial instruction at school. Reasons for this are unclear and not addressed by Stanton (1990b). McDermott and Shaffer (1992) link the dissipative model to the confusion between energy and current. One might expect the consumptive model of current to naturally lead to drawings of circuits and wiring plans that were peculiar to the models of current informing their ideas about electricity.

The idea of small knowledge structures that are self-explanatory, or "phenomenological primitives" or p-prims as di Sessa (1993) has called them is one way to explain the existence of these mental models of electric current. In di Sessa's view, these fundamental pieces of intuitive knowledge that are based on a student's experience of the world are the cause of alternative conceptual frameworks and that these frameworks develop as a consequence of faulty activation of the p-prim. Chi and Slotta (1993), however maintain that alternative conceptions are generated as a result of the misclassification of naïve concepts. In the case of the unipolar model of current, this would be seen as being related to an intuitive idea that current or electricity is "stuff" or matter that flows, in the same way as water flows down a pipe. Such intuitive ideas produce conceptions of current and hence circuit construction such as the unipolar model as described by Shipstone (1988).

Other common difficulties outlined in the literature by McDermott and Shaffer (1992), include the confusion between potential difference and current, which is related to the common confusion which is between energy and current. More recent work by Küçüközer and Kocakülah (2007) confirmed in an extensive survey of Turkish students, all of the common difficulties outlined in earlier research summarised by McDermott and Shaffer (1992) and in addition found two alternative conceptual models that were peculiar to Turkish students, which they attributed to language issues and the way electricity was taught in school. Engelhardt and Beichner (2004) developed a useful test for the identification of alternative conceptions in current electricity and used it to compile an extensive list these conceptions. Much of their work has served to confirm earlier research in this area.

McDermott and Shaffer (1992) also identify the lack of concrete experience with real circuits with the failure by students to understand the need for there to be a complete circuit. Related to this is the problem students have in not being able to recognise that the circuit diagram does not necessarily represent physical or spatial relationships and that it is only a schematic representation of connections. While she acknowledges the limited generalizability of her study on naïve circuit diagrams drawn by children, Marshall (2008) concludes that the ability to decode circuit diagrams may not reflect an ability to think abstractly about electrical concepts. She does however suggest that alternative coding schemes used by children might be useful in designing instructional programmes.

Jaakkola, Nurmi and Veermans (2011) compared students' understanding of electric circuits when using simulations only and then using a combination of hands on and simulation exercises and found that the combination of hands on exercises integrated with simulations provided students with a better understanding of the way circuits work than simulations alone. This was even true when direct instruction was provided with the simulations. Work done by Tsai, Chen, Chou, and Lain (2007), found that students understood and made sense of different circuits in different ways and that student's conceptions of current were strongly influenced by context.

The drawing of short circuits has also been looked at in past literature. Fredette and Clement (1981) have identified "pattern matching" where students match circuits to idealized and simplified circuits. In this way, they tend to ignore the wire paths and focus on "active" elements of the circuit such as the light bulbs and the batteries.

*Conceptual change*

Treagust (2006) describes conceptual change as a process where a restructuring of pre-instructional conceptual structures takes place in order to allow deeper understanding of particular science concepts. Clement and Steinberg (2002) refer to a change that is structural in nature and not one that simply changes the surface features of the conception in question. Baser (2006) describes four teaching techniques that have been discussed in the literature to facilitate conceptual change. The best known of these approaches to dealing with alternative conceptual frameworks in the classroom, initially proposed by Posner, Strike, Hewson and Gertzog (1982), is the idea of providing opportunities for cognitive conflict to take place. In this approach, they suggested that students only change the way they think about a concept if they are first *dissatisfied* by their current conceptual frameworks. If the new conception is *intelligible, plausible* and *fruitful* in solving problems in new situations, it will take root (Posner et al., 1982). For this to happen effectively, a teaching strategy must allow time and opportunity for the student to first become dissatisfied with their current model and then work through the new model that is presented in order to understand it properly and then finally use it in a new situation.

Hewson, Beeth and Thorley (1998) proposed addressing the preconceptions that the learners have through direct intervention using exercises and questioning that exposed these preconceptions and put the learner in a state of *conceptual conflict* (also used by Arons, 1981). The Generative Learning Model (GLM) developed by Osborne and Wittrock (1983) explains learning as a process that focuses on the learner's generation of links between his / her memory store and selected inputs. New meaning is constructed as the learner tries to relate this new idea to experience and new ideas are then accommodated alongside already accepted ideas. Status is then placed on the idea depending on whether it is intelligible, plausible or useful. Problems arise in the implementation of this model, when the learner deviates in understanding from what is intended by the teacher.

Niedderer and Goldberg (1994) while studying the conceptual development of an individual student in learning about basic electric circuits noticed that the student started with common alternative mental models about current and then moved through conceptual development phases using intermediate concepts, prior to developing conceptions that were closer to the scientific view of electricity. This process of integrating prior, everyday ideas about electricity with ideas that were more closely related to the scientific approach they termed *conceptual ecology*, a kind of overall mental model of the process of moving through intermediate developmental phases. Niedderer and Goldberg's (1994) idea of intermediate or developmental models is supported by Grayson (2004) who uses the idea of conceptual substitution as a way for teachers to use the intuitively correct ideas of students as a platform to develop scientifically correct concepts. In her study she outlines the complexity of the conceptual change process in addition to the development of intermediate conceptions students have while this change is taking place. Clement and Steinberg (2002) reported the use of a strategy that used a cycle of concept generation, evaluation and then modification to teach direct current electricity in a single student case study. Hart (2008) describes the use of appropriate teaching models in developing student conceptions of electricity. She puts forward the idea that conventional physics models are not always good teaching models and that since models play such a significant role in our understanding of microscopic phenomena, these should be selected with care and introduced at times when students need them to facilitate conceptual change.

Borges and Gilbert (1999) describe a conceptual progression of mental models that students go through in developing their ideas about electricity, starting from the idea of electricity as a flow of "stuff" from the energy source to the various components. This then might progress to a model of "electricity as opposing currents" which describes two different types of electricity in a circuit, a notion that still does not conserve current. A development on this is the model of "electricity as moving charges", which Borges and Gilbert (1999) see as a mechanistic view of what happens in a circuit, finally leading to the field model of electricity, which can be used to explain the action of a single charge a distance from the electrodes. These models of how electricity works in circuits can be closely related to the models of current attributed to researchers like Shipstone (1988) and Tasker and Osborne (1985).

However, not all researchers have viewed conceptual change as the most important approach in learning. Linder (1993) suggests that context, particularly if it is socially determined, has some influence on conceptual appropriateness. Different contexts generate different concepts of the same idea and that what may be more important is conceptual appreciation. This is also supported by Hewson (1996) in his revision of previous work on conceptual change theory. In other words, a student could develop an understanding of a physical concept within a particular context. This would allow for multiple conceptions that are context dependent. The notion of phenomenological primitives (p-prims) as introduced by di Sessa (1993) reveal that mental models that students develop can be linked to naïve conceptions that are based on the student's experience of the world. These are more fundamental knowledge structures that form the basis of such "misconceptions" and which are created when the student approaches the problem or situation for the first time. In electricity, such a fundamental knowledge structure would be the sense that electricity is a kind of "matter" that flows from the "producer" to the "consumer". This intuitive conception that "stuff flows" can be applied to heat, water flowing downhill and electricity and as such, could form the basis of the unipolar models that are evident in student thinking.

While the development of new knowledge in science has for centuries made use of models and analogies to develop understandings of new phenomena, the use of models and analogies in the learning of science has only recently been acknowledged (Cheng & Brown, 2010). Earlier work on misconceptions sought to relate students' mental models to historically defunct theories in science, leading to descriptions of student thinking as "Aristotelian" or "Galilean" thus connecting this thinking to incorrect misconceptions that had since been abandoned historically through major paradigm shifts. Similarly, those researching the field of conceptual change in the learning of physics have relied on the notion of paradigm shifts to effect conceptual change in the classroom (Hewson, 1996).

More recently however, theorists have preferred to view the origin of these mental models that students' have in terms of "sub-conceptual" intuitive or naïve ideas that are used to construct the preconceived patterns of thinking that are then displayed in student work (di Sessa, 1993; Vosniadou, Vamvakoussi, & Skopeliti, 2008). Both di Sessa (1993) and Vosniadou et al.(2008) see conceptual change as being more gradual and both focus on intuitive pre-concepts. In di Sessa's theory, these are phenomenological primitives (p-prims) and in Vosniadou et al.'s theory, presuppositions. In Brown's framework for the interpretation of student misconceptions, as outlined by Cheng and Brown (2010), four core elements to conceptual development are discussed; verbal-symbolic knowledge (generalisations that are consciously remembered), explanatory models, implicit models and core intuitions that form the basis of students' preconceived ideas.

In summary, Shipstone's (1988) categorisation of mental models of current and the way circuits work is a useful framework for the analysis of common errors made by students in drawing circuit and wiring diagrams in this study. In particular it is interesting to note that there have been some recordings of the persistence of the unipolar model in other studies (Stanton, 1989) and that the work done by Borges and Gilbert (1999) identifies a progression of mental models of electricity that inform thinking about how circuits work. Issues of context are particularly relevant to this study and the work by Linder (1993) on the effect of social contexts as well as Tsai et al. (2007) on the effect of context might explain some of the data that will be presented. In addition, the identification of naïve intuitive conceptions or p-prims (di Sessa, 1993) could be helpful in interpreting student drawings of circuit and wiring diagrams.

## 2. Research design

The main focus of this study was to find out the extent and nature of the common errors students made in drawing both circuit as well as wiring diagrams. In order to do this, all the drawings made in two tasks and the final examination from a cohort of students were recorded, categorised and analysed.

*Who are the students?*

The students selected for the study were registered for a Design and Technology module as part of a Bachelor of Education degree at a South African University. This module was a single semester module used to prepare students to teach basic electricity to primary school pupils. The module was project based and the project used was the construction and wiring of a model doll's house, initially used as a context to learn electricity and to see the effect of context on performance in the tasks of drawing circuit and wiring diagrams. Context was integrated into the design of the

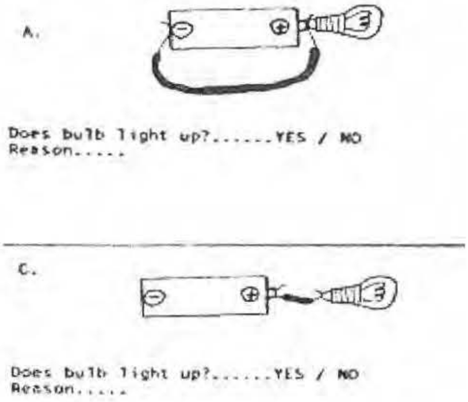


*Figure 7.1.* Sample test items for the diagnostic phase.

course as a way to improve students' attitudes as well as levels of self-efficacy (Bandura, 1994). Since 61% of the class was female, the wiring of a house was a context that was chosen to be appealing to female students. The sample size was 114, 70 of whom were female and 44 of whom were male. Of these students, 33% (38) had been scholars at educationally disadvantaged schools, while 67% (76) had been scholars at educationally advantaged schools. The distinction in this instance between an advantaged school and a disadvantaged school was made using a government approved data base and ranking system which is determined by the relative wealth of the school itself (Education Management Information Systems, 2006). The differential education provided under apartheid has resulted in differences in school performance, particularly in mathematics and science, where those students who went to educationally disadvantaged schools perform worse in science and mathematics related disciplines than do those who went to educationally advantaged schools (Perry & Fleisch, 2006). Typically, the class was made up of students who had had little scientific education at school (72%; 82) compared with those who had taken Physical Science to school exit level (28%; 32).

*Programme of instruction and rationale for the tasks given*

The programme of instruction was based on conceptual change strategies pioneered by Osborne and Wittrock (1983), Posner, Strike, Hewson and Gertzog (1982) and later developed by Kyle, Abel and Shymansky (1989). Into this were also integrated ideas of Socratic dialogue, particularly when it came to developing opportunities for cognitive conflict. An initial *diagnostic phase* that required students to predict whether or not a bulb would light up was designed to elicit preconceived ideas about circuits and the nature of current. Examples of test items are shown in figure 7.1. In order to ensure that the diagrams were understood properly, the light bulb construction was made explicit in a diagram in the students notes (see for example Shipstone, 1988; Stanton, 1990b). During the diagnostic phase of the Programme, students were asked to predict whether a bulb would light up or not (see sample questions in figure 7.1). Of the cohort, 44% appeared to use unipolar thinking in making these predictions.

The diagnostic phase was followed by a *problem solving phase* where students were required to design and make a number of circuits using standard equipment. The focus of this phase was the development of an understanding of fundamental electrical concepts such as current, voltage, energy, power and charge through a non-mathematical set of activities. In this phase, students were expected to design, construct and interpret wiring as well as circuit diagrams.

The *challenge phase* of the programme moved from circuit design and construction to designing wiring diagrams. Several tasks were given, two of which form part of the data collected in this study, namely, the design of a circuit and wiring diagram for a simple three roomed house and the design of a circuit and wiring diagram for a car. It must be noted that the intended circuit for the car was electrically identical to the intended circuit for the house.

Finally, in the *application phase* of the programme, students were required to design both circuit and wiring diagrams for a house of their own design and manufacture and then wire it according to these diagrams, producing in the end a finished product, a working electrified dolls house.

### 3. Results

A total of 246 errors were recorded in two different contexts (the wiring and circuit diagrams for a house, the wiring and circuit diagrams for a model car) as well as in the examination script. Errors were categorised according to similarity and any evidence of models of electric current as identified in Table 7.1 above. These categories are outlined below, grouped according to type as shown in Table 7.2 below.

***Error categories in the drawings***

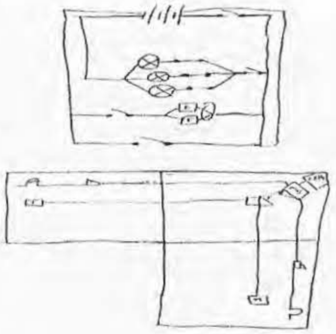

*Figure 7.2.* Unipolar wiring diagram (house).

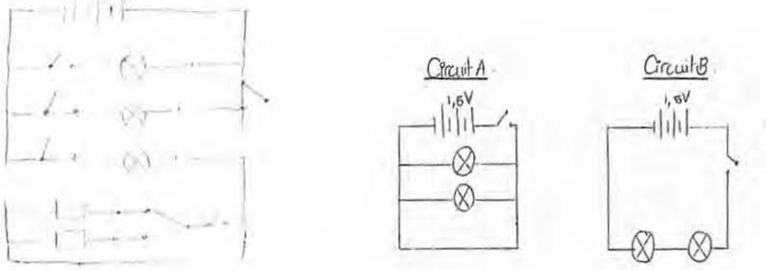

*Figure 7.3.* Examples of Short Circuits used in designing circuit diagrams.

**Error A:** (41/246) Figure 7.2 shows students drawing the correct parallel circuit diagram, but a wiring diagram that is unipolar.

**Error B:** (11/246) Drawing the circuit diagram when asked to draw the wiring diagram. Students confuse the circuit and the wiring diagrams, or simply do not understand the difference. Mostly the circuit diagrams drawn were correct.

**Error C:** (36/246) Figure 7.3 shows short circuit wires present in the Circuit Diagrams.

**Error D:** (28/246) Figure 7.4 shows components "left hanging" in the wiring diagrams.

**Error E:** (24/246) Short circuit wires in the wiring diagram. Similar to error C, the only difference is that the short circuits are shown in the wiring diagrams.

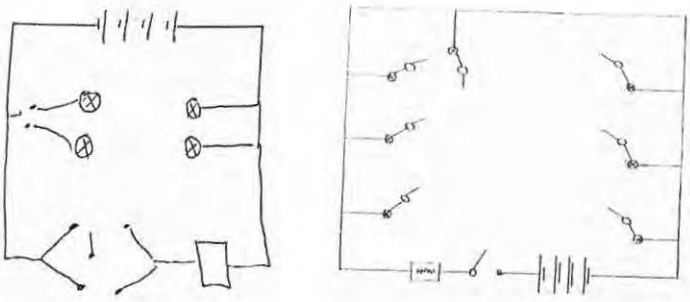

*Figure 7.4.* Error D: Components left hanging.

**Error F:** (6/246) Figure 7.5 shows the main switch is drawn in parallel with the battery. In this error, students drew a switch across the terminals of the power source, effectively causing a short circuit. This actually does work in that when the power source is shorted, everything is switched off. It is however, a poor design from a technological point of view in that the battery will run flat, or the power source over heat and / or a fuse will blow.

**Error G:** (12/246) Spatial visualisation problems when drawing the wiring diagram. Students who showed this error drew the wiring diagram simply as a set of wires that followed the shape of the house plan. This was taken to mean no understanding of what was happening in the circuit, apart from the fact that the circuit does need to be integrated into the plan of the house.

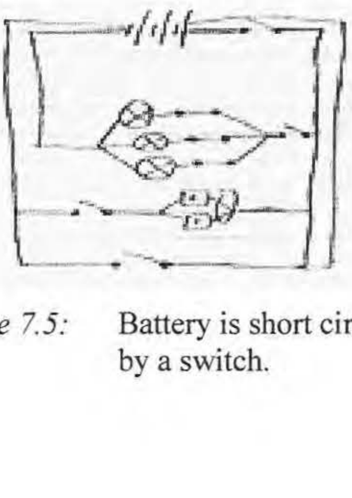

*Figure 7.5:* Battery is short circuited by a switch.

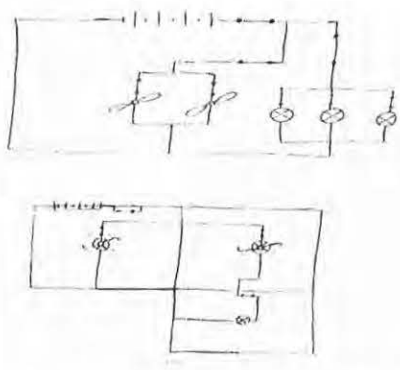

*Figure 7.6.* Example of the correct parallel circuit design and the corresponding series circuit wiring diagram from the same student.

**Error H:** (36/246) Figure 7.6 shows the drawing of a simple series circuit as the wiring diagram, while drawing the correct parallel circuit for the circuit diagram.

**Error I:** (7/246) The student draws the wiring diagram when asked to draw the circuit diagram. This is much like error B, where the circuit diagram is drawn in place of the wiring diagram. This could be that the student is confused about the question.

**Error J:** (3/246) Wiring diagram more accurate than circuit diagram. In some cases, the students drawing of the wiring diagram for the house contained fewer errors than the drawing for the circuit diagram.

**Error K:** (14/246) Non-functional loops in the circuit.

**Error M:** (1/246) More than required connections to lamp / component. In these cases, components were drawn with more than the number of connecting points they actually had.

**Error P:** (14/246) Diagrams drawn with no batteries, cells or power of any description.

**Error S:** (2/246) Switches for parallel circuit wrongly placed. On two occasions, the switches for each light in a parallel circuit were wrongly placed.

In order to determine common ways of thinking, errors were organised into groups that were similar or that were related to common alternative conceptions identified in the literature. These are shown in Table 7.2.

Table 7.2: *Groupings of common error according to Error type*

| Error Group | Common Error Label | Context: House (% of total) | Context: Car (% of total) | Exam (% of total) | House, Car & Exam Combined | Description of Common Error Group |
|---|---|---|---|---|---|---|
| **Type I** | A | 33 | 9 | 8 | 17 | Unipolar thinking used when drawing the wiring diagram but not in the circuit diagram |
| **Type II** | D & K | 4 | 27 | 22 | 17 | Components "left hanging" in the Wiring Diagram, non-functional loops in the circuit |
| **Type III** | H | 6 | 24 | 16 | 15 | Simple series connection portrayed as Wiring Diagram after a correct parallel circuit diagram has been designed |
| **Type IV** | C, E & F | 43 | 2 | 31 | 27 | Short circuit wires present in either the Circuit Diagram or the Wiring Diagram |
| **Other** | P,G,B,I, J,S,M,Y | 15 | 40 | 23 | 25 | |
| **Total %** | | **100** | **100** | **100** | **100** | |
| **(Actual Number)** | | **(82)** | **(68)** | **(96)** | **(246)** | |
| | X | 13 | 26 | 8 | 47 | Did not complete |

*Frequency of common errors*

The frequency of common errors recorded in the diagrams is shown in the graph in figure 7.7 below. This graph compares the actual number of errors made in each of the two contexts as well as the examination. The pattern presented here shows a shift from a large number of errors of category A in the house task to a fewer number in the car task and the examination. However, one can also see a simultaneous rise in frequency of errors such as C, D and H, which might be an indication of students' ability to transfer concepts from one context to another.

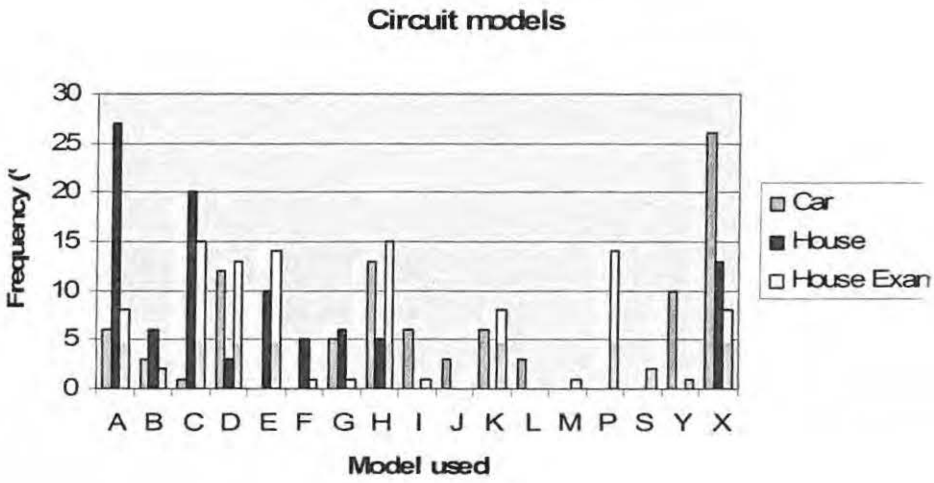


*Figure 7.7.* Frequency of errors in drawing circuit and wiring diagrams

*Types of error*

Four dominant types of error emerged from the analysis of the diagrams (Table 7.2). These types of error are described below. The largest single factor in circuit errors is the use of unipolar thinking in designing wiring diagrams. This amounted to 83/246; (34% of the total), which is shown in both type I and type II errors.

*Type I errors*

The simultaneous representation of unipolar and non-unipolar thinking in the circuit and wiring diagram design accounted for 17% of all the errors made in the three contexts. (Error A: 41/ 246)

*Type II errors*

In Errors D and K, which showed combined unipolar and completed circuit models (42/246, 17%), students appeared to accommodate elements of unipolar thinking into the design of completed circuits. This is shown in Figure 7.4, where the idea of a closed loop dominated the design of the circuit and components are connected to the loop in a unipolar way.

*Type III errors*

Figure 7.6 shows the simultaneous use of series and parallel circuits to represent the same physical circuit, which made up15% (36/246) of all the errors.

*Type IV errors - short circuits*

The drawing of short circuits in multiple ways and contexts was in fact the largest single error recorded. *(66/246, 27%)* The errors C and E both showed short circuits drawn by the students.

## 4. Discussion

While the study was limited by the fact that it was part of a larger differently focused study on the effects of context on students' attitudes to learning electricity, the evidence from the diagrams is sufficiently compelling to draw three tentative conclusions.

*Unipolar thinking*

The first important conclusion supported by the data is that the unipolar model is pervasive. Initially, 44% of students used unipolar thinking in the diagnostic component of the instructional programme. Of the errors made in drawing the diagrams, 34% (83/246) were of a unipolar nature. These were either integrated into other conceptual models (Type II - see figure 7.4) or as separate unipolar diagrams (Type I - see figure 7.2). This appears to be at odds with the commonly held belief that the number of students using the unipolar model is less than 10% (Tasker & Osborne, 1985; McDermott & Shaffer, 1992). Stanton (1990b) in work done with South African students however, suggests that the unipolar model survives quite well after initial instruction at school. The fact that after instruction 34% of errors made, suggests that the unipolar model is not easily dealt with through the instruction in the intervention. Whether it is simply resistant to prolonged instruction, or whether it resurfaces because students have difficulty in transferring mental models from one context to another (Linder, 1993; Tsai et al., 2007), it seems clear from the data collected that the unipolar models of thinking are not as easily removed as was previously thought.

*The effect of context*

It is possible that in different contexts students conceptualise electrical connections differently, and that using unipolar thinking in the wiring diagrams while drawing completed circuits in the circuit diagram is more a manifestation of the context and that students think differently about electrical concepts in different contexts. This fits with current understanding of conceptual change (Beeth & Hewson, 1999; Duschl & Hamilton, 1998; Linder, 1993; Tsai et al., 2007) where change takes place not only in a cognitive arena, but also in a social arena where context determines how the learner views the new concept. The context of connecting circuits in the house, a real object, could be viewed as being different from the more sterile stripped down context of a physics laboratory that has no information other than the electrical arrangement of the components.

Interestingly, the distribution of common errors by the same group of students was inconsistent and implies that the context in which the errors were made might have been a factor influencing the models that the students used in interpreting diagrams. A good example is that of error A, where the incidence in the house was 33%, the car 9% and the examination 8%. This could either be context depended or simply due to the fact that the car and examination tasks came after the house task. This finding is however supported by work done by Tsai et al. (2007) and also Linder (1993) who showed that context does indeed have an effect on the mental models students use when making decisions about electric circuits.

*Transitional thinking*

The third important observation from the data was the emergence of several different kinds of transitional thinking. Type II errors are perhaps the strongest evidence of accommodation of new knowledge (completed circuit) into an older schema (unipolar model). These errors could be intermediate conceptions half way between the initial unipolar idea and the concept of a completed circuit, part of a greater conceptual ecology as found by Niedderer and Goldberg (1994).

Transitional thinking is also evident in drawings by students that select to draw parallel diagrams for the circuit diagram, but series diagrams for the wiring diagrams (Type III errors). While this kind of transitional thinking does not indicate any non-scientific preconceived mental model, it might indicate that context influences the kind of circuit one would design when asked to connect circuits on a table compared with the circuit one would design to wire a house.

Related to this is the idea that conceptual transfer does not take place by itself, but rather has to be explicitly taught. In this case, however, constructing a wiring diagram was explicitly taught between the house task and the car task, which might explain the differences in frequency of the common errors between the two. It may be that the type II and III errors found in this study are also evidence of students using intermediate conceptions (Niedderer & Goldberg, 1994), or it could be that this is the effect of poor conceptual transfer. Type I errors where there is the simultaneous representation of both unipolar as well as non-unipolar thinking in two diagrams that are supposed to be the same circuit, may also be evidence of Borges and Gilberts (1999) notion of conceptual progression. The students possibly realize the need for a complete circuit, but see the house as a different context and so apply different rules. Understanding the circuit drawings in terms of phenomenological primitives provides a fruitful avenue for analysis.

*Short circuits*

Short circuits were the largest single error recorded (27%). This could have been as a result of "pattern matching" as identified by Fredette and Clement (1981), however, this error was not extensively investigated as it was felt that there was insufficient data to analyse. In addition one would have had to have interviewed students or probed their understanding of the meaning of short circuits in a much deeper way in order to ascertain whether this was in fact the case.

### 5. Implications for teaching and further research

The use of wiring diagrams as a context that is different from the standard physics classroom could provide us with an opportunity to gain some insight into the way students interpret electrical concepts and learn electricity. This could have an influence on the design of instructional programmes as it could be a useful tool for the both the detection and the amelioration of preconceived mental models of circuits and current. In the same way, the overlap between context and cognitive factors in conceptual change situations such as the wiring of a dolls house is a fertile avenue for further research. Whether or not the transitional thinking found in developing wiring diagrams from circuit diagrams is evidence of the influence of context and the failure of students to transfer conceptual knowledge from one context to another or of the development of intermediate concepts within a conceptual development process needs further investigation, as does the high prevalence of unipolar thinking amongst students. In addition the connection of drawings with unipolar elements to phenomenological primitives or naïve conceptions about the nature of electricity also needs further investigation.

## 6. Conclusion

In conclusion, while the limitations to this study have not allowed me to draw detailed conclusions about the connection between phenomenological primitives and the drawings made by the students, it does seem possible that the use of wiring diagrams could be a useful tool to expose such thinking. Whether the origin of the unipolar features of the wiring diagrams is as a result of p-prims, context, the development of intermediate models of thinking or a combination of some or all of these, is something that requires a more detailed study. This study simply points to the issues that have arisen as a consequence of the drawing of these diagrams.

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## Concluding remarks

In this concluding section, I would like to first summarize the findings of the last three chapters. Chapter 4 provided evidence of differences in conceptual thinking that were based on gender. It is assumed that these differences are not due to ability, but rather due to societal influences that position electro-technology as male knowledge. This I feel has led to low levels of self-efficacy in the learning of electricity by female students and while I did not explore the impact of learning electricity on students perceptions of their own femininities and masculinities, there was sufficient evidence indicating that attitudes towards the "maleness" of electricity had an impact on levels of self-efficacy. This is discussed in chapters 5 and 6.

Wiring diagrams are technological by nature and provide a context for the development of electrical ideas. The drawing of wiring diagrams can I believe be used to further understand the transitions that students make when they assimilate and accommodate new information. It is clear from evidence presented above that many students are able to operate in two worlds, where they separate their old ideas from their new ideas. Sometimes these two are mixed in a transitional model that somehow accommodates both worlds. This aspect of mental modelling needs further research.

Students showed poorer performance in developing wiring diagrams than circuit diagrams, along with regression to unipolar models of design as well as (in fewer cases) simple series circuits, suggesting that when students are asked to plan a circuit spatially, they retreat to models of thinking that we as teachers believe they have "left behind". This could be related to poor spatial visualisation that has been found in other literature to be common in non-science majors and learners from educationally disadvantaged backgrounds.

There is some evidence gathered to suggest that the context of the wiring diagrams affected performance based on gender. Interviews with selected female students who drew wiring diagrams suggests that for some female students context does have some effect on whether or not they feel able to design circuit and wiring diagrams. This will be discussed later in the final chapter.

**Addressing the use of the theoretical frameworks**

In this article, the overriding framework for analysis is that of constructivism, conceptual change theory and the wealth of literature on learning electrical concepts. It is through this lens that I have interpreted theoretically, the errors made in the drawing of wiring diagrams. While there was an initial element of interpretation through the lens of gender theory, there was insufficient evidence for this and so the paper remains one that looks at the data through one lens only.

**Addressing the research questions**

This article addresses the last research question 4.
"*What common errors were made in drawing both circuit and wiring diagrams and in what way do these errors reflect the students' conceptual thinking?*"

In the analysis of common errors in drawing circuit and wiring diagrams, I have been able to make a connection between the errors on the one hand and models of thinking on the other and in addition connect the work done on phenomenological primitives and the drawings made by the students. From this, it seems that the use of wiring diagrams could be a useful tool to expose such thinking. Whether the origin of the unipolar features of the wiring diagrams is as a result of p-prims, context, the development of intermediate models of thinking or a combination of some or all of these, is something that requires a more detailed study. This study simply points to the issues that have arisen as a consequence of the drawing of these diagrams and in so doing, addresses this last question.

# Chapter 8
# General discussion and conclusion

I start this chapter with a synthesis of the four papers that make up the core of the study. In this synthesis I extract the main findings from each paper and draw connections between these findings. This is followed by a reflection on the entire study in which I examine the research process for each part as well as the way these processes connect with each other. In addition, I discuss the limitations of each paper and the limitations of the study as a whole. I have also used the findings from each paper to suggest ways in which the teaching of electricity in schools and in tertiary institutions can be implemented. Finally, I treat this study as the beginning of an on-going investigation and suggest ways in which this investigation could be expanded in the light of the findings of this study.

Before continuing, I would like to revisit the original research questions that were developed in chapter 1. The overarching question for the study was:

*What factors affect the learning of electro-technology by female students?*

This is a general and very broad question that can be broken down into four more focused questions, each of which has been addressed by the papers outlined in chapters 4 to 7 above. These questions are as follows:

**Question 1**

*What are the differences between male and female students in the way they understand electrical concepts?*

**Question 2**

*How was performance on the Doll's House task affected by the perceived self-efficacy of female students?*

**Question 3**

*What were the students' emotional responses to the Doll's House Project?*

**Question 4**

*What common errors were made in drawing both circuit and wiring diagrams and in what way do these errors reflect the students' conceptual thinking?*

In the synthesis of the papers outlined below, I will discuss how each paper addresses these research questions.

## Synthesis of core research papers

This synthesis begins with an examination of the key findings of each paper, from which I proceed to draw connections between these findings, concluding this section with a summary of the main findings and what this piece of research tells us about gender and learning electricity. In this section, I will refer to the papers outlined as chapters 4, 5, 6 and 7.

*Chapter 4: Gender differences in conceptual thinking amongst technology teacher trainees*

This chapter provides insight into what conceptual difficulties students have on entry into a design and technology course. This paper had a quantitative emphasis where differences in performance in the diagnostic phase of the project which are recorded according to the overarching categories of gender, level of advantage in schooling and whether or not the students had opted to take physical science to the end of high school.

Three variables were considered in a statistical analysis using t-tests to determine whether or not there was a significant difference between the means of each of the groups tested. This was done at the start of the start of teaching intervention. It was found that there were significant differences based on gender, but not on how much science students learned prior to coming to university and also not on the relative educational advantage of their schooling. The significance tests were conducted on the performance on two diagnostic tests that were administered at the beginning of the study. The second test interestingly yielded no significant differences between genders, kind of schooling (whether advantaged or disadvantaged) and whether or not the students had studied science to the end of their high school. All students performed equally poorly. In hindsight, this was to be expected, since the test items looked for models of current that were advanced from the unipolar model of current. It seems that for this cohort of student, thinking about circuits hinged on whether or not they used the unipolar model.

The first four questions of the first test predicted quite clearly the kind of model that students used when interpreting circuit diagrams. These four questions differentiated between those students who used the unipolar model and those who did not. The fact that there is a difference in performance between advantaged males and females in the first four questions in the category that did not do science at high school suggests that schooling is not a factor in determining conceptual understanding in this case. Proceeding from the assumption that there is no difference in academic ability between the male and female groups (this is accepted since all students registered for this course gained a university exemption and were enrolled for university study which in South Africa puts them in the top 10% of academic achievement (Perry & Fleish, 2006)), this difference in achievement can be explained through socialisation and the gendered way electrical knowledge is perceived as being "male", an issue I will discuss later when I examine the next two papers.

The data also tells us that for the category of students who have not done science, there is a difference in performance between advantaged and disadvantaged male students only. This is not true for the same categories of students who had taken science, suggesting that firstly, schooling does have an effect on conceptual models used and also, even if the schools are underperforming, taking physical science helps develop scientific models.

Generally speaking however, gender is identified as the most significant factor in determining performance on the first test, with males outperforming females. What is an unexpected result is the lack of effect the quality of schooling had on the development of scientific thinking about circuits and also the lack of effect the taking of science had on the development of scientific conceptual frameworks. The literature points to the level of educational advantage as being a significant factor affecting performance (Perry & Fleisch, 2006). However, whether or not a student used the unipolar model of thinking in responding to these diagnostic test items does not seem to be influenced by level of educational disadvantage in this study. Similarly, taking physical science to the end of school, as well as whether or not they had actually connected any circuits in their pre-university education appears not to have any influence on the model of electric current used for the students in this cohort. It appears that the most important factor in determining the development of scientific models of circuits is gender. Given the history of schooling in South Africa, one might have expected the relative level of educational disadvantage to have been a greater influence than gender. This could be an indication that few of the students gained much knowledge of electricity at school, but that the male students learned about electrical circuits from home, where they might have played more with electrical components. This is however speculative.

The paper also outlines the results of correlations between the initial pre-tests and the final assessments in terms of gender reveal further interesting results. The coefficients calculated for this are low (< 0.5) indicating that the pre-tests do not have substantial predictive powers for the examination score and the Project mark. This is not surprising and in fact is somewhat encouraging as it shows that the students have learned something in the course. This is supported by the fact that the advantaged females managed to perform as well as advantaged males on the house project.

In this paper, the analysis and interpretation of the data painted a picture of a major influence of gender on patterns of thinking when interpreting simple circuit diagrams. This has implications for instructional design as well as for further research, which will be discussed later.

*Chapter 5: Gender, self-efficacy and Achievement among South African technology teacher trainees.*

The focus of the second paper was the development of self-efficacy amongst female students and the effect that this has on performance. This study was conducted on the same cohort of students, but was focused on the relationship between the attitudes the students had to the intervention task and the final performance on that task as well as the examination. The population was divided into four distinct samples that were compared with each other, namely; advantaged males, advantaged females, disadvantaged males and disadvantaged females. To repeat what was stated in the study, the reason for this was not to look at the differences in educational performance between advantaged and disadvantaged students, as this is well documented and understood. My interest was rather in the differences between male and female students and in order to control for the persisting differential in education due to apartheid, I needed to separate out advantaged from disadvantaged students. As with chapter 4, t-tests were used to look for differences in performance based on gender. This produced interesting results with significant differences between males and females for both advantaged and disadvantaged groups of students.

In this study male technology teacher trainees from both educationally advantaged and disadvantaged schools were found to be more likely than female counterparts to have taken science to grade 12. In each group around 50% of male students had taken science to grade 12. However there were fewer than 20% of the female students in each category who took science to the end of grade 12. From this we could conclude that on average male students might have had a better theoretical understanding of electricity than their female counterparts on entry. Considering the findings of chapter 4, this is certainly true of the mental models the students had on entry into the course. However, the data from chapter 4 also shows that this is not due to having taken science to the end of grade 12 for this cohort of students. Unsurprisingly, male students outperformed female counterparts in theoretical knowledge of electricity tested in the examination, but again if the findings of chapter 4 are taken into consideration, this might not be due to having taken science to the end of school. It was also clear, however, that educationally advantaged female students had better theoretical understanding of the concepts tested in the examination than did male students from disadvantaged schools. However, this anomalous situation does show that gender expectation might be more important than is theoretical knowledge in building confidence in the ability to perform practical tasks such as the wiring of a Doll's House.

When examining student achievement in the Dolls' House Task and the final examination, the grades achieved by the students differ according to both gender and level of educational advantage. Females scored significantly lower on average than did males for both advantaged and disadvantaged groups of students in the final examination. By contrast, advantaged female students marginally outperformed their male counterparts in the dolls' house task, but this was not significant at the 95% level of confidence. For those students from educationally disadvantaged schools, female students were significantly worse than their male counterparts for both the examination and the Dolls' House Task. Interestingly, the diagnostic test 1, which predicted for patterns of thinking about electrical ideas, showed no significant difference between advantaged and disadvantaged students except for males who had not done science at high school. There was however a considerable difference in performance on the test, significant at the 95% confidence level between male and female students. Correlations between performance on the diagnostic tests and the examination as well as the Dolls' House Task indicated that there was no relationship between these sets of scores. The diagnostic test, while being a good predictor of models of thinking, was not a good predictor of examination success. The explanation for this could lie in two directions. The first is that while test 1 tests almost exclusively for application of the unipolar model, the process of going through the course has in fact eradicated much of this thinking from the students. Alternatively, while the examination was validated through normal moderation procedures (see chapter 3), like many traditional assessments it could bear little resemblance to what is being tested in the diagnostic tests. In other words, the traditional questions that were set in the examination did not test for conceptual understanding; similarly the Dolls' House Task did not require students to have a scientific conceptual framework about electricity.

Data presented in chapter 5 from two questionnaires, interviews and written reflections indicated that female students were less confident in their abilities in electricity-related subtasks embedded in the course project: making and wiring a dolls' house. This data showed low self-efficacy of female students relative to male counterparts in their ability to do a range of subtasks including connecting the wiring and components and drawing a wiring plan. At the end of the course, the reflections indicated that female students experienced more anxiety, frustration and difficulty and that they were also more likely to reflect on increased levels of confidence and to express pride in their achievement than were male students. Male students showed greater interest and enjoyment in the project. The fact that society expects that males be better at technological tasks benefit male students, because success is more likely at tasks when there is an expectation that we will succeed (Aronson et al., 2005 p. 485). On the other hand, tasks where there is no societal or personal expectation of success are seen to be more difficult, as in the case of female students' expectation that they would not succeed in the making and wiring of the doll's house task.

By contrast with examination performance, female students performed as well as male counterparts in making and wiring a doll's house. The literature leads us to expect female students to be good at and enjoy designing and making houses, but not wiring circuits. In spite of lower confidence, worse school background and lower theoretical understanding, female students appeared to perform as well as their male counterparts in a practical task.

Contextualising an area (electricity) of which most female students had little theoretical background in a task which the literature leads us to expect female students will enjoy (design and make a house) does appear to have been successful in developing a positive attitude to electricity in particular and Technology in general. However, the hands-on nature of the task as well as the need to do a task individually and to master the skills required were equally important in developing female students' self-efficacy. What this research shows is that providing contexts that assist students in mastering difficult tasks on their own builds self-efficacy and may contribute to improving participation of female learners in the technology classroom.

*Chapter 6: ''My very own mission impossible'': an APPRAISAL analysis of student teacher reflections on a design and technology project*

In chapter 6, an APPRAISAL analysis was used to compare the end of course reflections on the design and make process for the Doll's House Task and the course in general. While the methodology used in interpreting the student reflections is a linguistic framework for interpreting interpersonal meaning from text, the interpretation of the results of the analysis connects our social context to the way we view the world. From this, one can see a design and technology class that is fractured along gender lines and one where it is naturally assumed that being male means being competent at electro-technology.

In the APPRAISAL analysis, AFFECT (appraisal of own emotions) and JUDGEMENT (judgement of human action) were chosen more frequently by female students in both groups than they were by their male counterparts, who selected more APPRECIATION (judgement of artefacts) as a resource. Only half of the appraisal items used by female students in both groups were positive, compared to three-quarters of the items for male students. This is significant because students used affect and judgment to appraise their own emotions and behaviour, and appreciation to appraise the assignment or course. Generally, female students appraised their own emotions and actions negatively, while male students appraised the task and the course positively. Disadvantaged females avoided APPRECIATION and focused almost entirely on their own emotions and behaviour, construing them relatively negatively. It is interesting to note that the female students did not achieve worse in the Doll's House Task than did their male counterparts and yet, they experienced the task far more negatively than did male students, passing harsher judgments on their own performance and experiencing more negative emotions. This negative view on themselves, contrasted with the positive view the male students had of the task is supported by the data discussed in chapter 5, which showed that the female students had lower self-efficacy than the male students.

*Chapter 7: Using circuit and wiring Diagrams to identify students' mental models of basic electric circuits*

The findings from this paper on wiring diagrams indicate clearly that the use of the unipolar model in this study is pervasive. In chapter 4, it was reported that 44% of students used unipolar thinking in the diagnostic component of the instructional programme. Of the errors made in drawing the diagrams, 34% (83/246) were of a unipolar nature and these were either integrated into other conceptual models or as separate unipolar diagrams. This is in contrast with the commonly held belief that the number of students using the unipolar model is less than 10% (McDermott & Shaffer, 1992; Tasker & Osborne, 1985). Work done with South African students (Stanton, 1990b) however, suggests that the unipolar model survives quite well after initial instruction at school. The fact that after instruction 34% of errors made were of a unipolar nature, suggests that this model of current is not easily dealt with through normal instruction. Whether it is simply resistant to prolonged instruction, or whether it resurfaces because students have difficulty in transferring mental models from one context to another (Linder, 1993; Tsai et al., 2007), it is clear that the unipolar models of thinking are not as easily removed as was previously thought.

The findings reported in chapter 7 indicate that it may be possible that in different contexts students conceptualise electrical connections differently, and that using unipolar thinking in the wiring diagrams while drawing completed circuits in the circuit diagram is more a manifestation of the context and that students think differently about electrical concepts in different contexts. This is supported by Beeth and Hewson (1999), Duschl and Hamilton (1998), Linder (1993), and Tsai et al. (2007) who maintain that change takes place not only in a cognitive arena, but also in a social arena where context determines how the learner views the new concept. The inconsistent distribution of common errors by the same group of students implies that the context in which the errors were made might have been a factor influencing the models that the students used in interpreting diagrams. This finding is however supported by work done by Tsai, Chen, Chou, and Lain (2007) and also Linder (1993) who showed that context does indeed have an effect on the conceptual thinking in current electricity.

The third important observation from the data collected in chapter 7 was the emergence of several different patterns of thinking that could have several explanations. One of these explanations is the possible emergence of phenomenological primitives (or p-prims). It is possible that in constructing wiring diagrams, students revert to the use of these naïve conceptions or p-prims. Another possibility is that these errors could be evidence of transition between conceptions and that students are attempting to accommodate new knowledge (completed circuit) into an older schema (unipolar model) and that these diagrams represent intermediate conceptions that are half way between the initial unipolar idea and the concept of a completed circuit, part of a greater conceptual ecology similar to that found by Niedderer and Goldberg (1994). On the other hand, these instances of transitional thinking could be evidence of poor conceptual transfer from one context to another or they may also be evidence of Borges and Gilberts (1999) notion of conceptual progression.

## Summary of the main findings of the study

In this next section I synthesise the main findings of the papers I have described above, under headings that connect evidence in many cases across the four different papers.

### Initial conceptual tests

Initial Conceptual tests revealed interesting differences on entry into the course in conceptual understanding and performance. While these differences were particularly marked for students from disadvantaged backgrounds, it was not the level of disadvantage that was the most significant indicator of performance on the test. This was gender. Five important findings were recorded from the analysis of student responses to the conceptual tests at the beginning of the course. These were:

1. The Unipolar model of thinking about electric circuits was frequently used, indicating that it is not as easily eradicated with instruction as was found in

other studies. This may be something peculiar to South Africa, as similar results have been found in other South African studies (Stanton, 1989).

2. There is a significant difference between Male and Female participants in answering the questions.
3. There was **no** significant difference between those students who had attended advantaged schools and those who had attended disadvantaged schools.
4. There was some difference in the way the questions were answered between those who took science to the end of school and those who did not.
5. Connecting circuits at school or home had no effect on performance on the tests.

**Developing self-efficacy**

In the second paper described in chapter 5, what became clear was that both male and female students seemed to believe in a greater fitness of male students to technological work than female students. However, students strongly disagreed with the idea that technology was a boy's subject. Interestingly, this tendency was greatest amongst disadvantaged female students. In addition, the study found that:

1. Female students were less confident, had lower self-efficacy and experienced greater anxiety, frustration and difficulty with the task than did the boys. However, completing the task generated pride for the female students and improved their self-efficacy levels.
2. Female students performed as well as the boys on the Doll's House Task, but not in the examination.
3. Context does appear to have been successful in helping female students develop higher self-efficacy levels, however, the hands-on nature of the task as well as developing mastery of core skills and a positive attitude were equally important. The latter having a direct influence on self-efficacy levels (Bandura, 1994).

**Student writing in the reflections**

The student writing was analysed using an APPRAISAL analysis as described in chapter 6. This analysis revealed a class that separated along gender lines rather than according to educational background. Female students in both groups chose to use more AFFECT and JUDGMENT than did their male counterparts, while for male students the balance shifted toward APPRECIATION as a resource. Only half of the APPRASAL items used by female students in both groups were positive, compared to three-quarters of the items for male students. The significance of this becomes greater considering that students used AFFECT and JUDGMENT to appraise their own emotions and behaviour, and APPRECIATION to appraise the assignment or course. Female students generally had a negative appraisal for their own emotions and actions, while male students appraised the task and the course positively. This is particularly marked for disadvantaged females who avoided APPRECIATION (of the task) and in their reflections, were focused almost entirely on their own emotions and behaviour, construing them relatively negatively. This is interesting since female students did not achieve worse in the Doll House Task than male students. As this analysis shows, they experienced the task far more negatively than males and passed harsher judgments on their own performance, showing that they experienced more negative emotions.

1. Both the performance on the initial conceptual tests as well as the performance on the Doll's House Task and an analysis of affective elements in the student writing (chapter 5) of student writing revealed a class that was separated more along the lines of Gender than along the lines of relative educational advantage.

2. There is also evidence (both qualitative and quantitative) to suggest that the intervention had some impact on those male students who came into the course from relatively disadvantaged schools. They too developed a positive attitude to learning electricity and in addition improved in performance.

**Wiring diagrams**

Wiring diagrams provided evidence of pervasive unipolar thinking even after instruction as well as transitional patterns of thinking that incorporated more than one model of electric current and circuit. These diagrams were useful for identifying the nature and the extent of the students' preconceived patterns of thinking and mapping these patterns of thinking onto currently accepted alternative conceptual frameworks.

1. There was an overall return to unipolar thinking and transitional models of thinking when it came to designing wiring diagrams for the house. This can be explained by the reversion to prior non-scientific models of thinking or naïve conceptions (p-prims) when faced with the rather more complicated task of designing the circuit to fit into the space of the house.

2. The use of transitional models of thinking about circuits supports Borges and Gilbert's (1999) work on conceptual progression and possibly provides insight into di Sessa's (1993) notion that preconceived patterns of thinking are determined by phenomenological primitives..

3. There was no evidence to suggest that female students performed worse than males on this task, however, in a related task, where students were asked to draw a wiring diagram for a car, female students performed worse and reported that this was to do with the fact that the context was a "male" one.

4. The differences in models used to draw the wiring diagram for the car compared with those for the house suggests again that context has some influence on whether students can draw the correct diagram or not. This is supported by the fact that the distribution of the different types of error made in the wiring and circuit diagrams differs depending on context (whether it was for a house or a car).

**Performance on the doll's house task**

There was a differential performance on different components of the Dolls House Task, but overall, females performed as well as male students.

1. What was really interesting about the project was that while female students came in conceptually not as well prepared and with low self-efficacy levels, they performed as well as male students on the task.

2. On the final examination however, while there was a shift in conceptual thinking, it was not sufficient to perform as well as male students in the theory questions.

## Reflection on the research process

In this section, I discuss the limitations of the study as a whole. The research process had several weaknesses that I have discussed in the conclusions of chapters 4-7, but many of these are common and in this section, I would like to synthesis this information.

### Small sample size

Small sample size was a factor that had to be accommodated in all of the papers, except perhaps chapter 6, which was mainly interpretive in nature. While sample size was largely out of my control, as it was determined by the size of the cohort, the sample size was small, leading to data where statistical tests needed to be scrutinised carefully before conclusions were drawn. The added issue of having to divide the classes into smaller groups to control for variables such as whether the students were from a disadvantaged background or not or whether they had done science at school or not, made the samples smaller. In order to draw sensible conclusions from the quantitative data, t-tests for small samples were used to compare means. While this meant that in the context of this study, we were able to make reasonable judgements based on these comparisons, there was no way in which the findings could be generalised. In order to do this, there needed to have been a much wider general statistical survey, perhaps with a number of schools in the area or across the country.

One way in which this effect could have been addressed would have been through the investigation of a number of cohorts of students. This would have made the sample large enough, but would have introduced a further issue of my own development as a teacher and the learning that would have taken place from one cohort to the next. While this in itself might have been interesting from an action research point of view, it would have muddied the waters somewhat.

**The data collected**

As with many research projects, the focus changes and new ideas and ways of working become known to the researcher after the initial plan has been articulated. It was no different in this study. The initial plan needed changing in order to accommodate evidence that emerged from the data collected and in addition, there were possible fruitful avenues and questions that I asked for which there had been no data collected. While the avenues of investigation that were pursued once the initial data had been collected proved fruitful, they also had their limitations in that often there had been no initial plan to collect some of this data, and so had it been done differently, more conclusive evidence could have been found. The APPRAISAL analysis of the student reflections was one such avenue that turned out to be particularly fruitful. However, it was not the initial intention of the study to seek this particular data. The wiring diagrams too were not initially intended to be data that was to be analysed. This was something that I noticed in the marking of the student tasks as well as their examination; however, since the timeframe was such that this happened only after the event, it was impossible to collect further data. This could have happened with the next cohort. However, this would not have provided me with congruence in the sense of dealing with the same cohort of students. The demographic profile of the classes was also in transition from year to year and this would have been a further factor affecting the comparison of data from one year to the next.

While the study on the wiring diagrams was limited by the fact that it was part of a larger differently focused study on the effects of context on students' attitudes to learning electricity, the evidence from the diagrams is sufficiently compelling to enable me to draw tentative conclusions.

**The nature of the participants**

As mentioned previously, the participants in the study were drawn from different educational and socio-economic backgrounds. This fact muddied the waters somewhat when I was trying to unravel what might be the effect of gender and what was not. There are two important issues that need to be considered. The first is the issue of relative disadvantage, which I have used as being "one size fits all" in itself while in reality, there are various shades of disadvantage. In the same way, not all advantaged school children experience the same education. Private schools, richer or poorer government schools, not to mention those who were home schooled provides a mixture of what is generally termed advantaged schooling that is clearly not a variable that is properly controlled in an empirical sense. Thrown in with this is the issue of those students of Indian origin who went to schools that were disadvantaged in terms of funding, but on the other hand experienced the proud tradition of good education from well qualified teachers in many cases provided for by funding drawn from the Indian community in Durban during the years of apartheid. This combination of educational and socio-economic factors that could influence the attitude and performance of the participants in the study was out of my control.

## Implications of this research for pedagogical design

In this section, I outline the implications the main findings in this study have for teaching. In so doing, I have attempted to integrate factors that are specifically to do with learning with those that are to do with creating an enabling environment in the classroom for female students.

What has been confirmed by the data collected in this study, is that girls view learning electricity as being akin to learning a "boy's skill" at best and "being a boy" at worst. This does not allow for open minded engagement with the conceptual material and it is possible that there lies in this one of the many reasons why there is a poor take up of physics courses by girls. In this study I looked at a number of interconnected issues, ranging from gender issues such as view of the self and learned helplessness when it came to doing tasks that were socially designated male, to the progressive development of elementary electrical ideas, an area that in traditional physics education research has been considered to be located very much with the individual and the way the individual constructs scientific knowledge. While there is no evidence to suggest innate differences in conceptual understanding between sexes (Young, 1990), there is clearly from the data presented in this study a difference between males and females in the initial way students conceptualise electric circuits (prior to the project). How do we view this finding? It seems clear from the fact that in the end there was no significant difference in performance between the males and females that female students managed to "catch up" their original so called deficit in conceptual understanding, at least to become as good as the males in the performance on the final task. Typically in any classroom intervention, changes in improvement can be attributed to a number of factors and in this case, there are a good number to choose from. However, this was not a classical experimental study. There was no control group and no factors were isolated. The evidence gathered, from a number of sources; including the interviews and the reflections suggest that several factors are influential in the success of the intervention. This study provides us with evidence that multiple approaches are appropriate when designing teaching strategies for electro-technology, particularly if a large portion of the class is female. In the sections below, I have outlined several such approaches that could be included in a model for teaching electro-technology at both school and introductory university level. Outlined below are suggestions for changes to the way we teach science and technology in school that could be included in future curricula.

**Using a context as a way to develop interest and identify alternative conceptions**

This study showed that context does indeed have an effect on the way we learn and that the gendered effect of context specifically has an effect of the way female students learn electricity. In choosing a context that is stereotypically female, building a doll's house, it is hoped that female learners will enter the intervention with a positive attitude towards learning electricity. Care should be taken when designing teaching materials so that contexts are complementary to learner's interests and if this requires a stereotypically gendered response from the materials developers, then there is a pragmatic argument presented by the findings in this study that this would be effective.

**Using a conceptual change approach to teaching electricity**

The conceptual change strategy based on Osborne and Wittrock's (1983) generative learning model that was designed to facilitate conceptual learning of electro-technology in this study, showed itself to be effective in not only ameliorating female students alternative conceptions, but also those male students who had similar preconceived ideas. The fundamental concepts of basic current electricity were taught in such a way that learners were made aware of their conceptual ideas and where change was necessary; they were led to develop their own conceptual frameworks. All conceptual models were tested by the students with their own apparatus. Alternative conceptions were identified and given a name. The conceptual change approach to teaching electricity was based on the phases of the Generative learning model (GLM) as outlined in chapter 3. The use of the different phases of diagnosis, focus, challenge and application in the teaching model were also effective in teaching teachers to teach electricity, as they could understand the learning of electricity by tracing their own development.

**Using wiring diagrams to both identify and ameliorate the learning of electrical concepts**

The use of wiring diagrams as a context that is different from the standard physics classroom could provide us with an opportunity to gain some insight into the way students interpret electrical concepts and learn electricity. This could have an influence on the design of instructional programmes as it could be a useful tool for the both the detection and the amelioration of preconceived mental models of circuits and current.

**Developing self-efficacy in the use of tools and construction skills**

The specific targeting of self-efficacy in the intervention was something that was identified by the students as being particularly helpful to them and something that helped female students overcome the sense of being helpless in the face of a "male" task. My own sense is that there could also be a contribution to the sense of power one has in achieving a goal or overcoming a particularly difficult obstacle. For female students using the tools was daunting. This came out strongly in the reflections and was indeed my own observation at the time of doing the project. Success in practical science or technology benefits from particular interventions aimed at improving mastery. This was mentioned by Bandura (1994) and was in my experience true of this project.

The course was designed so that by its completion all students would be able to handle tools and perform tasks that were peculiar to electro-technology in addition to being able to design and connect circuits. This was to ensure that all students, both male and female, could cut, glue and solder by the end of the course. The work done by students was closely monitored to ensure that each student actually did their own work (something that had not happened in the students' past at school).

**Gender specific interventions in the classroom**

Arranging the students to work in either male or female groups, but not groups of mixed gender, meant that female students were forced to rely on themselves for task completion. In mixed groups, male students were observed to control the activities, thereby not allowing female students to participate as much and not acting upon their suggestions. Interviews with female students indicate that while they did not like the idea initially, they appreciated that without it, many would not have accomplished the tasks themselves.

## Implications for further research

No study is really complete and in isolation as a whole. There is always some work that has gone on before, from which the author draws in order to support findings or demarcate a deviation from current trends and there is always some work that will continue after the study is finished. Throughout this study, there have been interesting results I would like to have pursued. However given that the original design of the study had not provided me with sufficient data, I was unable to do so. This is both a frustrating and exhilarating exercise and in this section, I have outlined some of the indications in the data that are currently insufficient to develop further, but do point to further areas of research that could and in my opinion should be developed. Some of the areas emanate directly from the major findings of the study and in these cases it is fairly obvious that as outlined above, there is already a substantial contribution to current knowledge, but that with a well-planned and more focused study, there is a wealth of knowledge that could still be found. This section naturally also leads on from the reflections I have made on the research process as a whole and the inadequacies of this study will clearly lead to areas that will bear more fruit should a more comprehensive study be initiated. It may be that much of what I have found is not generalizable and that it is peculiar to the group of participants I have taught, or the group that generally enrols for this course. This in itself is an indication that further research to ascertain the generalizability if the findings are needed and much of my discussion from here onwards will refer to this. I have listed several of these ideas below and will discuss each one in turn in the sections that follow.

**The pervasive and resilient nature of the unipolar model**

The *lack* of prevalence of the unipolar model in studies that have been conducted in various parts of the world, for example by Tasker and Osborne (1985), Shipstone (1988) and McDermott and Schaffer (1992) all point to low incidences of reported unipolar models of thinking. Stanton (1989) however, has provided evidence of the unipolar thinking present in answers given by engineering students at another South African university and these confirm the evidence put forward in this study. This evidence is provided in chapters 4 and 7, which both show that the unipolar model of thinking about electric circuits is common in the class that went through this study. This was for a particular group of students and in South Africa, where science and technology education is not as strong as in other countries, so it may also be something that is peculiar to the South African situation.

The first source of evidence is from the pre-test in unipolar thinking that was given at the beginning of the course and the second from the wiring and circuit diagrams that were collected from students during the course of the study, where there was evidence of unipolar thinking in the way in which students answered questions in examinations as well as the ways in which they drew diagrams for classroom tasks. There is other anecdotal evidence from my own observations where I have seen students attempt on two different occasions to get a bulb to light up using a unipolar circuit construction. The first was in the beginning of the course when they were asked to light up a bulb given a torch cell and a piece of wire and the second was a few weeks later in the construction of the house, where students were asked to wire the houses they had constructed. On both occasions, several students openly tried to make these unworkable circuits work and on both occasions they needed and asked for help in doing so. Whether or not the unipolar model is as widespread as this study seems to indicate, or whether this is simply an anomaly, needs to be investigated.

**Transitional patterns of thinking and the conceptual change process**

Wiring diagrams in this study provided a context for the development of electrical ideas. The drawing of wiring diagrams can I believe be used to further understand the transitions that students make when they assimilate and accommodate new information. It is clear from evidence presented in chapter 7 that many students are able to operate in two worlds, where they separate their old ideas from their new ideas. Sometimes these two are mixed in a transitional model that somehow accommodates both worlds. This aspect of mental modelling needs further research.

Students showed poorer performance in developing wiring diagrams than circuit diagrams, along with regression to unipolar models of design as well as (in fewer cases) simple series circuits, suggesting that when students are asked to plan a circuit spatially, they retreat to models of thinking that we as teachers believe they have "left behind". This could be related to poor spatial visualisation that has been found in other literature to be common in non-science majors and learners from educationally disadvantaged backgrounds.

Further investigation on the use of wiring diagrams in eliciting preconceived ideas as well as ameliorating these ideas needs to be carried out. The evidence of transitional thinking in some of the diagrams that were drawn by the students is a further indication that wiring diagrams could provide us with a "window" into the conceptual progression and transitional concepts that students develop when they learn electricity, as outlined by Borges and Gilbert (1999). Detailed study of the conceptual change process that happens when students attempt to draw wiring diagrams from circuit diagrams could provide insight into this change process.

To conclude, while the limitations to this study have not allowed me to draw detailed conclusions about the connection between phenomenological primitives and the drawings made by the students, it does seem possible that the use of wiring diagrams could be a useful tool to expose the origins of such thinking. Whether the origin of the unipolar features of the wiring diagrams is as a result of p-prims, context, the development of intermediate models of thinking or a combination of some or all of these, is something that requires a more detailed study. This study simply points to the issues that have arisen as a consequence of the drawing of these diagrams.

**The link between gender and alternative conceptions in electricity**

Engelhardt and Beichner's (2004) finding that female students who took their diagnostic test showed results that had a greater number and more varied set of alternative conceptions is supported by the data gathered in chapter 4 in this study. Specifically, the notion that the unipolar model of thinking is more prevalent amongst female students that it is amongst male students in interesting in that the literature has not elaborated on the nature of this gender difference or tried to elicit the reasons behind it. Furthermore, while there was no evidence collected of gender differences in the drawing of the wiring diagrams in chapter 7, (which is conceptually determined) there could be a differential performance on this task between male and female students, since initially; there was a gender difference in conceptual thinking regarding the unipolar model. This possible difference in conceptual thinking in the design of wiring diagrams is clearly something that should have been explored in this study, but due to insufficient data was not and would therefore be something worth pursuing.

The extent to which there are differences between males and females alternative conceptual frameworks is something worth investigating as well. It may be that the differences between males and females on the pre-test are simply anomalous, or it could be a much more general trend. The significance of this is far reaching. If there were to be significant differences in performance between male and female learners, it would have a significant impact on teaching strategies at all levels of schooling.

**The link between gender and context in the development of electrical ideas**

There is some evidence gathered to suggest that the context of the wiring diagrams affected performance based on gender. Interviews with selected female students who drew wiring diagrams suggests that for some female students context does have some effect on whether or not they feel able to design circuit and wiring diagrams. This is supported by evidence from similar tasks given where the circuit remained the same, but the context was changed. Female students interviewed reported that they felt less able to design a wiring diagram for a car (it was seen as a male domain) than for a house. The pattern of errors for the car wiring diagram was also different from the house wiring diagram, suggesting that students (predominantly female) found this difficult in a different way than they did for the house. Low self-efficacy levels amongst female students in terms of spatial visualisation could also have led to regression to unscientific thinking when it came to designing the wiring diagrams. In this instance, there is a need for further research to be carried out.

When it came to developing wiring diagrams, it is clear that a greater number of students did not complete the car task than the house task. This I have put down to the context being different, since the task was the same and called for the same parallel circuit to be designed into the space of a car in this case and not a doll house. While this effect needs much greater investigation, poor performance on the car task when compared to the house task could easily be due to lower levels of self-efficacy amongst female students Chapter 5. This is borne out by the interviews. Of the eight students that were interviewed, all were female and all but one expressly indicated that the fact that the context was a car made the task difficult or impossible. Common responses in the interviews to the car task were:

> Student 1: "This is impossible – how do we know about cars. This is for boys"
> Student 2: "I found it difficult, because I don't know about cars, I am a girl"

The overlap between context and cognitive factors in conceptual change situations such as the wiring of a dolls house is a fertile avenue for further research. Whether or not the transitional thinking found in developing wiring diagrams from circuit diagrams is evidence of the influence of context and the failure of students to transfer conceptual knowledge from one context to another or of the development of intermediate concepts within a conceptual development process needs further investigation, as does the high prevalence of unipolar thinking amongst students of all ages.

In conclusion, the wiring diagram is a useful diagnostic tool for eliciting "hidden" non-scientific ways of thinking as well as addressing issues of spatial visualization. Evidence of some differential performance dependent on context suggests that there is clearly a need to explore the link between context and gender in the learning of electricity. More research on the contribution of context to the development of self-efficacy, attitude and performance is needed.

**The existence of different femininities and masculinities**

As discussed in Mackay and Parkinson (2009, p. 149), Weedon's (1987) contention that our thoughts and emotions (such as fear, pride, and concern about competence) may be reconstituted in our utterances is confirmed at the grammatical level by the findings outlined in chapter 6. The belief about whether a task is more or less appropriate to our gender does influence us emotionally, and appears to have real consequences for how easy or difficult we will experience the task as being. Notions of gender appropriacy pervade society and are learned firstly in the family and later encountered on a daily basis in public texts, behaviours, and activities, making them difficult to change. The way technology is taught in schools, as a single subject for male and female learners, rather than Domestic Science for girls and Woodwork for boys, while unlikely rapidly to do away with gendered beliefs altogether, is likely to have an impact on beliefs about gender appropriacy of technological tasks. In this study, such a change has resulted in expressions of pride in accomplishment by female students in that are an indication that accomplishment of ''male'' tasks in technology classrooms makes gradual inroads into such attitudes (Mackay & Parkinson, 2009). What has not been discussed is the influence of different femininities on performance in technological tasks. Some evidence from my interaction with students indicates that there could be such an influence and that this could be worthy of further investigation.

One female student who indicated that the context did not matter, described herself as a "tomboy" who loved "boys games". She described her social and sporting life as being mainly to do with action oriented "boys things". Interestingly, the house she chose to design for the house task was a fire station and the wiring she created, while it worked perfectly, lacked the stereotypical neatness and organization of other female students. Interviews with students alluded to this being an issue, with some students explaining that they took on different kinds of femininities depending on what they were doing. Some tasks they said appealed to their "nerdy-girl" nature, while others such as the decoration appealed to their "girly-girl" sides. These self-aware comments were made by a group of female students who were high achievers and who wanted to do well in the project, but who also enjoyed traditionally "girly" activities.

Similarly, the male students were from some of the anecdotal evidence driven by different beliefs in their masculinity. There were comments from rugby playing students that they were disappointed in the fact that they had to construct such a "girly" artefact. Traditionally, male students put in less effort into the decoration of the house, as is evidenced by the grade distribution outlined in figure 4 in chapter 5. However, there were exceptions to this where the male students excelled in the decorating of the house. In addition, there were male students who were unsure of their electrical knowledge and from my observations looked equally unhappy about being expected to perform in this environment. Some male students looked decidedly uncomfortable about not being able to answer female students' questions, or help them, almost as if it were a critique of their masculinity.

The existence of different femininities and masculinities and the related production of different gendered performances could have been interesting to look at in the context of the wide diversity of the class. This is a limitation of the study and would indeed be worthy of further investigation.

**The development of a theoretical framework that includes elements of constructivism, feminist theory and self-efficacy to interpret teaching and learning practice**

In this study, I have used a pragmatic approach to investigate several aspects of learning electrical concepts and in so doing; I have in a sense oversimplified what is more likely to be a much more complex phenomenon. I think that this study is able to identify issues surrounding girls understanding of electrical concepts, but not really explain why a difference in performance on conceptual diagnostic tests has been detected in paper 1. Part of the difficulty in this has been the choice of an appropriate theoretical framework on which to hang these items of data for interpretation, since this study crosses several boundaries. The first boundary crossing that has been relatively well investigated by researchers such as Aronson et al. (2005) is the intersection of feminist theory with the idea of perceived self-efficacy.

The intersection of self-efficacy with learning in general (which includes conceptual learning) is also relatively well understood (Bandura, 1997). What is not well developed is the understanding of the intersection between gender constructions and the specific construction of electrical knowledge. This requires the framing of a unified comprehensive theory that includes elements of all three of these ideas, developing self-efficacy, constructing electrical concepts and constructing gender. The focus on self-efficacy, which can be linked to identity theory and through this Butler's theory of performativity (Butler, 1988) could challenge traditional notions of gender and see gender as being constructed in connection with particular areas of knowledge, such as electro-technology that might in the same person be differently constructed with respect to another body of knowledge. This could lead to different performatives that influence girls perceived self-efficacy levels dependent on how they see themselves in relation to what it is that they are learning.

**The influence of spatial visualisation in the development of wiring diagrams**

The completion of the task in this study requires of the students that they visualise the flat 2-dimensional circuit that they have designed using learned scientific principles as fitting into a 3-dimensional space (either a car or a house). In order to do this, the student needs to be able to spatially represent the circuit, a process that requires more of a technological skill than a scientific one. Gilbert, Boulter and Elmer (2000) have compared modes of representation commonly used in technology with those used in science. While both disciplines use visual representations like diagrams, Design and Technology makes greater use of concrete modes of representation such as physical scale models. The use of such models requires the learner to transition between 2-D and 3-D thinking in Design and technology much more than it does in science.

Being able to understand and create visual representations such as 3-D diagrams is a cognitive skill that is fundamental to performing well in both science and technology. Mitchelmore (1980) points out that while there has been considerable work done comparing spatial reasoning abilities across cultures, gender and class backgrounds; there has never been any concrete evidence to suggest that it is related to innate ability. The differential performance in science and technology between male and female learners has according to Mammes (2004) been attributed to greater familial encouragement given to boys and the tradition of boys playing games that require spatial abilities.

In this task it would then seem that possibly gender is a factor in the performance on the wiring diagram tasks due to differential performance with regard to spatial visualisation. This would be another fruitful avenue for further investigation.

**The influence of school science**

The effect of not doing science at school was also something that was not fully investigated in this study. There are a number of reasons why a student might not have studied science at school and these might have different effects on the data collected. If the reason was poor teaching, this factor could also be related to the relative advantage of the schooling experienced. It is my general feeling that many of these issues are intertwined and that it would not really be possible to use the data from this study to investigate the impact school science has on the performance of students in practical electrical tasks such as wiring a Doll's House. This would be an area for further investigation.

## Final comments

The data collected from the first cohort of students who went through the intervention outlined above points to a differential experience with regard to learning electricity for male and female students. In general, the female students in the cohort stopped learning electricity much earlier than did their male counterparts and in addition to this, they are less likely to perform practical electrical tasks at school, something which would have helped develop their mastery of essential skills required to be successful in learning electricity. They do fewer experiments with circuits at school, but also, they are not encouraged to connect circuits at home.

In addition to the fact that female students do less electrical work at school than do males, is the fact that in this cohort at least, female students are much more likely to exhibit unipolar thinking when it comes to designing and connecting circuits. This may indeed be due to the fact that less electrical work is done at schools, but this study was not able to show that. All that it could show was that male students were much better conceptually than were the female students at the beginning of the intervention.

Coupled with fewer opportunities given at an academic level to the learning of electricity, is the effect of learned helplessness that seems to have been developed at school and carries on through university. This idea that females are essentially helpless in the face of any "male" task has as powerful effect on the development of female students' self-efficacy. They are generally fearful of connecting circuits, even if they have the correct ideas. They are also fearful of using the tools, especially the soldering irons which they consider to be dangerous. This fear which has been developed since school has a considerable effect on female students' ideas of their own abilities. They firstly do not believe that they are intellectually up to the task and secondly that they are able to develop the practical skills necessary to complete the task.

A third part to the profile is the very marked occurrence of gender based beliefs about the roles of men and women in the whole field of electrical knowledge. There is a clear belief mainly amongst female students that electricity is a "boy's thing". This at first is contradicted by students reported beliefs in gender equity and abilities. Male students are much less likely to say that electricity is a "male" domain, but at the same time, female students on separate occasions will insist that technology is no more a male subject than it is a female one. This belief system has, I believe a root in the development of feminine identity that has taken place as these young women develop from girls to women. I found it interesting that in conversations with pre-adolescent girls performing the same dolls house task, there was no strong resistance to doing electrical work, although there were signs even at that stage that they might have preferred something else.

The picture that has emerged is one where electrical work is never stated as being something that is male, as this would indeed contradict the pervading sense of equity that permeates contemporary South African culture and language. (It is almost seen as being politically incorrect to make an admission that electrical work is for boys), but nevertheless, when there is opportunity to do so, during times of stress, informally or when asked directly, female students would say that indeed electricity was for boys. This was not true of the boys; however, on numerous occasions I was told by male students that contextualising the task in a dolls house was inappropriate.

I am sure that electricity is not the only topic in the contemporary curriculum where ones gender determines ones performance, but from a scientific and technological point of view, it is possibly the most relevant. Electricity permeates everything in modern society. This is why it is important for electrical knowledge to be understood by all. The subtle exclusion of women from this body of knowledge that occurs throughout schooling as a result of peer and family pressure as to what is and what is not appropriate, has a profound effect on academic performance as well as the development of essential life skills. The lack of self-efficacy displayed by female students in completing this simple task and the casual acceptance that we need to wait for or encourage a man to help us, has I think been shown in this study to be disempowering and counterproductive. The great irony is that at the same time that students enact these gendered roles in the classroom, they also strongly support gender equity measures and curriculum statements in the schooling system.

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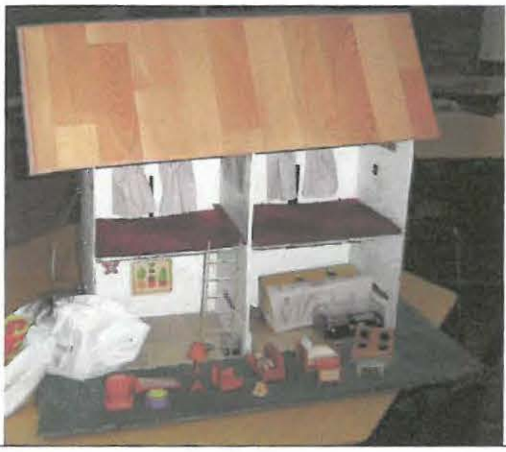
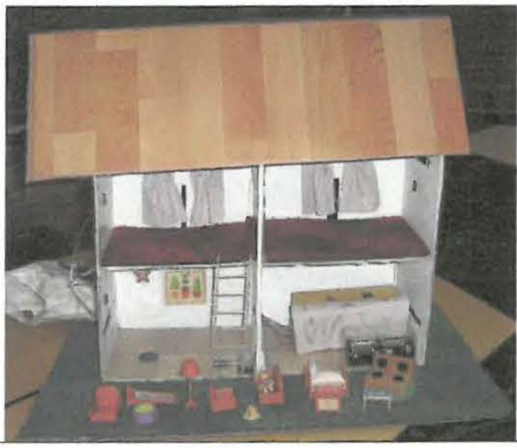
# Appendix A: Doll's House Photographs

1





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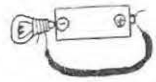
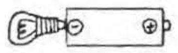
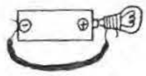
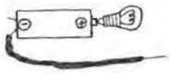
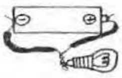
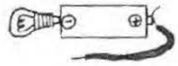
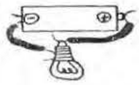
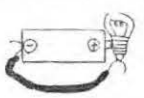
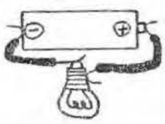
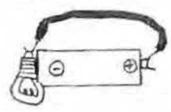
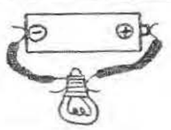
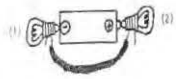
# Appendix B: Diagnostic Electrical Tasks

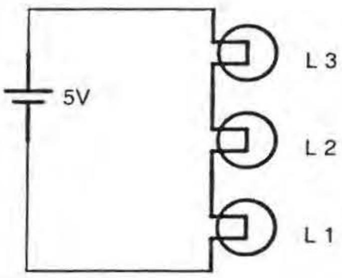
| Sample test items for the diagnostic phase | | | | | |
|---|---|---|---|---|---|
| TEST 1: Does the bulb light up, yes or no? | | | | | |
| Circuit | YES | NO | Circuit | YES | NO |
| A  | | | H  | | |
| B  | | | I  | | |
| C  | | | J  | | |
| D  | | | K  | | |
| E  | | | L  | | |
| F  | | | M  | | |
| G  | | | N1  | | |

# Appendix C: Focus Phase Tasks - Circuit Activities

## Lesson 2 – Ideas of electric current

### Activity 2.1 which bulb is brightest?

The diagram below shows three identical light bulbs connected to a battery. Say whether or not the following statements are true. Give a reason for your answer in each case.

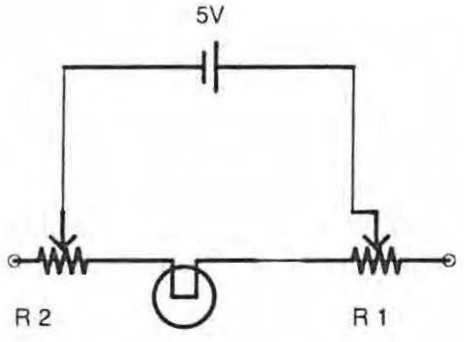



| Statement | TRUE | FALSE |
|---|---|---|
| A. bulb 3 is the brightest of all the bulbs. The dimmest is bulb 1 | | |
| B. bulb 1 is the brightest of all the bulbs. The dimmest is bulb 3 | | |
| c. all bulbs have the same brightness | | |
| d. the current flows from bulb 1 to bulb 3 | | |
| e. the current flows from bulb 3 to bulb 1 | | |
| f. the current is stronger through bulb 2 than it is through bulb 3 | | |
| g. the current is stronger through bulb 3 than it is through bulb 1 | | |
| h. the voltage across bulb 1 is greater than across bulb 3 | | |
| i. the voltage across bulb 3 is greater than across bulb 1 | | |
| j. the voltage across each of the bulbs is the same | | |
| k. the current through each of the bulbs is the same | | |

**Test your theory**

Use the kit provided to connect up the circuit and see for yourself which bulb is brighter. Write an explanation for your observations.

## Activity 2.2 – What makes the bulb go brighter and dimmer?




$R_1$ and $R_2$ are resistors which can either be increased or decreased.

a) If $R_1$ is ***decreased***, will the brightness of the lamp

*increase* *decrease* *stay the same*

Why do you say that?________________________________________

b) If $R_2$ is ***increased***, will the brightness of the lamp

*increase* *decrease* *stay the same*

Why do you say that?________________________________________

c) If $R_1$ is ***increased***, will the brightness of the lamp

*increase* *decrease* *stay the same*

Why do you say that?________________________________________

b) If $R_2$ is ***decreased***, will the brightness of the lamp

*increase* *decrease* *stay the same*

Why do you say that?________________________________________

Now check your predictions with the kit provided
Make up your two variable resistors using the resistance wire provided in the kit
Write down an explanation for your observations.

# Appendix D: Mid-Course Questionnaire

## Mid-Course Assessment (10 minutes)

Name____________________Student No________________________

### 1. How do you feel about the following?

| | Completely out of my depth | I still feel a little unsure | I feel on top of things | Very confident |
|---|---|---|---|---|
| Making a bulb light up | | | | |
| Connecting a circuit to switch on a bulb | | | | |
| Connecting a circuit that makes an upstairs/ downstairs light | | | | |
| Explaining how electric circuits work | | | | |
| Connecting a circuit that changes the direction of a motor with a switch | | | | |
| Planning a circuit for your doll's house | | | | |
| Drawing a wiring plan for your doll's house | | | | |
| Soldering | | | | |
| Connecting up the wires and components for the doll's house | | | | |
| Making the doll's house | | | | |
| Using the idea of wiring a doll's house in my own teaching | | | | |

### 2. Please write a paragraph on the following:

Has wiring a doll's house changed your attitude towards electricity in any way? If so please explain.

# Appendix E: Sample Interview Transcripts

**Interviews with Students 31 / 10 / 06** (Actual student names are not used.):

**Interview No. 1** : Andrew and Brian

Both students were doing SNR / FET and both felt that this project started too girly. They were initially put off. The problem it seemed was in specifying a dolls house. If it had simply been a house, then it would have been ok. It reminded them too much of Barbie dolls and this seemed not to fit with their image. They suggested that in future. Students be given a choice.

It was mainly the decorating that they hated.
Suggested the following:
Blue bulls theme, rugby stadium, sports ground, bridges, park, town, car, train.

They felt that females were equal but different and that it was not a genetic thing, but rather a matter of training (in the family). It's what parents do. They gave an example of a girl in the class whose father was a panelbeater and said that she was able to do the things that boys were expected to do.

I mentioned to them that a previous group was surprised by the fact that the boys were equally at sea with the task as the girls were. Thus did not surprise them they seemed to know that boys were not going to be good at the wiring task. Andrew felt however that it was not the wiring task that was the problem, but rather the decorating. I pointed out that there was one boy who had done well in decorating the house. They both agreed that he must have had help, or that he was perhaps "more in touch with his feminine side than most men" (One of the interviewees actually said that they would worry about him, if that were to be true, a clear reference that he was possibly gay)

In the end, both agreed that boys and girls have the same basic skills and knowledge. They said that making it a girly task gave them a mindblock.

**Interview No. 2:** Michaela, Bronwyn, Emily

This was an interview with three female students (white), all of whom finished the project early.

All of these students were studying to be teachers in the foundation phase and all said that the electrical work was very hard for them. They came into the project thinking that they knew nothing and that the boys would have been naturally good at theis task. They were all surprised at how little the boys knew and in fact that the boys were in the same boat as them.

They said things that "guys are naturally good at this stuff" "guys think in a more mechanical way"

" Guys know how to use tools"

Being a dolls house made it more practical. This was better for girls (especially the furnishing). It made it so that they could understand it better. If it had been contextualized in a car, it would have been the same effect. They felt that they could do this with learners in schools, but in the foundation phase, they could use only one room. In general, they agreed with the lecturer that the dolls house project could be expanded to include materials, structures, processing etc.

**Interview no 3:** Kerry and Jo.

This interview was with two girls. They were friends and they were both studying drama together. They had definite ideas about the role and capabilities of boys.

K – the project was time consuming in the sense that it took a lot of time to think through the problem of how to start doing the wiring. She did not understand what she was going to do. There was also the issue of workload.

J – knew how she was going to do the wiring . She knew how she was going to physically join it up.

The circuits helped.
K had help with the alarm. Her dad thought it was funny and was surprised that she could do the project.

J – did the work herself. Became very frustrated at times, but did not breakdown and cry ever, simply "threw a fit"
K - got frustrated at times as well. The project "took forever"

They were both proud of their efforts

J went on to say that her project took forever. She is obsessive compulsive and needed it to be perfect. The building time was a problem. The wiring was ok, since she has grown up around trade people (all her friends).

Her friends were surprised at the task. Her boyfriends grandfather helped her. She felt that if she had more time she would have produced something better. Both are studying drama. They felt that the skills learned here could have a real practical use in drama, with stage lighting etc.

They could use it with stage set design in under-resourced schools.

The recounted that in drama, the girls did all the technical stuff and that the boys were useless.
" The guys left the girls to make all the extension cords"

They also said that Mrs Parkinson treats the girls differently and that they were supposed to all be equal. They felt that the guys also enjoyed the DH project; however, most girls DH are more beautifully decorated. Reiterated: female lecturers treat the girls as inferior. I mentioned to them that in the other interview, the girls were surprised that the guys knew as little as they did. This did not seem to surprise them at all
"guys were just as weak as girls"
"guy friends were pretty useless"

They in fact helped two other guys build their houses and recounted that these guys did not know how to do anything.

They felt that the girls houses would score higher. They also said that girls were more likely to ask for help, as they were not expected to know. It was an ego thing.

On play things at home:

J "played with scalelectrix and remote controls. Fed her Barbie to her grans dog" However, "keeps soft toy collection"

K- was into girly stuff, but played with lego

J – loved TV games, PS, racing games, tactical computer games like prince of Persia

They felt that they did learn electricity better as a result of the DH.

K – did appeal to her at first
J – did not appeal to her

Were girls attitudes more positive in general?

"Cars would have been just as good"

On How they would adapt this for guys:

1. guys had no inclination to start the DH
2. wire up garage door
3. car "guys are sloppy"

# Appendix F: Biographical Questionnaire

## Questionnaire

1. Name ______________________________

2. Student number ________________________

3. Gender M F

4. Age ______________

5. School Attended ______________________________________

6. What grade(s) did you do Technology in at school? _______________________

7. Did you do electricity in your technology lessons at school Yes No

8. What grade(s) did you do science in at school ___________________________

9. Did you do any electricity in your science classes? Yes No

10. Describe what electricity you learnt at school, whether in technology or science:

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

Did you connect circuits at any time in your school career? Yes No

11. If yes, describe what circuits you connected at school:

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

12. Did you ever connect any circuits at home? Yes No

13. If yes, describe what circuits you connected at home.

____________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________

| | Strongly agree | agree | Disagree | Strongly disagree |
|---|---|---|---|---|
| 14. Electricity is very useful | | | | |
| 15. Electricity is hard to understand | | | | |
| 16. You need to be scared of electricity | | | | |
| 17. I feel confident that I can learn to connect electrical circuits | | | | |
| 18. Technology is a boy's subject | | | | |
| 19. My Technology teacher at school connected electrical circuits in class | | | | |
| 20. My Science teacher at school connected electrical circuits in class | | | | |
| 21. I have a father or mother with a technical background who understands how electricity works | | | | |
| 22. Boys are better suited to technical jobs than girls | | | | |
| 23. My Science teacher encouraged boys and girls equally | | | | |
| 24. My technology teacher encouraged boys and girls equally | | | | |
| 25. My parents encouraged me to do technical things | | | | |
| 26. I feel confident that I can connect up electrical circuits | | | | |
| 27. Boys are better at connecting circuits than girls | | | | |

28. As a child did you have any toys that ran on electricity? If so describe these

____________________________________________________

____________________________________________________

# Appendix G: Rubric for assessing the Doll's House Task

## Dolls House Assessment

Name________________________ Student
No.__________________

| Weight Factor | Criterion | Not Achieved (0) | Partially Achieved (1) | Achieved (2) | Outstanding (3) | Comment and score |
|---|---|---|---|---|---|---|
| 3 | Circuit Diagram | There is no circuit diagram | The circuit diagram in not complete, or what was asked for | Circuit Diagram is clear and meets specifications | Detailed Diagram has been provided which provides additional information about the circuit | |
| 4 | Wiring Diagram | There is no wiring diagram | The wiring diagram does not reflect the circuit diagram | Wiring diagram reflects the circuit and the house plan | The wiring diagram is exceptionally well organized | |
| 4 | House construction | There is no house | The house is not complete | Basic three roomed house has been constructed | The construction is beyond the initial brief of the project | |
| 3 | House Decoration | The house has not been decorated at all | There is some attempt to decorate the house | House has been painted | The decoration was beyond the initial brief | |
| 12 | House wiring (Basic circuit) | Little or4 no wiring has been done | The circuits have been connected, but they are simply hanging or are loose | House has been wired in accordance with the wiring diagram. Wiring is neat. The circuit works | The basic circuit is well done and has been properly wired to include other features | |
| 3 | Alarm | No alarm has been added | There is an alarm, but it does not work | An alarm that works has been installed | The alarm construction is beyond what was asked for | |
| 3 | Additional Features | There are no additional features added | Some attempt has been made to add additional features to the circuit | Additional features have been added to the house | Features that have been added are exceptionally innovative | |
| 2 | Reflection | No reflection written | | A reflection has been written | | |

**TOTAL** [ ]

# Appendix H: Wiring Diagram Task

## Technology 210
### PROJECT
**Due Date: 12.00 Noon, 26th May**

### Wiring a Dolls house.

In this project you must make a doll's house out of cardboard and then wire it so that it has lights and an alarm. Any extra electrical features that work will earn extra points.

Specifically you must:

- Your house must have at least three rooms
- Each room must have a light operated with a switch
- There must be a mains switch to control all the electricity in the house
- Lights must be attached from the ceilings and switches must be in the walls
- There must be some kind of alarm that alerts the inhabitants
- You must provide a detailed wiring plan of your house (find out how this is usually presented)

# Appendix I: Sample Examination Question

**Question 5: [8 Marks]**

You have been asked to electrify a three roomed model house. Draw the circuit diagram you would use to wire the house. Each room must have both a light and a fan, each with its own switch. The lights must all be on one circuit, which must be controlled by a sub switch. The fans need to be on a separate circuit, also controlled by their own sub switch. Both circuits need to be controlled by a main switch that will need to be connected to a battery pack.

# Appendix J: Ethical Clearance Documentation

## *CONSENT FORM FOR PARTICIPANTS*

### *Doll's House Project*

I have read the Information Sheet concerning this project and understand what it is about.

All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project at any time, including withdrawal of information provided, without any disadvantages;
3. I consent to my interview/focus group being audio/videotaped;
4. The data [video-tapes / audio-tapes will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed;
5. There will be no remuneration for participation in this project
6. The results of the project may be published and available in the library but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

........................................................ (Signature of participant)

............................................ (Date)

This project has been reviewed and approved by the Ethics Committee of the Faculty of Education of the University of Kwa-Zulu Natal.
Any concerns can be directed to the Project Researcher or their
Nominee (031) 260 1404

# UKZN Ethical clearance certificate

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

**Research Office (Govan Mbeki Centre)**
**Private Bag x54001**
**DURBAN, 4000**
**Tel No: +27 31 260 3587**
**Fax No: +27 31 260 4609**
**Ximbap@ukzn.ac.za**

28 March 2012

**Mr James Ross Mackay (951058946)**
**School of Education**

Dear Mr Mackay

**PROTOCOL REFERENCE NUMBER: HSS/0083/012D**
**PROJECT TITLE: "We shouldn't have to do this we're girls". An examination of Gender, Self-Efficacy and conceptual understanding in electro-technology for a class of teacher trainees in Design and Technology at a South African University**

**EXPEDITED APPROVAL**

I wish to inform you that your application has been granted Full Approval through an expedited review process:

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.**

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

**Professor Steven Collings (Chair)**
**Humanities & Social Sciences Research Ethics Committee**

cc Supervisor Professor Paul Hobden
cc Mrs S Naicker/Mr N Memela

# Appendix K: T-Scores

**(Downloaded on 28/11/2011 from http://www.statsoft.com/textbook/distribution-tables/ )**

## *Table of Critical Values for T*

| | Two Tailed Significance | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0.2** | **0.1** | **0.05** | **0.01** | **0.005** | **0.001** | **0.0005** | **0.0001** |
| 2 | 1.89 | 2.92 | 4.30 | 9.92 | 14.09 | 31.60 | 44.70 | 100.14 |
| 3 | 1.64 | 2.35 | 3.18 | 5.84 | 7.45 | 12.92 | 16.33 | 28.01 |
| 4 | 1.53 | 2.13 | 2.78 | 4.60 | 5.60 | 8.61 | 10.31 | 15.53 |
| 5 | 1.48 | 2.02 | 2.57 | 4.03 | 4.77 | 6.87 | 7.98 | 11.18 |
| 6 | 1.44 | 1.94 | 2.45 | 3.71 | 4.32 | 5.96 | 6.79 | 9.08 |
| 7 | 1.41 | 1.89 | 2.36 | 3.50 | 4.03 | 5.41 | 6.08 | 7.89 |
| 8 | 1.40 | 1.86 | 2.31 | 3.36 | 3.83 | 5.04 | 5.62 | 7.12 |
| 9 | 1.38 | 1.83 | 2.26 | 3.25 | 3.69 | 4.78 | 5.29 | 6.59 |
| 10 | 1.37 | 1.81 | 2.23 | 3.17 | 3.58 | 4.59 | 5.05 | 6.21 |
| 11 | 1.36 | 1.80 | 2.20 | 3.11 | 3.50 | 4.44 | 4.86 | 5.92 |
| 12 | 1.36 | 1.78 | 2.18 | 3.05 | 3.43 | 4.32 | 4.72 | 5.70 |
| 13 | 1.35 | 1.77 | 2.16 | 3.01 | 3.37 | 4.22 | 4.60 | 5.51 |
| 14 | 1.35 | 1.76 | 2.14 | 2.98 | 3.33 | 4.14 | 4.50 | 5.36 |
| 15 | 1.34 | 1.75 | 2.13 | 2.95 | 3.29 | 4.07 | 4.42 | 5.24 |
| 16 | 1.34 | 1.75 | 2.12 | 2.92 | 3.25 | 4.01 | 4.35 | 5.13 |
| 17 | 1.33 | 1.74 | 2.11 | 2.90 | 3.22 | 3.97 | 4.29 | 5.04 |
| 18 | 1.33 | 1.73 | 2.10 | 2.88 | 3.20 | 3.92 | 4.23 | 4.97 |
| 19 | 1.33 | 1.73 | 2.09 | 2.86 | 3.17 | 3.88 | 4.19 | 4.90 |
| 20 | 1.33 | 1.72 | 2.09 | 2.85 | 3.15 | 3.85 | 4.15 | 4.84 |
| 21 | 1.32 | 1.72 | 2.08 | 2.83 | 3.14 | 3.82 | 4.11 | 4.78 |
| 22 | 1.32 | 1.72 | 2.07 | 2.82 | 3.12 | 3.79 | 4.08 | 4.74 |
| 23 | 1.32 | 1.71 | 2.07 | 2.81 | 3.10 | 3.77 | 4.05 | 4.69 |
| 24 | 1.32 | 1.71 | 2.06 | 2.80 | 3.09 | 3.75 | 4.02 | 4.65 |
| 25 | 1.32 | 1.71 | 2.06 | 2.79 | 3.08 | 3.73 | 4.00 | 4.62 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 26 | 1.31 | 1.71 | 2.06 | 2.78 | 3.07 | 3.71 | 3.97 | 4.59 |
| 27 | 1.31 | 1.70 | 2.05 | 2.77 | 3.06 | 3.69 | 3.95 | 4.56 |
| 28 | 1.31 | 1.70 | 2.05 | 2.76 | 3.05 | 3.67 | 3.93 | 4.53 |
| 29 | 1.31 | 1.70 | 2.05 | 2.76 | 3.04 | 3.66 | 3.92 | 4.51 |
| 30 | 1.31 | 1.70 | 2.04 | 2.75 | 3.03 | 3.65 | 3.90 | 4.48 |
| 35 | 1.31 | 1.69 | 2.03 | 2.72 | 3.00 | 3.59 | 3.84 | 4.39 |
| 40 | 1.30 | 1.68 | 2.02 | 2.70 | 2.97 | 3.55 | 3.79 | 4.32 |
| 45 | 1.30 | 1.68 | 2.01 | 2.69 | 2.95 | 3.52 | 3.75 | 4.27 |
| 50 | 1.30 | 1.68 | 2.01 | 2.68 | 2.94 | 3.50 | 3.72 | 4.23 |
| 55 | 1.30 | 1.67 | 2.00 | 2.67 | 2.92 | 3.48 | 3.70 | 4.20 |
| 60 | 1.30 | 1.67 | 2.00 | 2.66 | 2.91 | 3.46 | 3.68 | 4.17 |
| 65 | 1.29 | 1.67 | 2.00 | 2.65 | 2.91 | 3.45 | 3.66 | 4.15 |
| 70 | 1.29 | 1.67 | 1.99 | 2.65 | 2.90 | 3.43 | 3.65 | 4.13 |
| 75 | 1.29 | 1.67 | 1.99 | 2.64 | 2.89 | 3.42 | 3.64 | 4.11 |
| 80 | 1.29 | 1.66 | 1.99 | 2.64 | 2.89 | 3.42 | 3.63 | 4.10 |
| 85 | 1.29 | 1.66 | 1.99 | 2.63 | 2.88 | 3.41 | 3.62 | 4.08 |
| 90 | 1.29 | 1.66 | 1.99 | 2.63 | 2.88 | 3.40 | 3.61 | 4.07 |
| 95 | 1.29 | 1.66 | 1.99 | 2.63 | 2.87 | 3.40 | 3.60 | 4.06 |
| 100 | 1.29 | 1.66 | 1.98 | 2.63 | 2.87 | 3.39 | 3.60 | 4.05 |
| 200 | 1.29 | 1.65 | 1.97 | 2.60 | 2.84 | 3.34 | 3.54 | 3.97 |
| 500 | 1.28 | 1.65 | 1.96 | 2.59 | 2.82 | 3.31 | 3.50 | 3.92 |
| 1000 | 1.28 | 1.65 | 1.96 | 2.58 | 2.81 | 3.30 | 3.49 | 3.91 |
| Infinity | 1.28 | 1.64 | 1.96 | 2.58 | 2.81 | 3.29 | 3.48 | 3.89 |