Imagination in Learning Electrical Physics

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at

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by

Kenneth Meyer

Master of Educational Studies, Bachelor of Vocational Education and Training

Charles Sturt University

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Certificate of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Charles Sturt University or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to the research by colleagues with whom I have worked at Charles Sturt University or elsewhere during my candidature is fully acknowledged.

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To ‘The son [who] is the image of the invisible God, the firstborn over all creation. For in him all things were created. Things in heaven and on earth, visible and invisible, whether thrones or powers or rulers or authorities; all things have been created through him and for him. He is before all things, and in him all things hold together. In him lie all the treasures of wisdom and knowledge. (ESV Bible)’
Abstract

The reason and context for this study are the difficulties I have experienced in teaching electrical physics over the past twenty years. It has been my experience that most students have difficulty with the concepts of electricity. This observation is borne out in the literature as study after study indicates that the anecdotal concepts gained by incidental interaction with electricity are counter-intuitive. The result is that most students of electricity start with misconceptions that have become embedded over many years and are difficult to change. The major reason electrical concepts are counter-intuitive is the non-sensory or abstract nature of the phenomena. Electricity is always at least one step removed from direct sensory experience.

Humans can only observe the effects of electricity, not electricity itself. In an electric light, for example, we see the light, but not the movement of electrons heating a tungsten filament causing photons to be emitted as light. We see the effect of the photons and hence our sense of sight is two steps removed from the phenomenon of electricity. The domain of electricity can only be understood as an abstraction and learning abstract concepts is a difficult place for most learners to start.

This study explores the use of imagination in electrical physics as a way of assisting students with the complexities of abstraction caused by the non-sensory nature of the phenomena. It is my contention that the abstract nature of electrical physics requires strong mental modelling skills to work with electrical concepts. Mental modelling skills, in turn, may be enhanced by actively and purposefully employing imaginative skills. Thus improving imaginative skills will improve mental modelling ability, leading to improvement in aptitude for abstraction. The result is an electrical student better equipped to conceptualise in electrical physics and to overcome prevalent misconceptions.
In this study, a cohort of eighteen full-time Diploma of Electronics and Communication students was invited to be participants and co-researchers in actively improving their imaginative skills during the first year of their study with TAFE. They were encouraged to video record their stories of learning using imagination through semi-structured interviews every two or three weeks. In parallel, and underpinning the narratives, were three action research cycles. These interventions encouraged metacognitive engagement with the research question. The resulting eighteen narratives were thematically examined. The resulting data were analysed using a newly developed matrix. The matrix filtered the narrative data against six principles and six questions. These yielded thirty-six questions to address the research question at many levels and from many facets.

The outcome showed that all students reported a significant positive shift toward using imaginative skills for learning. Most students reported that the imaginative skills had improved their learning, because imagination had given them access to learning methods they had not recognised previously. For some, imagination had always been used, but they had not been conscious of it. Further to this, some participants reported a paradigm shift: for them imagination became a language that gave them access to the un-observable. They referred to it as a sixth sense.

The participant stories confirmed that imaginative skills did improve learning in electrical physics by:

- Recognising an existing skill and amplifying it;
- Opening new ways of learning that were not previously obvious via imagination; and
- Recognising the abstract nature of electricity and using imagination as an appropriate tool or language to extend one’s ability into the non-sensory realm.

The results and implications of this study are directly applicable to teaching and learning electricity and may, potentially, be extended into any highly abstract domain. During the study, ten imagination categories were
developed along with associated imaginative skills activities to encourage imagination. This imagination produced a language that assisted with complex abstraction. Activities to develop these imaginative skills have focused on particular electrical concept areas. The imagination activities encourage the creation and re-creation of mental models, thereby helping students with appropriate conceptions and to overcome or re-work misconceptions. These focused activities can now be used without further modification in the teaching and learning of electrical physics.

Further implications are that the teaching of electrical physics needs to move away from the predominant and largely empiricist worldview to a more holistic one. This can be achieved by training electrical teachers to understand that there are many ways of knowing something, imagination being one. A wider implication is that the principles behind the imagination activities approach will be applicable to many abstract domains – possibly all.

This study is a paradigm pioneer, standing on the edge of the scientific rationalism represented in electrical physics and stepping out into the substantially ignored world of imagination.
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Conventions

In preparing this thesis, I have endeavoured to assist the reader by using consistent conventions and nomenclature.

Chapters

There are six chapters. The main sections in each chapter are divided and numbered, one further subdivision of these main sections is also numbered. Any further subdivisions are headed in bold 12-point font.

Figures and tables

Figures and tables are identified using the chapter and section numbering system, that is, figure 5.1 denotes the first figure contained in chapter 5. If readings in electronic format, cross references have been inserted, which will take the reader from the page to the particular table, figure or text.

Acronyms

I have used acronyms only where these have been previously identified in the preceding text. For reader convenience, I include the following list.

AC   Alternating Current
ASA  Airservices Australia
DC   Direct Current
DMM  Digital Multi-Meter (electrical instrument that measures potential, resistance and current)
MC   Memory Card (This is the location of the appendices)
RPL  Recognition of Prior Learning
TAFE Technical and Further Education
VET  Vocational Education and Training
Referencing participant video and written evidence

When quoting a participant a pseudonym is used as a first name and is followed by the video clip number indicated by #. When quoting from the participant’s written work (of which there is only one per student), there is no number only the pseudonym is given.

An example of the participant referencing system is as follows.

To this point, the most interesting activity I had to represent Ohms’ law in some way other than mathematically. The way I did it was with a bat and ball kind of analogy. To explain: so the balls are the electrons (6 off), this is your starting voltage (bat), and they get smashed through (decreasing size cone), they hit the sides and stuff and stop... and there’s two left from the original five, six...

(Greg #5)

In this sample, student participant Greg (pseudonym) is quoted from video clip number five.

Gender

All the participants of the study are male with the exception of one female. As one in eighteen is statistically insignificant in the context of this study, no attempt has been made to separate or consider gender in the analysis. As a result all the pseudonyms assigned to each participant are male oriented to protect the anonymity of all the participants.

Appendices

The appendices of this thesis are contained and organised electronically on a MC (memory card) attached to the back cover of the thesis document. Appendix A contains an electronic form of the thesis in Microsoft Word format and the remaining appendices are organised alphabetically as they are chronologically referred to.
Chapter 1

Introduction and Overview

‘At the entrance to Strawberry Field, the garden in New York’s Central Park dedicated to the memory of John Lennon, there is circular mosaic framing a single word *imagine*. This word is one of the most powerful in the language. It refers to a capacity that is sometimes revered, sometimes reviled, but always present (Brookfield, 1987, p. 111).’

1.1 Introduction

The adventure that has been the imagination project has taken me to unexpected places, unexpected thinking and back again. With some naivety, I waded into the pool of further academic study to soon find myself out of my depth and unable to swim back. Added to this was the sharp awareness that the more knowledgeable I became, the more apparent was my ignorance and the necessity for humility. My adventure has focused on the nature of imagination and how it may be used in abstract realms of learning by electronics students. The process has involved reading, thinking and searching the educational and other literature, discussions with friends and colleagues, many levels of engagement with my students and study participants, interacting with other researchers in conferences and seminars as they present their findings, the ongoing development of my own thinking, perceptions and understanding through reflection. I know that there is much that I have forgotten or deliberately rejected during this adventure of reading, listening and discussing; but all has been beneficial. It has been through relationships with others, indirectly or purposefully, that we come to be shaped by our social world. This is the unfathomable richness of what it is to be created human.
1.2 Research Focus

The prime purpose of my research has been to better understand how people can be encouraged and supported in using imagination to learn completely abstract concepts representing physical realities since that is what learning electrical physics demands. The objective of the research was to explore how imagination could be used to improve mental modelling skills which, in turn, would improve abstraction skills.

This led me to develop a series of imaginative skills categories which focused on characteristics or facets of imagination, these activities were designed to improve imagination skill. The focus of the research was to determine imaginative skills and improve these by direct and purposeful activity.

The eighteen research participants were electronics and communications students in a full-time diploma program fully supported by Airservices Australia. They can be divided into three groups:

- Year Twelve school leavers;
- University graduates and undergraduates and
- Career-changing mature age students.

The aim was to enable students to develop new learning skills from an imagination paradigm and, give them a voice to express how this may have affected their learning. Although the metacognitive approach to engagement is not new, the deliberate development of imagination to improve abstraction ability, within teaching and learning electrical physics, is breaking of new ground. This required a tailored approach to the analytical method paradigm and to the research design in order to generate the appropriate types of data.
1.3 Research Rationale
The research was undertaken as a result of anecdotal observations, over the past fifteen years, that students who perform well in grasping electrical concepts were often those who displayed other strong creative skills (Eisner, 2002, p. 53; Pacey, 1999, p. 96). Many of my high-achieving electronics students played musical instruments and played in local bands, for example. I became interested in creativity, as I contemplated possible reasons and relationships to learning. My interest led from creativity to the underpinning role of imagination and its connection to the learning of abstract concepts.

My ideas about the role of imagination in electrical physics gestated unnoticed for twenty-five years throughout my own apprenticeship as an electrician and engineer until I started teacher training. During my undergraduate work in VET and in the Master of Educational Studies program, the ideas of creativity and imagination began to germinate, not just as a way to make learning attractive, interesting and motivational, but as an intrinsic part of learning. Five years ago, a thesis emerged in crystallised form that the non-sensory, abstract nature of electrical physics hinders learning and that imaginative skill could effectively redress this difficulty.

1.4 Research Objectives
The focus and rationale, outlined above require a research question based on the perceptions of students of electrical physics on the helpfulness of enhancing their imaginative skills. The research aimed to improve students’ abstract electrical mental modelling skills through improving imaginative skills metacognitively. Consequently the following research question was formulated:

*Will being metacognitive about imagination, individually and collectively, assist TAFE electrical engineering students in their learning and application of electrical physics?*
This question has directed the investigation of the participants’ learning experiences over fifteen months, three work placements and several related activities. Full-time Diploma of Electronics and Communication students were chosen as participants because:

1. The full-time study mode would afford opportunities for deep interaction and reflection by the participants.
2. The logistical availability of large amounts of time each week (4 hours) would produce strong engagement with the research question by the participants.
3. The delivery mode of the diploma program offered the prospect of good retention of participants throughout the study.
4. Daily repetitive study gives the opportunity to foster ongoing narratives that would align with the research design approach of the parallel blending of participatory action and narrative research.
5. A class learning together would produce an ethnic and social collective that would multi-dimensionally link into a social constructivist analysis paradigm.

There has been little published research in this area; one exception being Clement whose work is discussed later in this account. The present thesis addresses a broader perspective than Clement, investigating the underpinning reasons that affect abstract learning as applied to electrical physics.

Whether in Australia or elsewhere, very little research has been carried out focusing on learning electrical physics from the perspective of the abstract via mental models and imagination. This study attempts to redress this deficiency by exploring how learning in the abstract, and in particular learning electrical physics, can be significantly assisted with a strong understanding of the use of mental images in the andragogy of adult learning.
1.5 Significance of the Research
This study adds the practitioner’s and learner’s voice to both learning theory and practice. Current learning theories are generalisations that have been derived from the research literature. They are reapplied throughout this study by re-contextualising the learning approach to include imagination. This re-contextualisation of learning is a necessity in the domain of electricity because of the non-sensory nature of the phenomena, which results in immediate and high levels of abstraction.

This research collects and investigates the experiences and opinions of electrical physics students. The study explores learning as a theory grounded in the practice of the participants.

The use and acknowledgement of imagination is not generally recognised in learning theory but is sometimes implied. There is an ‘imagination hole’ of sorts and is articulated in the edited book titled *Transformative Learning in Practice* by Mezirow and Taylor (2009). In a chapter in this book, Mezirow (2009, p. 27) explains;

Colleagues have raised several important questions pertaining to transformation theory as I have interpreted it. One view is that I have neglected the role of imagination, intuition and emotion. This criticism is partly justified. ... “Imagining how things could be otherwise” (Green, 1998) is central in the initiation of the transformative process. Because transformation is often a difficult, highly emotional passage, a great deal of additional insight into the role of imagination is needed and overdue.

This research study in response to Mezirow (2009, p. 27) has made a significant attempt in the areas of imagination, intuition and emotion with regard to learning in abstract domains.

The processes used in this study were designed to help participants actively and consciously engage in their learning using imaginative skills as a way of interrogating the theory of imagination. Various artefacts were used to mediate learning ranging from theoretical learning cycles, different
worldviews, personality surveys, and purpose-designed imagination activities. This has allowed an accumulation of knowledge, insight and practical accounts of how imagination assists with learning and, in particular the learning of electrical physics.

This thesis might be interpreted as abstract conception research. As such, the focus is in the nature of learning as it applies to constructing mental models relating to abstract concepts, not any particular model, and how imagination may support this process. Osborne and Gilbert (1979, p. 214) use ‘interview of instance’ to explain the anecdotal mental models that lead to the construction of misconceptions. The thesis examined in this study is that imagination, when actively engaged, will enable students to reconstruct misconceptions appropriate for the individual that will account more appropriately for the performance of the phenomena.

However, the importance of this thesis lies not just in adjusting misconceptions, but in using imagination to improve creativity and to explore new ways of learning in abstract domains. This research contains significant insights and findings relevant to the current learning contexts of electrical physics in the classroom and the workplace.

1.6 Outcomes of the Research
The primary outcome is insight into the improvement of learning through the development of imaginative skills of the learners. Such insights are derived from the analysis of the documentation of the eighteen participants’ learning perceptions as they metacognitively engaged the learning of electrical physics. The narratives focus on a fifteen-month period that varies in context from formal institutional learning through to more informal workplace learning. The participants also provided evaluative material on their experience of participating as co-researchers.

This thesis provides a new understanding of how learning may be assisted in highly abstract domains. It also provides a new approach to the
collection and analysis of narrative data through the customised and contextualised methodology and design used.

Other outcomes have been the development of an imaginative skills category framework and a range of purpose built imaginative skills activities or exercises. The imagination categories framework assists students to understand the depth and breadth of the role that imagination plays in everyday adult learning. It also provides alternative pathways into learning in an abstract domain, giving students learning options that may better fit their individual preferred learning approaches in any particular context.

Each imagination activity spans several imagination categories but is designed to focus primarily on one category. The imagination activities have been developed with rationales, explanations, resources and applications.

A personal outcome from my research journey, documented in this thesis, has been the improvement and insight that I now apply in my teaching practice. The transformation experienced was grounded in the lived-in experience of the participants and their learning from imaginative approaches.
1.7 Structure of the Document

1.7.1 Chapter 1: Introduction
Chapter 1 gives a bird’s-eye view of the thesis document. It establishes the colour, context and shape of the research by describing the structure as if standing on the central hill of imagination, echoing into the past through the literature and experience, then reflecting on the present (the actual research at hand) and, finally, looking into the future through discussion.

1.7.2 Chapter 2: Literature Review
The literature review was diverse and wide ranging, as the subject of imagination has no single place in the literature. The review begins with an abridged survey of research in the teaching and learning of electrical physics over the past thirty years. The literature is then explored from the major perspectives of learning in the electrical domain; definitions of imagination; research methods/design and philosophy.

Learning in the electrical physics domain is examined in detail, ranging from explanations of electrical phenomena to traditional approaches to learning, not just learning about electricity. The centre of the review is an explanation of imagination and its many facets. Each aspect of imagination is defined, examples are given, and application is made to the complexity of abstraction. The review then shifts perspective to consider appropriate research methods and the designs that were investigated and finally used to engage the research question. The ethnographic nature of the research is explained, highlighting, as an underpinning, the investigation of a group of people learning collectively and individually.

Finally, the literature is engaged from a philosophical perspective as a response to the social and cultural perspectives on imagination encountered through the research. This investigation has had important ramifications for the research outcomes and how they may be applied in the future.
1.7.3 Chapter 3: Method and Design
This chapter is divided into the major categories of method and design. Even though these sections substantially overlap, the division enables separation of the data collection and the analytical framework.

Mixed methods are used in this research. These methods have been selected on the basis of their ability to find a solution to the research question. The methods used include a blended process of ethnographic strategies, action research and narrative research.

The design section discusses the analytic process used to explain how participatory action and narrative research have been used in parallel to interrogate the research question. This has produced dense interwoven narrative data. These data were then analysed using a blending of activity theory (Engeström et al., 1999) and the theory of tension field learning (Illeris, 2003). In addition participant narratives were thematically evaluated using NVivo 8 software in preparation for the analysis phase.

1.7.4 Chapter 4: Data
The participants produced eighteen narratives of using imagination to enhance their learning. Four representative narratives are discussed in this chapter.

The first, representing approximately a third of the participant cohort, is from a student who experienced a large positive shift in his value and use of imagination during the study. The second and third stories are from students who experienced significant changes as they used imagination actively in their learning. These two stories are typical of two thirds of the participants in the study. The final story is from the participant whose views on the efficacy of using imagination to enhance learning fluctuated throughout the study.
The purpose of this chapter is to give a first-hand picture of the narrative data in a well-rounded and holistic manner that can inform the discussion in the final chapter.

1.7.5 Chapter 5: Analysis
The analysis chapter documents the analytical paradigm created by combining and reforming activity theory (Engeström, 2000) and tension field learning theory (Illeris, 2003). The reformational theory of expansive learning is then articulated in a matrix of six principles and six questions. This was used to analyse the themes of the narrative data and provide answers to the research question.

1.7.6 Chapter 6: Discussion
This chapter discusses the findings and outcomes of the study as a whole. The research findings are further explored and linked to learning contexts. This includes a discussion on the categories of imagination and learning activities to develop these categories. The outcome of this discussion is to provide insight into how imagination may be used to improve educational outcomes in abstract domains and electrical physics in particular.

After determining the usefulness of imagination activities as tools for improving learning, the discussion turns to implications for learning and teaching electrical physics. Finally, the discussion is completed by re-examining the research objectives and how they have been achieved.

1.8 The Research Expedition
The research journey or more accurately expedition has challenged me in areas I did not even know existed. As a server dyslexic, the challenge of large amounts of reading and then written expression has been difficult but not loathsome. The journey has given me many skills that eluded me in earlier education.
My scholarly growth has moved from the worldview of a scientific positivist as an electrical engineer educator to a new space, where the vistas of learning are far more diverse, but at the same time more consistently connected. I have completed many things that in naivety I had not contemplated. On reflection, that level of naivety was essential or the expedition would not have been commissioned. The experience of this project has irreversibly enriched and changed me as I interpret the cultural cosmos in which I find myself.

My nature is basically practical and my proclivities lean toward action. It is through purposeful reflection on the events and situations of this study that I have learnt to understand my experiences and this reflection informs and enriches my current, and expected future practice. The design of the research and its implementation reflect both the research question and my tendency towards innovative experimentation. The expedition has traversed much terrain but has also drilled deep in an attempt to find better ways to use imagination to improve learning in the domain of electrical physics.
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Chapter 2

Literature Review

2.1 Introduction
This study in investigating the relationship between learning electrical physics and the use of imagination does not have a single fit into current literature. The use of imagination is not addressed directly with the academic literature. As a result the study draws from several domains and facets.

A thorough search of the literature for the period 1980 to 2011, shows that research into learning electrical physics is largely associated with direct current (DC). An example is Clement’s (2002) ‘Step-wise’ approach that is solely concerned with DC. There is very little research into learning about alternating current (AC) and in the two studies that mention AC (Carstensen & Bernhard, 2007, June) and not directly related to the focus of this research. A probable reason for this is that DC is the conceptually simpler end of the electrical abstraction continuum, with AC at the other far end. Only one major study of mental modelling in relation to learning and understanding electrical physics that provides some signposts has been found. No mention of imagination in relation to electrical physics has been found.

Research that mentions imagination deals with mental modelling and imagery appears to be confined to the domains of graphic arts and language acquisition. An example would be a study entitled Mental image interpretation and poetic metaphor (Gibbs, 1999). The use and understanding of imagination is limited by narrow definitions, largely confined to the single dimension of fantasy. Example is found in the online Journal of the Imagination in language and learning teaching and an article that uses Magical Boxes as window to the imagination (Friedman & Simone, 2000).
A significant amount of work in physics and electrical physics considers conception and misconception. Notable in this area is research that investigates anecdotal concepts of electrical physics using an ‘interview of instance’ (Osborne & Gilbert, 1980, p. 214). Also in this area is important research examining ‘learning by doing’ and electrical problem-solving in the US Air Force (Gott, 1987, October, 1990; Lesgold, 2001), but linked not directly to electrical physics itself.

At the hub of any discussion of imagination is the need to define what is meant by the term imagination. Eight definitions have been developed, and these demonstrate the complexity and diversity of imagination. Subsequently ten imaginative skills categories have been defined and an important part of this process has been the contribution of metaphor, analogy and elaboration.

Because of this contribution, the research design approach has been to select an appropriate ethnography that allows students/participants to express their learning stories and, in recording these stories, offer the researcher an effective way to engage with the student learning and to analyse that learning from an imagination perspective. For this purpose a blend of participatory action and narrative research approaches was selected. The methodological technique for the purpose of analysis is a blend of activity and tension learning field theory. In philosophy and imagination, the final domain, the literature survey targets imagination generally and the treatments of imagination from several significant worldview perspectives.

The following chapter has been organised to use the available literature to support subsequent chapters on the research design and implementation, the data analysis and the formation of conclusions. In order to do this, the current chapter has been subdivided into the following headings; existing research, definition of imagination, research paradigms, philosophy of imagination and consolidation.
2.2 Collection of existing research from 1980-2011

2.2.1 Introduction
The research into existing studies demonstrated that there are possibly seven themes which need further investigation in the wider literature. These are problem-solving, misconception, abstraction, complexity, mental modelling, teaching and imagination.

2.2.2 Problem-solving
Problem solving in electrical physics has many types and layers ranging from standard mathematical formulas to complex imaginary number systems; from simplex component positioning to extensive component miniaturisation; from primitive circuit diagrams to refined computer programming and from common applications to sophisticated and innovative solutions. Problem solving in electrical physics is more often a combination of many types and layers all interacting at the same time, over an extended period of time (Cornford, 2000, p. 80). It is this constant interaction that makes defining problem-solving in electrical physics demanding.

Many studies focus on problem-solving around algebra or deductive fault-finding (application) rather than understanding the physics of electricity: Gott (1987), Gregson and Little (1998) and Lesgold (2001) are good examples of studies of this type. In these cases, students are taught algebraic modelling systems or the modelling systems of circuit diagrams, both of which are abstractions of the results of the phenomenon, not the phenomenon itself. They are restricted to a “learning by doing” approach, and use abstract modelling systems as students are required to move quickly from hands-on results of the phenomena to circuit drawings or connection drawings. Students are then given further abstractions: the names that represent the phenomenon they cannot directly sense. The name for electrical pushing force is given as potential or voltage (both abstract names). ‘Current’, as a term to describe electron flow, is rarely defined and ‘resistance’ describes a blocking or restriction to the flow of undefined current (Licht, 1991). Because of the difficulty of abstractions...
upon abstractions, electricity is simply taught through the standard modelling systems and the result is narrow problem-solving, using predefined models. The complexity of electrical physics means that it is often taught using these standard models that in themselves become a limitation in the way that they can be used. As a result narrow problem-solving is perpetuated.

2.2.3 Misconception in electrical physics
The literature is strong and consistent about misconceptions in learning about electricity. Misconceptions are often found not only in the learner but also in the teachers (Cohen, Eylon, & Ganiel, 1983, p. 408; Heller & Finley, 1992, p. 259; Sencar & Eryilmaz, 2004, p. 260). Misconceptions are logical for the holder. This makes them strongly held and consequently difficult to change.

Heller and Finley’s (1992) study provides a typical example of the origins of misconception in understanding electricity. They find that conceptions in electricity are counter intuitive. Intuitive conceptions are logically consistent and strongly held conceptions that differ from scientific conceptions (p. 259).

The study does not suggest why the misconceptions occur, but hints that the misconception is intuitively gained from daily interaction with electricity. For example, an electric light turning on or off does not give scientific insight into how electrical phenomena operate.

Another study suggests that the problem of misconception is the ontological categories used by students learning about electricity (Chiu & Lin, 2005, p. 458). This study suggests that students struggle with electricity because they have preconceived mental models that are matter-based (things they can directly sense) and so they place their understanding in the wrong ontological categories.

Sencar and Eryilmaz proffer another explanation for misconceptions in electricity. This failure (learning electricity) is often attributed to the seeming inconsistency between the conservation law and every day
experience, which suggests that something is being used up in process rather than being conserved (2004, p. 446). Again the students of electricity encounter a disconnect between the outworking of the phenomena or physic and the scientific explanations of the physic (Krieger, 1998, p. 5).

2.2.4 Abstraction in electrical physics

Abstraction in electrical physics is unavoidable because electricity is non-sensory – that is, humans cannot directly sense electricity by sight, touch, smell, taste or sound. We can see the result of electricity as a light illuminates, but not the energy itself. We feel electric shock, but this is our bio-electrical system being disrupted. This system is designed to sense heat and pressure; we are not feeling current flow. Electrical faults often have a distinctive smell, resulting from the production of ozone (O₃) as air is ionised. The smell is the ozone not the electrical energy. We cannot taste electrical energy; a tingle on the tongue from a battery indicates disruption of our bio-electrical system. Finally, sometimes the crackling sound near a high voltage substation (above 33Kv) is the sound of air ionising from sharp points producing sound waves, not the electrical energy itself.

All dealings with electrical energy are abstract by their very nature. The next level of abstraction is the modelling systems used to represent the physics. The third abstraction is the use of language and the words used to bring meaning to electrical physics. An example is the use of words with historical significance, particularly in describing electrical units. ‘Voltage’, for example, is derived from a person’s name. A fourth layer of abstraction lies in general physics concepts such as the conservation of energy: energy is neither created nor lost but may transfer from one state to another.
All levels of abstraction create problems for the learner.

Examples from the literature at the first level of abstraction include:

Many students see physics stuff, lamps, batteries etc., but do not comprehend power and current (Licht, 1991, p. 274).

The fundamental reason it is difficult to teach electricity is the main domains of resistance, current and voltage are not directly observable (Arnold & Millar, 1987, p. 553).

Electricity is a difficult topic for students to come to terms with. The invisible nature of what is happening makes it an abstract topic (Arnold & Millar, 1987, p. 341).

The above examples demonstrate the previous point that electricity is not directly observable and therefore learning about and within the phenomenon is immediately abstract. This builds on the non sensory premise of the thesis.

Cases from the literature that demonstrate the second level of mental modelling as abstractive include:

However, we have found that the use of model building as an instructional strategy is usually not sufficient (Shafer & McDermott, 1992, p. 1008).

Instruction of Ohm’s law from electricity theory serves as an example domain. All of the instruction discussed below can be supported with one simple model (Figure 5-10), a circuit whose behaviour is expressed in a rule that applies Ohm’s law: current (I) equals potential (E) divided by resistance (R), different presentations can either be made from copies of this basic model, or they can be constructed as overlays upon it (Gregson & Little, 1998, p. 143).

Here the research indicates that to deal with the first level of abstraction a second layer needs to be added using existing models, particularly the
model of algebra. The project encourages discussion in this area by the participants through their narratives.

Instances from the literature that focus on the abstractive levels of language include:

The classroom context led her to bring up her “physics class” model, Newton’s third law, but common-speech wording of the question led her to bring up a common sense response, larger objects exert larger force (Redish & Steinberg, 1999, para. 45).

Certain words in a particular culture are difficult to encode because they have varying meanings (Carspecken & Walford, 2001, p. 18).

The third facet of abstraction is that of the use of language. In particular technical languages, as words like ‘current’ have multiple meanings in different contexts.

This group of illustrations from the literature demonstrates the final level of abstraction that is inherent in the electrical physics concepts.

Problems with abstract frameworks when dealing with energy and its conservation (Sencar & Eryilmaz, 2004, p. 462).

Turning to the specific point, it has been implied strongly that the differentiation of ideas of electric “current” and “energy” is crucial for further development of understanding (Sencar & Eryilmaz, 2004, p. 562).

This final abstractive level is with reference to the actual concepts embedded in electrical physics. The concept of current expended over time as energy is an abstractive relationship concept as an example from just above. The project’s intent is to explore deeply these levels of abstraction in relation to learning using imagination skills to assist with learning.

These multiple levels of abstraction create ever deepening dimensions of complexity in the learning of electrical physics. While the depth of complexity is difficult, learners need to be able to cope with these complexities.

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2.2.5 Complexity of electrical physics
Because electrical physics is abstract, many of the modelling and imaging systems used create complexity. The complexity arises when representations of concepts cross multiple levels of abstraction as in circuit diagrams. A circuit diagram uses graphical symbols (a zig zag line for resistance), abstract text representation (I for current) and algebra to represent relationships such as Ohm's law (I= R/E).

Aggregating these forms of abstraction in a qualitative way requires complex mental imaging skills (Clement, 2002, p. 25). The complexity of scientific concepts also contributes to the abstractions, as students have difficulty conceptualising the trans-phenomenological nature of electrical energy. That is, electricity can exist as several different phenomena states of chemical, magnetic, static and the transfer between the states creates further complexity (Sencar & Eryilmaz, 2004, p. 459).

2.2.6 Mental modelling in electrical physics
The complexities encountered through the very nature of electricity and the abstract nature of the modelling systems of diagrams and mathematics and others all lead to some form of mental model for the student. This mental model, constructed appropriately, will allow the student to systematically predict the phenomena of electricity.

Most studies only casually mention mental modelling as though it is assumed. However the exception specifically concentrates on mental modelling (Clement, 2002).

However Clement (Clement, 2002, p. 3) uses analogy as a place to start mental models. No one analogy is able to carry the complete electrical concept. So Clement uses ‘bridging analogies’ (Chiu & Lin, 2005, p. 432) which evoke student intuitions to help them think through a series of analogies.
Developing mental models based on a particular electrical concept or unit of measurement is popular. Cohen’s et al. (1983) study suggests that a model formed from a potential difference perspective is most appropriate (p. 411). Clement (2002) and others also indicate that students use a current model more often because this is easier to model and contextualise.

2.2.7 Teaching and learning of electrical physics
The teaching and learning of electricity according to the literature feeds the following aspects: hands-on or integrated theory/practical; simulations with worked examples; analogies and their connections; visual representations and the ability to reflect. Although these traditional teaching approaches are seen as ineffective (Sencar & Eryilmaz, 2004, p. 445), students continue to find difficulty with electrical concepts.

Technical, somatic and sensory levels or modes are required when teaching electricity...

(Sencar & Eryilmaz, 2004, p. 226)

The writers of most electrical trades level text books understand this and provide hands-on and contextualised examples (Sencar & Eryilmaz, 2004, p. 614; Taylor, 2009, p. 11).

For those who teach in a virtual environment, it is important to contextualise electrical simulations with a variety of worked examples (Mareels, Naidu, & Labura, 2001, p. 109).


Much learning in electricity is spatial – an example is the connecting of circuits which requires the ability to move between abstractions of a circuit.
through a diagram to the actual wire and components. This ability is enhanced for those with reflective skills (Mareels et al., 2001, p. 110).

Underpinning most of the above is a strong constructivist learning approach (Clement, 2002, p. 3; Sencar & Eryilmaz, 2004, p. 122). Clement uses analogies to build up and re-work concepts. It is also important to note that the connection between the analogies is paramount (Clement, 2002, p. 26). Sencar emphasises that learners construct or generate their own meaning from information to which they are exposed (Sencar & Eryilmaz, 2004, p. 122) and the process involved (Brown & Duguid, 2000, p. 95).

2.2.8 Imagination in electrical physics
Imagination is a central concept in this thesis. It is therefore important to understand what little there is about imagination in the literature of electrical physics in particular. There is little direct mention of imagination and what there is has negative connotations. Imagination is far more often mentioned in an oblique fashion, using words like ‘innovation’, ‘creativity’ or ‘visualise’.

Sencar and Eryilmaz (2004) in a study of misconception indicate that some of the conceptualising problems ‘leave too much to the imagination of some students’ (p. 1096). This of course is a negative slight on imagination as though the student’s imagination was not capable or appropriate to the task. Eisner (2002) make the point this way; ‘In the arts, imagination is given licence to fly. In many – perhaps most – academic fields, reality, so to speak, imposes its factual face’ (p.198). I would suggest that improving their imagination would have assisted their conceptualising. Elsewhere innovation and creativity are mentioned as skills that assist fundamental conception (Gregson & Little, 1998, p. 373; Sencar & Eryilmaz, 2004, p. 96). Finally, imagination is often correlated with image creation and the use of analogies (Clement, 2002, p. 19).
At some point the physics, the phenomenon of electrical energy, is assumed because of its non-sensory nature. It is in this assumption that much about the teaching of electrical physics is lost and the research largely silent.

2.3 Electrical physics

2.3.1 The nature of electrical physics

Electricity is a phenomenon that is un-observable (Arnold & Millar, 1987, p. 553; Osbourne & Gilbert, 1979, p. 86; Towne, 1995, p. 197), that is not directly able to be sensed. It is not the only physical phenomenon that is unobservable – gravity, magnetism and most of the light spectrum, ultraviolet light for example, is likewise unobservable. Gravity is the force that gives all objects weight, all these examples are the results of forces that humans only sense indirectly. Likewise, you cannot directly sense ultraviolet light, but, after a day outside without protection, the resulting sunburn soon makes it obvious. The difference between electricity and these other non-observable or non-sensory phenomena is that gravity and radiation exist in daily life as part of the natural world for everyone and we experience the results of their forces every minute. Electricity, however, only occurs occasionally in the natural world as we see and hear lightning.

Electricity has two basic forms: DC or direct current and AC or alternating current. DC flows in only one direction producing stable effects of heat and electro-magnetism. AC alternates back and forth. The alternating aspect of the current may be regular, and household electrical supply is of this type. AC may also be irregular – for example, sound produced through a speaker.

The complexities introduced by AC are the ‘meta-contexts’ (Marton & Booth, 1997, p. 198) of the physic. Most students initially have difficulty with DC because the concepts are deep (Krieger, 1998, p. 1) and students need direct understanding of how material substances react (Reiner, Chi, & Resnick, 2000, p. 1). Then how much more deep and difficult are the concepts of AC. Electrical engineering concepts are very abstract and
involved (Mareels et al., 2001, p. 112). My experience over the past thirty-seven years has been that no TAFE student learns AC easily. Most students struggle and only a minority ever really fully understand AC.

Not only are the physics concepts multi layered and abstract but so too are the modelling systems. The metaphor (Gibbs, 1999, p. 223) of AC 3-phase, using phaser diagrams is often the starting point for representing AC., an abstraction at multiple levels that most learners of AC find difficult, is a better starting place than complex numbers. One of the reasons suggested for the difficulty is a lack of abstraction skills (Gregson & Little, 1998, p. 368).

Another way to imagine or model electrical physics is using a quantum physics approach. In quantum physics sub-atomic relationships between particles remain similar and are represented as energy levels that constantly change, resulting in quantum numbers to represent elements.

2.3.2 Conceptualisation and abstraction in electrical physics

Reasoning in science, and so reasoning in electricity, requires reasoning in the abstract (Osborne & Freiberg, 1985, p. 55).

Conceptualisation and abstraction are closely linked. Abstraction is the conceptualisation apart from matter. This is an idea or construct that has no basis in the material world.

For the purposes of this study I have defined a conceptualisation as an abstract and simplified idea of the world that we wish to represent apart from or removed from its context (Lesgold, 2001, p. 6). When abstraction is thought of as separate from concrete realities or specific objects, an abstract idea or concept is produced.

Abstract conceptualisation attempts to make meaning when meaning is not obvious from concrete reality. This is the focus of the project as students are encouraged to explore this aspect through the use of measurement instruments during circuit construction and testing. Another
example of this is concept-mapping or mind-mapping. This is the process of systematically mapping the relational connections and so bringing meaning to those connections or ‘making sense’ (Sencar & Eryilmaz, 2004, p. 1080; Smith, 2006, p. 63). Many studies in the literature examine misconception, which again is about meaning and is about the production of incorrect meaning (Bull, Jackson, & Lancaster, 2010; Garnett & Treagust, 1992; Linke & Venz, 1997; McDermott, 1998; Smith, DiSessa, & Roschelle, 2006; Smith, 2006, p. 73). At its centre, meaning creation comes through problem-solving and reflection as Quinn explains.

At its core, individual learning is about engagement in activity encountering a problem and reflecting to create an abstract conception, and then testing that conception through more activity in an ongoing cycle.

(Quinn, 2005, p. 24)

Abstraction is strongly associated with complexity. Progress and vertical movement are characterised by higher and higher levels of difficulty (Gott, 1988, p. 125). So, as conceptions become more abstract, the more involved they tend to be. The outcome is that electrical physics is a series of highly abstract concepts and so it becomes very complex (Guzzetti, 2000, p. 93).

The most common method to deal with abstraction is analogy (Chiu & Lin, 2005, p. 459). Analogy is an attempt to use a system or process that is similar to the abstract concept but based in observable physical reality. The analogy of water in pipes is often used in electrical physics when first learning about Direct Current. An example is the use of a water non-return valve to represent the operation of a diode. Millar and Burton (1994) claim that the visual aspect encourages abstract reasoning. Unfortunately, the analogy quickly breaks down in its attempt to make the abstract concrete and is totally ineffective for AC.

Analogy is not the only way of connecting the abstract to the concrete in an attempt to bring understanding and meaning. In electrical physics, the use of animated simulation or visual metaphor is often used (Gibbs, 1999,
This is effective because abstraction and the concrete are both parallel continuums. Not every concept is completely abstract or completely concrete (Smith, 2006, p. 26). Metaphor in the form of animation often finds or explains, even bridges, the abstract and concrete thus sense is made (Tang, 2003, July, p. 2).

One of the main abstractions used in electrical physics is text. Text, or written language, is an abstraction of spoken language. The particular textual abstraction in electrical physics is the use of jargon (Olsen, 2002, p. 566). Many of the terms in electrical physics only find their meaning in the context of electrical physics. An example from simple DC would be ‘voltage’. The term ‘voltage’ has no direct relationship to potential difference, even though this is its meaning and is the value or unit of potential difference.

The final aspect of conceptualisation and abstraction is generalisation. The more often a phenomenon is repeated, the greater the likelihood of generalisation and this is a short step to abstraction (Jarvis, 2006, p. 21). Electrical physics, the phenomenon, is repeatable anywhere in the universe, such is its nature, and the result is abstract generalisation (Licht, 1991, p. 341). An example of generalisation is Ohm’s law (Osbourne & Gilbert, 1979, p. 86) a law that can be applied successfully in all situations.

2.3.3 Adult learning in electrical physics
Of the literature surveyed that directly relates to the learning of electrical physics, 37% relates to adults learning electrical physics and 23% is related to adolescents. The total of the research into the learning includes 40% relating to children and the vast majority of all the research focuses on DC.

The predominant learning theories underpinning the studies are cognitive learning theory and humanist learning theory (Gott, 1988, p. 111; Roblyer & Doering, 2010, p. 42; Sencar & Eryilmaz, 2004, p. 623). Typically these use a social constructivist and or a situated constructivist approach. In addition, behavioural theories are mentioned and sometimes used.
Adults’ learning, some times called andragogy, about electricity is, in the first instance, about making meaning from the behaviour of a phenomenon, a physic, they cannot directly sense.

Electrical students learn and make meaning in a triangle of concept, activity and culture (Brown, Collins, & Duguid, 1989, p. 93). The concepts are abstract. The activity is the connection and testing of circuit outcomes with a mediating artefact (Brown et al., 1989, p. 33; Stevenson, 2003, p. 16), for example a digital multimeter. The third corner of the triangle is the cultural context. For most students, the first level of context is working in a class group, at TAFE or a university tutorial. The larger context is the everyday interaction with electricity. For the purposes of this study, the classroom context then uses a three-part learning cycle (Down, 2006, p. 195) starting with the physic or phenomenon, then the physics modelling systems and, finally, the generalisation or workplace application. All of this is guided by a teacher, expert both in electrical physics and in pedagogy. It is the expert’s ability to help the students make the connections in the cycle from his/her experiences that facilitates learning (Stevenson, 2003, p. 5).

Adults need to learn for a reason or have a need to learn (Race, 2005, p. 25). Illeris explains the motivation of adults to learn:

> It is, first and foremost, a matter of viewing learning from the perspective of the learners because adults are not very inclined to learn something of which they cannot see the point on the basis of their own life situation.

(2003, p. 167)

Illeris (2003) also notes that adults often have a semi-automatic defence against learning which also must be overcome (p. 404). It is easy for the science of electricity to lack apparent relevance and so learning motivation is low (Osborne & Freyberg, 1985, p. 51; Rossing & Long, 1981, p. 32; Skowron, 2005, p. 1).

The nature of electrical physics is non-sensory, so the predominant approach in the literature to the learning of electricity is ‘learning by
doing’. This approach is about learning the patterns, which is the physics modelling systems, in the hope that an understanding of the physic will come later (Kirsner, 2002, p. 223). This is not the approach of the present study or the approach in the context of this study in TAFE. This study, as will be described fully later, uses an approach of integrated theory/practical. There is much about this approach that is just doing and so is ‘learning by doing’ (Reigeluth, 1999, p. 164) and this is often taken for granted (Jarvis, Holford, & Griffin, 2003, p. 40). Jarvis also points out that ‘learning by doing’ can be improved into what he terms ‘Action Learning’ by the student learning from doing within the specific social context (Jarvis, 2006, p. 154).

Metacognition is another strong aspect of this study along with risk, memory, context transfer and electrical illiteracies. All of these will now be discussed further in the light of adult learning literature.

**Metacognition in the learning of electrical physics**

Metacognition involves learners monitoring their own thinking, being aware of what they do and do not know, and being able to actively and critically (Brookfield, 1987, p. 14) reflect on what has to be learnt (Reigeluth, 1999, p. 287).

The reason for a metacognitive approach is to improve student learning outcomes (Gott, Glasser, Parker-Hall, Dibble, & Pokorny, 1996, p. 283). As mentioned above, action learning is a form of metacognition (Jarvis, 2006, p. 154). In problem-based learning (PBL), the very process develops self-regulated learning which is metacognitive (Askell-Williams, Murray-Harvey, & Lawson, 2005, p. 2). Metacognition encourages learners to make visible learning that otherwise is inarticulate or invisible, so it can be assessed (Smith et al., 2006, p. 67). This aspect of metacognition plays a strong role for the participants in this study. With respect to metacognition, the challenge here is that the participants’ perspectives are largely developed from a logical positivistic position. So conceptualisation and abstraction involved means that they are being introduced to constructionist learning paradigms of which they are
not aware, like naive realism and relativism (Huberman & Miles, 2002, p.77). This is metacognitively making them aware that there are other ways to construct and view their learning.

Lesgold suggests that metacognitive learning and transfer processes that are instrumental to the student are planning, strategic problem-solving and the ability to use additional information (Lesgold, Lajoie, Logan, & Eggan, 1990, p. 181). Wilson and Win-Jan propose that there are five Ps that the metacognitive learner uses: ‘predication, ponder, probe, pause and pose’ (2008, p. 63). Predication is the skill to be able to reflect and elaborate. Pondering is finding the relational connection that allows sense to be made. Probing is testing the elaboration from prediction. The pausing, taking the time for learning to be challenged and readjusted, is a required part of learning. The final step is the posing or articulating thinking and learning to others.

Despite some Australian research that indicates that VET students are not typically characterised by well-developed metacognitive skills (Smith & Dalton, 2005, p. 12), this doctoral imagination study uses metacognition to great advantage in both reflective learning and in exposing unarticulated learning that can be used for even further learning.

**Risk**

Risks in this doctoral study have two primary aspects. The first is the ethical risk involved in using student perception as the basis of the study. There is a further explanation of this risk in the research component of this literature review. The second aspect of risk is asking students, employers and the TAFE to support a new and novel approach to the andragogy of teaching and learning electrical physics, including the findings of the research and its implications.

Whenever a new approach is suggested, it comes with the risk of something that has not been done before (Down, 2006, p. 98). Along with the unknown is a risk associated with creativity (Hefner, 2002, p. 665; McNiff, 2003, p. 23; Thomas, 1999, p. 231). This study combines these two...
characteristics of risk, being creative in approaching electrical physics through imagination and being something completely new to TAFE and students. As a further indication of risk, two of the activities in this study required the participants to be blindfolded – that is, have their sight temporarily removed. This is often risky for adults (Litt, 1993, p. 1) because this creates a sense of loss of control.

The next form of risk for the student participants is having their preconceptions challenged in the public forum of the classroom. No-one enjoys having their ideas challenged, particular if these ideas have served them well for a long time (Sencar & Eryilmaz, 2004, p. 165). A second fear for many students is the fear of failure and so it is often a risk to try a new learning approach (Kirk, 1992, p. 6; Rossing & Long, 1981, p. 32) and this is amplified by the very context of the research as it focuses on discovering new learning approaches.

The opposite of risk is safety (Vella, 2002, p. 33). However learning is an appropriate risk taking activity. In this imagination study, the ethics process focuses on safety as paramount. The design of the study and the selection of participant activities always considered the students’ safety at all levels, from physical (particularly electrical equipment use) through to educational.

**Mental modelling/Visualisation**


Mental representations or models are not often mentioned, in association with learning electrical physics. Clement (2002), is the exception to this specifically examining mental modelling in DC (p.13). Other studies examine conceptual change and mention mental representation but focus on analogy as a basis for these representations rather than the

Reigeluth states that in learning electrical physics, mental modelling is based on a constructivist approach (1999, p. 143). Mental models are constructed and re-constructed from many smaller pieces of sensory information to explain complexity (Huit, 2009, p. 232; Smith et al., 2006, p. 64). In the process of model construction, the links or relationships between the component parts give meaning (Billett, 2003, p. 227).

There is one important point on which virtually all of the definitions offered in cognitive science fields agree, namely, the idea that the structure of mental models "mirrors" the perceived structure of the external system being modelled.

(Doyle & Ford, 1998, p. 14)

That quotation is a little problematic in relation to the construction of mental models in electrical physics. The ability to ‘mirror’ an electrical system is difficult because of the phenomenon’s non-sensory nature. The result is that there are three approaches evident in the literature for the construction of mental models in electricity. The first is to determine what a best particular model is, that is a model that is used by the experts and easily grasped by the novice (Brookfield, 1987, p. 85; Lesgold, 2001, p. 7). This approach is evident in the frequent use of analogies, the typical analogies coming from hydraulics (Chiazzese et al., 2005, p. 189), a bowling alley (Licht, 1991, p. 343) or air pressure (Clement, 2002, p. 3). Again, these model analogies only apply to DC.

The second approach is to encourage novices to challenge their preconceptions and re-construct mental models that work best for them, without a specific model being suggested. Typically most novice models are strongly held and as such are difficult to change (Murray, Schultz, Brown, & Clement, 1990, p. 82). However as the learner moves toward competency, they become insufficient and often rely on questionable assumptions. Hence the need to reconstruct mental models on the basis of continued
learning and experience, until the model becomes an established one and this often requires strong learner-teacher relationships (Brookfield, 1987, p. 91). It is imaginative critical thinking that will assist in challenging these assumptions (Brookfield, 1987, p. 13). When an appropriate mental model is established, its enduring nature is what will turn the novice into an expert (Doyle & Ford, 1998, p. 16; Mestre, 2001).

The third approach lies between the two extremes of ‘learn a specific model’ and ‘re-construct a mental model from the beginning’. This approach suggests a range of sub-models and encourages the novice to construct and re-construct, producing an aggregate model (Frederiksen, White, & Gutwill, 1999, p. 825; Lowe, 2001, p. 24; Smith et al., 2006, p. 64; Towne, 1995, p. 143). This approach is used in Clement’s study as he follows a novice’s ‘learning out loud’.

This is a direct example; because Susan articulates several of the model revisions before the tutor does, we believe she is doing some generative adductions, although the context for these is certainly set up by the tutor. (2002, p. 22).

In this case, the tutor has set up sub-models and the novice is connecting them and making revisions or actively re-casting the model on the run (Jenson, 2007, p. 79).

The ability to build mental models often starts with visual representation. In electrical physics it is often the connection diagram or the circuit diagram. The connection diagram uses contextualised symbols (graphic of an actual battery or lamp, for example) and these are spatially arranged as they may appear in reality (Gott, 1988, p. 130). The circuit diagram can be similar, but uses abstract symbols rather than graphics and the components are not spatially arranged to reflect reality. The symbols are arranged on the page to make interpreting the drawing as clear and convenient as possible – often top to bottom and left to right. It is this arrangement and use of symbols that contributes to mental models and produces modelling literacies. Modelling literacies have their basis in visual
literacies (Burmark, 2002, p. 3). Modelling literacies vary in their approach, but all have an abstract symbol of some kind.

In electrical physics there are several modelling system literacies, the most common being algebra (Towne, 1995, p. 113) and the obvious example is the literacy of Ohm’s law: ‘I’ represents electrical current expressed in Amperes, potential difference is represented by ‘V’ and measured in Volts, resistance is expressed in Ohms and represented by the letter ‘R’ which is a modelling construct (Rae, 2005, p. 165). This is the simplest example. The algebraic modelling literacy of electrical physics gets more complex and more abstract as AC is explored. Another example is a circuit diagram, which is constructed from abstract symbols. The novice needs a strong understanding of the meaning of each symbol and so constructs a symbolic or modelling literacy that makes the diagrams meaningful (Pettersson, 1993, p. 79).

Although it may seem that mental modelling is the most appropriate approach to understanding a non-sensory physic like electricity, the literature is not unified on this. Some studies indicate that the use of mental models has its limitations. Sencar and Eryilmaz (2004) suggests that mental models can over-generalise if applied too literally (p. 1095). This perspective I find difficult to support in the domain of electricity. Ohm’s law cannot be a law unless it can be generalised. Doyle and Ford (1998) object to the term mental model and would prefer mental representation (p. 15). Having noted this, I find the terms mental model and mental representation interchangeable in the literature and have treated them thus in this doctoral study. Turchi (2004) indicates that mental models are inaccurate because they are based on personal selective experience, our knowledge and ignorance, and misinformation (p. 28). The points Turchi makes are valid but, Gott et al. (1996) note that in the learning of electrical physics, there is appropriate guidance with the mental models and opportunity to test those models through application (p. 265).
Memory and cognition

Knowledge, and how it may be represented in the human mind, is a diverse subject. For this study, my approach to memory and cognition has been influenced by a cognitive constructivist approach (Illeris, 2003, p. 402). Thus this section concentrated more on thinking rather than training in the domain of education (Ralston-Saul, 2001, p. 295).

In the domain of learning electrical physics, cognitive change is at the centre. This change occurs through the sensors and with the use of short and long term memory connecting and reconnecting to form schema (Clement, 2002, p. 42; Koestler, 1964, p. 44; Lowe, 2001, p. 18). These schema are the building blocks of the mental modelling systems used in electrical physics (Thomas, 1999, p. 218). This is because an electrical schematic is a relational connection of abstract ideas or symbols that represent those ideas.

Sencar and Eryilmaz (2004) suggest that cognitive change has three dimensions: time along a scale, content, and abstraction as a measure of complexity (p. 619). Learning electrical physics certainly takes much time (Lesgold, 2001, p. 17). The content is large and diverse. The level of complexity is also high because of its abstract nature. The result is that cognitive change is difficult to achieve in electrical physics from all three dimensions because time is often short, content is diverse and complexity is high.

From another perspective, Jarvis suggests five types of thinking or thought processes: memorising and interpreting; creative and critical thinking; problem-solving and decision making; directed and undirected thinking; deductive and inductive reasoning (Jarvis, 2006, p. 101). This also is an appropriate lens through which to examine the learning of electrical physics. In electrical physics there is much declarative knowledge (Hall, Gott, & Pokorny, 1995, p. 6) that needs to be memorised or automated. An example is the resistor colour code system. Creative and critical thinking is needed in the interpretation and analysis of circuit diagrams. Problem-
solving and decision-making play a strong role in taking the circuit diagram to the completed and operational physical circuits. Directed and undirected thinking are at work while the novice learns about electrical physics from an expert and through exploratory learning. Deductive and inductive reasoning are used through all the above-mentioned dimensions as the novice makes deductions from previous learning and makes inductive or creative links in their learning.

If learning is significant as indicated above, then the amount of change and rate of change must be important. The amount and rate of cognitive change has been dubbed ‘cognitive load’ by Sweller (Cooper, 1998, p. 108). By way of example, Cooper, uses Sweller’s suggestions and reduces cognitive load in relation to electrical connection diagrams by using well-placed text that is numbered in appropriate sequence for interpretation (1998, p. 111). This reduces cognitive load by giving the students a place to start, a sequence to follow and a place to finish. This does not diminish the need to have an extensive knowledge in the domain. It is this broad knowledge that Egan (2005) links to the development of imagination as he states;

A central feature of imaginative education ... worth emphasising again and again, is that for imagination to develop adequately and to work effectively the student needs to know a lot. Ignorance is not a condition that favours the development of the imagination (p. 169)

**Context and transfer**

The non-sensory nature of electrical physics gives rise to much that is abstract.

This abstraction needs to be linked into the context of learning (Brown et al., 1989, p. 93) and whenever possible to find meanings (Silverman, 2003, p. 348) in order that learning can be applied in the real world.

This leads learners to ‘chase’ context (Brown et al., 1989, p. 13) whenever possible to find meaning (Silverman, 2003, p. 131). Learning that is
meaningful requires links back into previous contexts. The use of imagination as image with regard to learning context is first posited by Comenius in the seventieth century (Piaget, 1993, p. 5). The renowned psychologist Jean Piaget (1993) even goes so far as to recognise Comenius’ particular use of images, with etymological links to imagination, as a key component of effective learning (p. 5).

Artefacts can provide the links between context and abstraction (Egan, 2005, p. 1; Lowrie, 2004, p. 352) and this is particularly applicable to electrical physics. For example, common artefacts are the digital multimeter (measuring current, resistance and voltage) and the digital oscilloscope. These artefacts allow the student to remotely monitor the effects of using electricity thus contextualising what is happening.

Problem-solving also brings context in electrical physics (McKavanagh & Stevenson, 2004, p. 14). For the students in this study, most problem-solving takes the form of mathematics as they apply this modelling skill in the classroom and workplace. The mathematics is often mechanistic, that is, done without understanding (Tang, 2003, p. 3), an echo from school learning, that often impedes understanding of the phenomenon.

Down argues that we learn through experiencing differences (2006, p. 121). The students in this study learn through experiencing the difference of electrical physics applied in the classroom and the workplace or transferring between classroom and workplace. The learning is often amplified as the student transfers contexts again in moving back from workplace to classroom.

2.3.4 Literacies in electrical physics
As in any learning, there are many literacies involved in the learning of electrical physics. These include: diagrams, colour, text, visual, algebraic and the literacy of language.
Diagrammatic literacy is a specific part of visual literacy (Burmark, 2002, p. 1). As mentioned earlier, electrical physics learners soon find that many of the abstract concepts are represented by a specialised literacy symbol system (Hansberry et al., 1995, p. 2). The system is often context-sensitive, which can be confusing for the novice. For example, the symbol for a Field Effect Transistor varies according to the diagram type, orientation, standard used and/or power rating.

Colour literacy is very important for all in electrical physics, but especially for electricians. The assignment of yellow/green for protective earth and active as red can be a problem for those with colour blindness. The system is not consistent; so it is important to understand the contexts of the colours used. In Australia, active is red, neutral is black, and protective earth is green/yellow. However, because of international standards, the standard for flexible cords, because of international standards arrangements, has the active brown, the neutral is blue, and the protective earth can be green or green/yellow. Without a good understanding of context, this can become confusing. Also the standards for colours change markedly as you move across different countries. For example, in China, the 400V phase colours are red, green and yellow.

The electrical physics learner uses visual literacies to gain greater contextualisation through visual representations (Sandberg, 2000, p. 50). A definition of visual literacy is explained by Stokes (2008, para. 5) as he quotes Wileman as follows:

Wileman (1993) defines visual literacy as "the ability to 'read,' interpret, and understand information presented in pictorial or graphic images (p. 114). "Associated with visual literacy is visual thinking, described as "the ability to turn information of all types into pictures, graphics, or forms that help communicate the information (Wileman, p.114)". A similar definition for visual literacy is "the learned ability to interpret visual messages accurately and to create such messages (Heinich, Molenda, Russell, & Smaldino, 1999, p. 64)".
For example photo literacy (Goin, 2001, p. 366), a subset of visual literacies is significant for the electrical novice. Many new text books and e-learning resources use digital photography and video as major teaching and assessment tools.

Algebraic literacy not only uses standard alpha-numeric symbols to represent abstract electrical quantities, but there is also a range of Greek symbols. In a typical example, a resistive quantity of six point two micro ohms can be expressed as $6.2 \mu \Omega$ or $6\mu\Omega$ or $6.2 \times 10^{-12}$ R or $6.2 \mu \Omega$. Each of these representations is used for specific reasons to give clarity in different situations and or contexts. This leads to a specific algebraic literacy that needs to be understood by the learner.

The literacy of language also plays a strong role in electrical physics. The reason for this is that the abstract nature of the physic lends itself to the use of jargon or sub-texts. That is the sub-text words have different meanings related to the context of use (Down, 2006, p. 97). The following sentence provides an example of this. “In relation to the reverse bias, the current characteristics of a zener and its ability to break down at low voltages and recover, allows it to be used as a shunt voltage regulator.” In this single sentence, I have used direct and indirect jargon and, to the novice without a strong understanding of the jargon, the sentence would be unintelligible.

A further notion in this area is that of Technacy. The learning and literacy of technology (Turner & Seemann, 2004, par. 6) has been a part of the Australian school curriculum since 1991 (par. 4) but does not seem to have prepared students for learning in abstractive domains. Turners and Seemann (2004) suggest this is the case because ‘Design and Technology’ is a mere elective rather than mandatory course of study (par. 5).

All literacies associated with electrical physics have at least two levels of complexity. The first level of complexity is a result of the non-sensory nature of the physic. This non-sensory nature causes the concepts of electrical physics to be abstract and the result is abstract literacies to
represent them. The second level of complexity is again caused by the abstract nature of the physic as many of the representative literacy systems are context sensitive to the workplace and their application.

2.4 Imagination definition and categories

2.4.1 Definitions and meanings of imagination
Imagination has a multiplicity of, often, overlapping meanings. A survey of the literature and dictionaries reveals eight meanings or definitions of imagination (The Collins Australian pocket dictionary, 1981, p. 26; Stevick, 1993) relevant to my purposes.

The first of these definitions is the ability to and process of forming mental models or images of things not actually present to the senses. This is the case with electrical physics, which is a non-sensory reality and demands the use of mental models to create meaning. The outcome of this process is called metaphysics.

The second definition is the forming of mental images to facilitate the production of ideal creations, consistent with reality in language. This is the creativity in storytelling, language, drama and poetry (Eisner, 2002, p. 53). Clement in using Finke’s definition of mental modelling or imagery implies that imagination is an integral part of the mental modelling process (Clement, 2002, p. 14). In the arts and sciences, imagination is directly asserted as the missing link between mental imagery and creativity (Thomas, 1999, p. 235).

Another definition is the skill to produce ideal creations consistent with reality in pictures. This is the art/istry of pictures, arts and sculpture (Eisner, 2002, P. 4). ‘Creative’ and ‘imaginative’ are often used synonymously (Jarvis, 2006, p. 102), hence to be imaginative is to be creative using this view of imagination (Koestler, 1964, p. 27). Narrative is concerned with making sense with interconnectedness and this requires creativity and so imagination (McNiff, 2003, p. 3).
The fourth definition of imagination is the production of concepts not consistent with reality, being baseless or fanciful. *The Penguin Dictionary of Philosophy* under ‘imaginary’ defines the concept as fictitious (Mautner, 2000, p. 268). Imagination is often thought of as vague (Lewis, 1955, p. 15), dreaming (Ford, 1998; Schredi & Schredi, 1997; Silverman, 2003, p. 515), delusional (Nettle, 2001, p. 161), not real (Ryle, 1968, p. 237), pretending (Wolley, 1995, p. 174), or tricky as in not trustworthy (Ryle, 1968, p. 261). This concerns the entertainment and escapism that can apply to all forms of art and expression. It might be obvious that artistic art production, be it drama, painting, sculpture or any mix, is imaginative – that is, communicating aspects of our world from perspectives that are often unexpected (Lowe, 2001, p. 7/8). In the domain of electrical physics, circuit diagrams are considered artistic and so are also imaginative (Asher & Silvers, 2002, p. 4).

The next definition is the capacity to solve difficulties resourcefully (Eisner, 2002, p. 30) in a non-linear manner. Often-used terms are ‘innovative’ or thinking ‘out of the box’ or to thinking ‘laterally’. ‘Good thinkers: Build on other people’s ideas and create new ideas’ (Wilson & Win-Jan, 2008, p. 98). Again this is the link between creative and imaginative. Problem-solving balances imagination, inquiry and impact (Roschell & Jackiw, 2008, p. 18). Creative thinking is divergent thinking, synthesising approach that marshals mental raw materials to promote creative thinking (McKavanagh & Stevenson, 2004, p. 8). Imaginative problem-solving is not linear (McNiff, 2003, p. 93). As an example Pacey (1999) quotes Gordon Glegg; ‘the secret of inventiveness is to fill the mind and the imagination with the context of the problem and then relax and think of something else for a change’ (p.59).

The sixth imaginative definition is the power to build and reproduce images in the ‘field’ (long term memory), pictorially or linguistically – or perceiving with the ‘inner eye’ (Eisner, 2002, p. 99). This aspect relates to remembering the relationships rather than the image literally and being able to reconstruct the image from the relationships or patterns (Pacey,
This is a complex concept. Images we see enter the short-term memory or visual buffer (surface representation) and what we ‘see’ is compared with long-term memory (deep representation) for the purpose of recognition. The process is assisted by the mind’s eye or imagination as an interpretive function (Thomas, 1999, p. 212). Building images in long-term memory means that the more you already know about a subject area, the more you will be able to ‘see’ (imagine) in illustrations depicting aspects of that subject, even if you have never viewed particular illustrations previously (Lowe, 2001, p. 3/22). Really seeing or imagining can be practised and encouraged (Kirk, 1992, p. 2).

Another definition is the capability of creating new images from former experiences, pictorially or linguistically (Eisner, 2002, p. 82). This facet relates to the way we construct mental images and/or schema to represent concepts and our ability to construct, adjust and reconstruct these. Imagination is more than putting things into and out of memory and, conversely, memory is more than repeated imagery (Ralston-Saul, 2001, p. 147). Imagination in our language means more than recalling ‘remembered’ images, even though that is involved in some aspects, but it is the creational aspect that produces learning, connecting relational aspects using imagination (Asher & Silvers, 2002, p. 6). Images in the memory are direct representations rather than schema being organised and re-organised. This means that the brain uses imagination to put things and ideas together (Thomas, 1999, p. 218). It is this form of brain operation that remembers relational patterns rather than specific images. For example, electronics technicians who were highly skilled could reproduce proper drawings from memory with only a short viewing. They did not do as well with random drawings (Sweller, 1999, p. 9).

The final definition of imagination is the means to synthesise sensory data into ideas with metaphysical meaning. In this concept the whole is greater than the sum of its parts. Narrative and imagination are closely intertwined. Narrative is about making meaning (Atkinson, 1990, p. 70; Smythe & Murray, 2000, p. 311), so imagination and making meaning must
also be interconnected. Making meaning is an indication that we are more than complex biological machines. There is a social interrelatedness (Willis, 2007, p. 369) in the practice of imagination that is grounded in the understanding that there are intelligences outside the realm of reason (McNiff, 2003, p. 96). ‘If reason is used in isolation from other attributes, imagination, intuition, memory, you end up with linear thought which is an illusion for truth’ (Ralston-Saul, 2001, p. 280).

2.4.2 Ten imagination categories as they apply to electrical physics
From the aspects of imagination above, and from research into imagination expanding or improving activities, the following ten categories have been formulated. The imagination activity categories are problem-solving, spatial relationships, visualisation, abstraction, psychomotor, mental modelling, metaphysics, storytelling, gaming and history. These categories create a framework that represents the interrelationships that occur among the different aspects of imagination and also account for aspects of imagination that are critical in the domain of electrical physics.

During the literature research process, I have developed student imagination activities or exercises that fit into, or across, the ten imagination categories. These are provided below as illustrations.

**Problem-solving**

Problem-solving is an imaginative task using critical thinking (Brookfield, 1987, p. 8; Rautins & Ibrahim, 2011, p. 28) in the scientific world and it is likewise in the electrical physics world (McComas, 1998, p. 18). Understanding, and therefore problem-solving, not only requires reason or critical thinking but also imagination (McNiff, 2003, p. 101; Turchi, 2004, p. 224). An example of imaginative problem-solving is brainstorming or concept mapping (Quinn, 2005, p. 118).

Much of the problem-solving in electrical physics follows predetermined processes associated with the community of practice. These include the
use of algebraic manipulation (Ohm’s law), geometric considerations (phase relationships and complex numbers) and conceptual translations (circuit diagram to a printed circuit board). This demands a mixture of imagination and process skills.

Using interesting electrical problem-solving contexts encourages imagination (Osborne & Freyberg, 1985, p. 118). An example is creating a circuit that will simulate traffic lights. This problem-solving activity is more challenging than it sounds.

**Spatial relationships**

Spatial relationships in imagination are often part of problem-solving and visualisation. The example above of conceptual translation is a typical example, particularly when done in reverse, that is, producing a circuit diagram from a printed circuit board. This is an example of the abstraction of reality and involves mental modelling, an imaginative skill.

Spatial thinking is also related to psychomotor awareness. It is often only through handling an object that one gains all the spatial relationships that allow the imagination to perceive the object as whole (Gibbs, 1999, p. 10). Many of the objects of electrical physics are encoded by spatial properties of the standard three dimensions of height, width and breadth, but there are also other spatial relationships (Miller & Burton, 1994). In a circuit diagram, for example, the supply rails are normally represented as parallels vertically or horizontally indicating a special spatial relationship.

Spatial relationships also play a strong role in mathematics and so are important in electrical physics. The base ten number system is a spatial relationship when written down. The least significant digit is always to the right and the most significant to the left. It is this spatial manipulation ‘that assigns the base ten multipliers’ (Sweller, 2002, p. 274).

In a final example, a farmer builds a dry stone wall. Spatial imagination is at work as he/she selects the appropriate stones visually and then uses psychomotor skills to place the stones to form a wall (Ralston-Saul, 2001, p.
In so doing he/she is using imagination and abstract visualisation to ensure that the selection produces a stone that will fit within the required space. An experienced farmer will be able to do this without actual visualisation.

During the doctoral study the use of three-dimensional block puzzles was used to improve spatial imaginative skills (Boytchev, Chehlarova, & Sendova, p. 5). In another activity the students learned how to tie up to six ‘Scouting’ knots. Once proficient at tying the six knots, the students then had to learn to tie the knots blind folded. The deprivation of sight helped the ‘imagining’ of spatial relationship only through the sense of touch.

**Visualisation**

Visualisation has an important role in electrical physics because of the physic’s non-sensory nature. This is the reason visualisation is important in electrical physics. Many of the mathematical tools require visualisation skills. Two typical examples are spreadsheets and graphs to assist in this visualisation process (Burmark, 2002, p. 53). The spreadsheet as a two and some time three dimensional array of numbers uses visualisations to depict the patterns (Pacey, 1999, p.61), patterns formed by the differences in the numbers. Many electrical characteristics are represented in graphs – for example, the voltage versus current relationship of a diode. Stokes points out that in such a high-image age, we would expect people to be good with visual literacy by now, but this often is not the case (2008, p. 65).

Perception is part of visualisation and is just one step removed from imagination (Thomas, 1999, p. 227). This is the ability to detect patterns that are not immediately obvious. A final example from electrical physics is visualising lines of magnetic force. These lines of force are invisible and three-dimensional and it requires imaginative visualisation to understand the phenomenon (Sencar & Eryilmaz, 2004, p. 109).

As part of the doctoral study the students participated in many activities in an effort to improve visualisation. One of the activities was to improve imagination through drawing for expression. This involved getting students
to draw images of their impressions not the actual subject (McNiff, 2003, p. 73). Another activity was using student-created posters articulating complex ideas or concepts (Jenson, 2007, p. 72). The practising of electrical drawing so that students become familiar with the literacies of this medium of communication is a critical visualisation skill (Lowe, 2001, p. 8/4; Pink, 2005, p. 36).

A metacognitive activity to improve visualisation was students critiquing instructional diagrams and rating them using Lowe’s paradigm for successful instructional diagrams.

Identifying all the relevant information in the diagram and realizing its significance in the context concerned; adding to this diagram information, whatever else is needed to build up a full representation of the depicted situation in the viewer’s mind.

(Lowe, 1993, p. 26)

Abstraction

Abstraction is unavoidable in electrical physics, such is its nature. Lesgold explains abstraction in this way:

Abstraction is what we do when we listen to the [cricket] on the radio. The terms used are terms relevant to situation assessment and adaptation. But they get their meaning from our experience either playing [cricket] or watching it.

(Lesgold, 2001, p. 6).

Abstraction disassociates the context (Brown et al., 1989, p. 92), but in electrical physics the direct action is never available – just the effects. In electrical physics, abstract skills are more about moving back and forth at varying levels of abstraction (Semerez, 2003, p. 168) in an attempt to come as close to the concrete as possible with our mental representations, all this in an attempt to build mental models that represent the material realities (Frederiksen et al., 1999, p. 808; Reiner et al., 2000, p. 29) of electricity that we cannot directly sense.
The use of circuit diagram and the symbols used within them is an example of abstraction. The symbols used differ in their level of abstraction (Lowe, 2001, p. 6/8). An example is the incandescent lamp (light globe). This is represented by a circle with a diagonal cross through it. Less abstract is the diode symbol of an arrow indicating the direction of the current flow. The diode symbol gives the appearance of a non-return valve of types for electron and as such is less abstract. All these symbols put together form an abstract literacy with its sub-texts that must be understood (Down, 2006, p. 97; Lowe, 2001, p. 6/26). This is literally learning to read between the lines of the abstract circuit diagram (Lowe, 2001, p. 1/10).

Abstraction is a helpful and highly valued tool (Gott, 1988, p. 125) in the learning of electrical physics. However students must not only carry out the process of abstraction from reality but must also have the necessary skills to address when, where and in what direction they need to move in the continuum between abstraction and the concrete. Societal values often assume that abstraction is associated with higher levels of technical action when it is often the realm of every day trade practice.

Many of the abstractive imaginative skills activities were based in creating and using open questions to solve problems and tell stories. Getting students to create open questions is a good abstraction activity (Wilson & Win-Jan, 2008, p. 62). Another form of questioning that amplifies learning and abstraction is questioning about metacognition (Osborne & Freiberg, 1985, p. 118) Students also created a story using a word array of electrical terms and resistor colour codes. This encourages imagination and contextualisation (Asher & Silvers, 2002, p. 7).

**Psychomotor**

The use of psychomotor skills, such as the connecting of circuits, handling components, soldering, cutting, shaping and drawing (Lowe, 2001, p. 7/5) allows students, via their senses, to come as close to the phenomenon of electrical physics as one can get. This imagination category brings together aspects of mental modelling, spatial skills and problem-solving that have
physical outcomes that could not be obtained using the aspects individually.

The use of psychomotor skills is closely related to ‘learning by doing’ (Race, 2005, p. 21; Reigeluth, 1999, p. 296) and taking the abstractions of electrical physics into the material world. Psychomotor also assists in reinforcing mental schema, thus improving and making mental models more resilient (Thomas, 1999, p. 220).

To encourage the psychomotor aspects of imagination in the students, drama was employed (Sadow, 1994, p. 1). Students as an activity put together a small drama that represents Ohm’s law.

**Mental modelling**

Mental modelling is a significant imagination category because of the relationship between cognitive schema (Askell-Williams et al., 2005, p. 3) and image representation in the brain (Lowe, 2001, p. 3/3). It is these connections and relationships which enable us to develop mental models and frameworks for understanding. The mental model developed with regard to a particular concept is not photographic in nature but, rather, relational fragments (Ryle, 1968, p. 241). Hence imagination is required to link these fragments and to interpret the holistic picture obtained.

Asher and Silvers assert that, if these images or models of the mind enhance communication, then ‘we believe that the ability of the individual to experience such imagination can be developed’ (2002, p. 1). This is fundamental to the research being undertaken, which is aimed at students generating flexible models by being involved in reasoning activities about electrical physics that encourage constructing and reconstructing ‘run-able’ models (Clement, 2002, p. 28; Gott, 1988, p. 128).

As a way of improving mental modelling skills several activities are suggested in the literature. By way of indication a few examples are provided.
Students listen to some well known music (Tchaikovsky’s 1812 Overture), and then draw one of the mental images the music evoked. The activity encourages mental modelling using imagination (Wilson & Win-Jan, 2008, p. 60).

Silk and Sunshine-Norwood (2002), and others suggest the following types of activities to improve students’ ability to visualise or produce mental images (p. 3): diagram your home from memory; each student describes an object and its story of significance to them.

**Metaphysics**

Narrative and or storytelling create meaning as they recall processes (Brown & Duguid, 2000, p. 95). Such meaning or ideas transcend the story itself and create a metaphysical concept (Mautner, 2000, p. 242; Ralston-Saul, 2001, p. 207).

Metaphysics as an imagination category, in relation to electrical physics refers to direct connection to how worldviews or metanarratives operate and how these treat imagination. In a sense, how people interpret through their worldview marginalises imagination in some way. So this category is concerned with challenging students’ worldviews in relation to imagination in an effort to encourage the use of imagination. The marginalisation of imagination is discussed in further detail on page (p. Error! Bookmark not defined.). Examples of such marginalisation are curiosity not being seen as motivational or imaginative (Rossing & Long, 1981, p. 25) and poetry seen as concerned with dreaming and therefore not important (Silverman, 2003, p. 529). Finally, Ralston-Saul expresses the marginalisation in the following way:

> Any marginalization of this central role of the imagination is an attempt at dehumanization. The denial of imagination as a central quality in the conceptualization of societies is an attempt to deny other.

(2001, p. 128)

The participants of the study examined their worldviews and those of others by completing a confidential survey tool and a discussion about
what they thought were timeless stories. Using survey tools encouraged students to determine what their worldview is and how understanding this will assist their learning (Zinn, 1998, p. 40) by engaging how their worldview considers learning. Getting students to explain what they think are the great timeless stories and what part imagination has played (Ralston-Saul, 2001, p. 250) often gives the student a new perspective to use with their learning.

**Storytelling**

Storytelling in this imagination category is not so much about making meaning as the ability of story to make connections and help deal with complexity (Down, 2006, p. 50). Stories capture emotions and context and link them in ways that engage the imagination (Egan, 2005, p. 12). Stories are cognitive activities that require critical thinking (Brookfield, 1987, p. 7) and that encapsulates a neat package of information, knowledge, context and emotion (Brookfield, 1987, p. 7; Pink, 2005, p. 24).

Storytelling is an imaginative task (Heikkinen, Huttunen, & Syrjala, 2007, p. 15; Marshall, 2005, p. 41). In electrical physics, storytelling is often the means of solving problems and conveying information in technical reports. So the imaginative task in electrical physics uses the capacity of story to manage detail, thus assisting with complexity and continuing to ‘fire the imagination’ (Turchi, 2004, p. 51) as a learning tool.

The students of this study were often required to tell stories. The stories may have been reporting back to the class on assigned learning or reporting the adventures of their last work placement. Storytelling encourages the imagination as the student finds concise and entertaining ways to convey a much longer narrative (Pink, 2005, p. 30).

**Gaming**

This imagination category has two dimensions. The first is that of fun and the ability of something perceived as fun to give participants permission for playing (gaming) with imagination and to be more engaged (Quinn, 2005, p. 15). The second dimension is that of playing games that require strategy.
This is the ability to imagine or see ahead of your opponents in the game or the game itself (Gee, 2003, p. 2).

Strategy games encourage students to use and expand their imaginative abilities. Games also encourage problem-solving in imaginative ways (Turchi, 2004, p. 106), a specialty of the strategy video game. Strategy play allows students to connect facts and manipulate them (Pink, 2005, p. 14).

Gaming and electrical physics are not normally associated directly unless, to provide motivation, one is constructing a video game (or other game) in the process of learning a particular aspect of electrical physics. This gaming category uses strategy gaming as a way of seeking to improve imagination for use in other areas.

Pink (2005) proposes strategy games, particularly electronic games, as a means of kick-starting the imagination (p. 42). Unfortunately, these were too expensive for this study, so I substituted strategy box games – for example, Risk TM, chess (several versions) and Scotland Yard TM. These games encouraged students’ thinking skills as they had to imagine or anticipate what other players might do. Also creating an appropriate level of competition encourages imagination and innovation (Gregson & Little, 1998, p. 373).

**History**

Imagination, electrical physics and history may not seem to have an obvious connection. However the connection rises from reflection and association in relationship with others (Taylor, 2009, p. 9). Imagination assists in relational connections and so it is that imagination is important in the process of reflection (Down, 2006, p. 48).

History whether in the immediate or distant past requires reflective ability and this has an imaginative component (Gelatt, 1989, p. 255). Encouraging students to investigate electrical history not only provides relational connections (Sencar & Eryilmaz, 2004, p. 110) for the physics itself but at
the same time encourages the imagination to be exercised (Egan, 2005, p. 167).

This historical aspect of imagination was encouraged through activities that required wide research. Creativity and innovation was encouraged through wide reading (McNiff, 2003, p. 80), particularly about discoveries and inventors in electrical physics.

This is not an extensive list of activities used in this study, but gives some background in the literature for the basis of many of the imagination activities that were used. For the detail of these activities, see the discussion chapter.

2.3.3 Imagination and associated concepts
There are a number of related concepts that are linked with imagination. These include metaphor, elaboration, curiosity, illustration and image and games which are discussed in this section.

**Metaphor**
Metaphor is one of the strongest indicators of the use of imagination in language and often goes un-recognised (Eliason, 1993, p. 1; Pink, 2005, p. 35; Ricoeur, 1997, p. 303). We use metaphor in our everyday language without much active consideration of the imaginative underpinnings that produce it (Ricoeur, 1997, p. 202). An example is frustrated parents telling their children that they are pigs when it comes to keeping their rooms clean and tidy.

Metaphor is the collision of two categories or ideas that would not normally be linked, and that new insight, understanding and knowledge is sparked by such a ‘collision’ (Gibbs, 1999, p. 18; Mautner, 2000, p. 351; Ricoeur, 1997, p. 83). Metaphor exists in two basic forms of language literacy and visual literacy. The ‘children as pigs’ metaphor, given above is a language metaphor. The picture of a new flower growing out of the pages
of an open book is a visual metaphor, invoking the idea of growth coming through reading (Engeström, 1999, p. 239; Gibbs, 1999, p. 39).

Metaphor has the ability to bring new revelations of reality through the imaginative clash of ideas. Engeström explains the clash this way:

Only by activating its inner system of tensions and contradictions can the content of the metaphor be generated as a new dimension of meaning.

(1999, p. 319)

It is the tensions and contradictions that bring new meaning and with new meaning change and with change activity (Mezirow, 2009, p. 24; Ricoeur, 1997, p. 14).

The ability of metaphor to bring new meaning and so produce activity also creates knowledge (Eliason, 1993, p. 1; Engeström, 1999, p. 321; Gibbs, 1999, p. 229). The knowledge created can be general or specific. By general I mean able to be generalised. An example is the flower and book metaphor: by reading, you will usually learn. Metaphor can also create specific personal knowledge, which is the ability to undertake conceptual thinking and reasoning (Gibbs, 1999, p. 215). An example of this is the conceptual metaphor of a circuit diagram. Its convergence of spatial geometry and abstract symbols sparks knowledge specific to individuals in the way they mentally model electrical physics (Arnold & Millar, 1987, p. 554; Gibbs, 1999, p. 5; Quinn, 2005, p. 34).

Metaphor is a form of abstraction (Ricoeur, 1997, p. 182) underpinned by imagination that allows the student to work innovatively in abstract domains (Gibbs, 1999, p. 220). It is this element of abstraction that makes metaphor and imagination appropriate for electrical physics, given its own abstract nature.

Cazeaux (1999, p. 3) considers that the connection between metaphor and the metaphysical falls into the two competing epistemologies of empiricism and phenomenology. Empiricism argues for the importance of language and the discrete nature of the senses. On the other hand,
phenomenology emphasises the role played by metaphor in understanding and asserts that the senses are interrelated facets of human bodily interaction with the world. Metaphor indicates that we are more than just the sum of our parts. There is a metaphysical dimension asserted by metaphor.

**Elaboration**

Gott (1988) suggests that deep understanding is having and being able to use multiple conceptualisations of the domain of electrical phenomena and that the conceptualisations are perspective of various devices and degrees of elaboration (p. 155).

Elaboration is the ability of the mind to make relational connections (Miller & Burton, 1994; Towne, 1995, p. 129), not only within a particular conceptual model, but between models. As argued by Wilson and Win-Jan (2008), this thinking process aligns with creativity, curiosity, complexity and imagination (p. 36).

Creativity requires elaboration (McMurray, 2002, p. 24) and both are underpinned by imagination in concept creation. Hedegaard (1999, p. 295) considers that elaboration and conceptual modelling are then inextricably interwoven.

**Curiosity**

Curiosity is the deprivation arising from perceiving a gap between knowledge and understanding (Loewenstein, 1994, p. 75). Expressed positively, curiosity is the recognition that arises when one’s informational reference point in a particular domain becomes elevated above one’s current knowledge base (p. 87).

Whilst curiosity and imagination would logically seem to be linked, Loewenstein sees little correlation between curiosity and creativity (p. 79) and so little connection between curiosity and imagination. Following on this, curiosity is used to explain some of the motivation to learn as a
positive emotion but having little substance, being more of a novelty (Kashdan, Rose, & Fincham, 2004, p. 292).

Despite this my research indicates that there are links between imagination and curiosity and this is explained when the outcomes of the research are discussed (p169).

**Illustration and Image**

In the domain of electrical physics, illustrations and images are generally electrical diagrams (circuit, connection, process, mechanical, printed circuit board, graph, representational, flow and single line) and photographs. To be able to use and apply these illustrations and images, visual literacy is a necessity (Lowe, 1993, p. 24). But visual literacy in the image producers or the user of the diagram is as, or more, essential, than the visual literacy required by the text reader (Lowe, 1993, p. 23).

There is no single visual literacy skill, as the skills required vary with each kind of illustrative or photographic approach (Lowe, 2001, p. 6/3). An example is the literacy skills difference in the interpretation of a circuit diagram and a connection diagram. A circuit diagram uses abstract symbols to represent components and the arrangement of the symbols on the drawing has no spatial correlation with the physical location of the material components. On a connection diagram, the spatial arrangement of the graphics does represent the spatial arrangements of the material components. Visual literacy demands in the production of an illustration are important because the selection of a particular illustrative mode (diagram type) will change the visual literacy requirement considerably (Lowe, 2001, p. 2/5). Photography is also extensively used in electrical physics and in each application a particular visual literacy is required. Photo-illustrations can be interactive (Lowe, 2001, p. 8/4) and so require different skills. An example of dynamic use of photo-images is their use in dismantling complex electrical equipment, which is later re-assembled, possibly elsewhere. The visual literacy here is directed towards order and sequence, so it is dynamic. Photographs are often used in the teaching of
high voltage equipment. For reasons of safety and operational use, we can rarely interact directly with high voltage or high energy equipment. In this context, photographs provide a means of safe interaction. The literacy of the images is found in knowing the equipment parts and sequencing the images to show operational use.

Photographs are representational images and are not the complete reality. Photographs do not convey sound, smell or texture that could be important if interacting with the picture of a high voltage circuit breaker. Not everything is conveyed by a photographic image (Lowe, 2001, p. 1/5).

From the symbols of algebra to the symbols of circuit diagrams, electrical physics and its communication tools have always been graphics-based. As new technologies of graphics production and interaction improve through iPhones, iPads and similar devices, the learner’s cognitive load will also encounter new demands (Lowe, 2001, p. 8/15).

**Games: strategy and fun**

This imagination category has two dimensions. The ability of something to be perceived as fun gives participants permission for playing (gaming) with imagination and thus to be more engaged (Quinn, 2005, p. 15). With deeper engagement, games are able to draw from the emotional side of learning (p. 12). This is because emotion and image are related (Mezirow, 2009, p. 25). The second dimension is that of playing games that require strategy, this moves the student into the zone of proximal development (Egan, 2005, p. 31). This is the ability to imagine or see ahead of your opponents in the game or the game itself (Gee, 2003, p. 2). This approach to gaming uses declarative and procedural knowledge for acquiring new knowledge, to develop fundamental concepts and to improve creativity and, in the process, imagination (Gregson & Little, 1998, p. 373).

Strategy games encourage students to use and expand their imaginative abilities. Games also encourage problem-solving in imaginative ways (Turchi, 2004, p. 106) which is the specialty of the strategy video game. Strategy play allows students to connect facts and manipulate them (Pink, 2005, p. 15).

2.5 Research paradigms

2.5.1 Introduction
The research question has driven the selection of the approach in this research; rather than a preferred methodology driving the type of question being asked. The research question is:

*Will being metacognitive about imagination, individually and collectively, assist TAFE electrical engineering students in their learning and application of electrical physics?*

Answering this research question has required a blended research approach based on both action and narrative. Therefore, principle and process from a number of different, yet related research approaches and methodologies have been drawn upon.

One of these research characteristics offered by the theory and process of participatory action research was selected due to the metacognitive requirement of the research question. This approach encourages the students to be direct and expected participants in the process. Such an approach provides narrative data.

In addition, in order to ascertain if the metacognitive approach to imagination has affected the participants’ learning of electrical physics, their stories of the process are collected. These two sets of narrative data provide the rationale for drawing on narrative research methods and approaches.

Overall the research approach is ethnographic and essentially a blending of participatory action and narrative research. The nature of these components is discussed below.
2.5.2 Participatory action research (PAR)

Action research has an inherent cyclic dimension that is qualitative in nature (Gay &Airasian, 2003, p. 166; Kemmis & McTaggart, 2003, p. 4). Action research is also ethnographic as the cyclic process most often involves a defined group of people (Compte & Goetz, 1982, p. 35). In this study the group of people is a class cohort of eighteen full-time Diploma of Electronics and Communication students and their teachers.

The typical action research cycle attempts to solve a real problem or investigate a particular practice (Gay & Airasian, 2003, p. 14; Schwandt, 2003, p. 150). The typical cycle starts with defining the problem/practice, then looking (collect data), thinking (analyse against the problem/practice) and acting (make any adjustments) (Gay & Airasian, 2003, p. 270). This cycle is repeated in a spiral process until the problem is resolved or sufficient has been learnt about a particular practice.

Participatory action research (PAR) has all the hallmarks of action research with two additional dimensions. The first is that the participants are equally involved with, and as, researchers in the process (Kemmis & McTaggart, 2003, p. 345). The second dimension lies in what constitutes the activity in the spiral/cycle. PAR begins with planning change with respect to the problem or practice that has been identified. This step is often more interactive than in action research. In PAR, there is already an idea of what is happening and how it may be changed. The second stage involves enacting and observing the process and the consequences of the change. This stage is more than a single act; it includes reacting. The acting and observing are inter-related, producing some analysis in the process. The third stage is the formal reflection about the process and its consequences. The result is then re-planning, acting and observing, reflecting, and so on (Kemmis & McTaggart, 2003, p. 381).

Student participation operates at several levels. The first is through understanding of the research, its process and its purpose. The next level is
to interact and engage purposefully with the research. The third level involves the students’ individual reflections on the research to make changes at a micro level and suggestions at the macro-level. For participants to be able to thus engage effectively, they will need an understanding of learning including learning cycles (Engeström, 2000, p. 970; Marek, Eubanks, & Gallaher, 2006, p. 189) and learning theory (Brown et al., 1989, p. 40; Illeris, 2002, p. 84). They will also need insight into ‘interview of instance’ (Osbourne & Gilbert, 1979, p. 91), and related techniques used in physics education enquiry (Schwandt, 2003, p. 144).

A significant reason for selecting this approach is that PAR assists with grounding theory in practice, a significant aspect of this doctoral study. This methodology has seven key features that make it appropriate (see Kemmis & McTaggart, 2003, p. 384). PAR is social as it deliberately explores relationships between the realms of the individual and the social. PAR engages people in examining their knowledge and their interpretive categories. PAR is practical and collaborative as it engages people in examining social practices that link them to others. PAR helps people recover, and release themselves, from the constraints of social structure that limit their self-development. PAR encourages critiquing the very culture of language, social media and modes of work. PAR is recursive, helping people to investigate reality with the purpose of change. PAR aims to be transformative of both theory and practice.

PAR is concerned with people, the way they think, act and change. For this reason the data used is always closely associated with the people participating in the project (Smythe & Murray, 2000, p. 317) and is seen as the result of collaboration and engagement (Kemmis & McTaggart, 2003, p. 336). Silverman (2003, p. 101) notes that the participant is no longer the subject, but rather the co-researcher. The PAR approach assists people to work together in community and minimises the differences (Daniels, 2008, p. 24). This community aspect also helps mitigate against the researcher’s hidden curriculum, which is the researcher unwittingly determining a preconceived result (Osborne & Freyberg, 1985, p. 123).
of the same coin is that involving students in their own learning via research will by definition improve their learning (Asher & Silvers, 2002). This is an example of a positive aspect of the Hawthorn effect (Adair, 1984, p. 334). The participants are also producing these narratives in the process of the research (Daniels, 2008, p. 67) and it is these narratives which necessitate narrative research (Heikkinen et al., 2007, p. 16) discussed below.

2.5.3 Narrative research

Reasons for Narrative research

Narrative is a primary way humans make sense of our world and deal with its complexities (Marshall, 2005, p. 52; Moen, 2006, p. 9). It therefore follows that narrative research is an appropriate approach to investigating sense-making (Lieblich, Tuval-Mashiach, & Ziber, 1998, p. 5).

Fielding (2007) asserts that narrative is concerned with communicating the human experience (p. 386). Narrative research is an appropriate approach for this project as it investigates students’ experiences of learning electrical physics.

Narrative provides the audience with access to the world of the storyteller that other approaches cannot offer (Fielding, 2007, p. 385) and allows access to the storyteller’s thinking, both conscious and unconscious (Lieblich et al., 1998, p. 9). Its diversity and depth provides useful information for analysis.

In bringing meaning, narrative also brings context. The contextual aspect is bi-directional and recursive. Narrative not only brings context but also has a context of its own (Daniels, 2008, p. 103). Narrative is ‘therefore’ never neutral (Taylor, 2009, p. 3) and, as narratives are produced, collected and analysed, these contextual dimensions must be taken into account.
Constructing reality

Storytelling, narrative, is wired into us as humans. We tell stories in a social context as this enables us to make sense of reality (Brown & Duguid, 2000, p. 106). This is what is known as narrative in academics. Storytelling in the social context is about relationships and our place within these relationships (Down, 2006, p. 153). From childhood right through to adulthood, narrative is how we learn to put the world together (Marchall, 2005, p. 46). Narrative builds or constructs by creating tension and then releasing the tension. Narrative builds a need to know or shows that there is a lack of need to know. The narrative releases the tension by then providing the answer or at least a strong signpost to the answer (Quinn, 2005, p. 44). This tension plays directly into the human imagination via curiosity.

Finding meaning

There is a connection between narrative and meaning that leads to action (Atkinson, 1990, p. 41; Jarvis, 2006, p. 64; Pink, 2005, p. 26). If the narrative engenders action, change in thinking and behaviour, then meaning has been established. Meaning is also created as the mind builds connections or schemas (Clancy & Lowrie, 2010, p. 44; Daniels, 2008, p. 99; Koestler, 1964). Meaning is also equivalent to the interpretation of the narrative which consequently yields value. External narratives come loaded with meaning received from outside the senses. Internal narratives are created from within one’s own thinking process (Stevenson, 2003, p. 19). Narrative can also have a community dimension or social basis. These narratives are used to communicate meaning (Beautell, 2000, p. 37). Any society has a norm or tradition that is communicated through narrative (Ralston-Saul, 2001, p. 256).

Dealing with complexity

We often think that narrative creates complexity (Silverman, 2003, p. 321). The universe in which we find ourselves is extremely complex and we, as humans, need to make sense of it (Capra, 1975, p. 346). Narrative helps us
to understand the detail of the complexity (Beautell, 2000, p. 37) and to resolve cognitive dissonance or disequilibrium (Edlin, 1999, pp. 224-225; Rautins & Ibrahim, 2011, p. 29). Otherwise overload would occur very quickly (Lesgold et al., 1990, p. 349). So storytelling or narrative is a human ability that is not just about communication, but about the storyteller using imagination in narrative to deal with the complexity; and so improving one's own learning in the process of storytelling (Down, 2006, p. 134) and also brings meaning (Schwandt, 2003, p. 298).

Narrative is a strongly imaginative process (Daniels, 2008, p. 68; Silverman, 2003, p. 456). Finally, narrative is an appropriate approach because narrative is ‘wired in’; it is part of what it is to be human (Lieblich et al., 1998, p. 7).

In the field of education, narrative research has traditionally focused on the teacher rather than the student (Bell, 2002, p. 208) and has not been directly used when researching the learning of electrical physics. Despite this lack of precedents, narrative is an appropriate ethnographic approach (Atkinson, 1990, p. 104) for this research.

**Types of narrative research**

Narrative research is difficult and complex and each type has its particular problematic aspects (Fielding, 2007, p. 389). The reason for the diversity in narrative research approach, and hence some difficulties, is the different versions of social construction from which they emanate (Moen, 2006, p. 2). The purpose here is a brief explanation and examination of the types of narrative and the narrative research types that have been developed in response.

Smythe and Murray (2000) explain that there are three distinct types of narrative (p. 327). The first is personal narrative (Pavlenko, 2000, p. 214). Typical examples are contemporary biography and autobiography. The second type is the archetypical or over-arching narrative. This is sometimes called a worldview. This narrative type is to be found in religious and spiritual texts which reflect fundamental spiritual and existential concerns.
The third narrative type falls between the personal and over-arching. This narrative is ‘typal’ (Smythe & Murray, 2000, p. 327) and attempts to concretely exemplify theory laden categories of social science. Typical narratives include stories of abuse, healing, trauma, discrimination, achievement and affiliation, not at the direct personal level but as a category of experience for a significant group of people.

I present narrative inquiry as a particular type – a subtype – of qualitative inquiry. Contemporary narrative inquiry can be characterised as an amalgam of interdisciplinary analytic lenses, diverse disciplinary approaches, and both traditional and innovative methods - all revolving around an interest in biographical particulars as narrated by the one who lives them.

(Chase, 2008, p. 58)

Chase (2008, p. 59) then goes on to explain that a typical narrative may be a short story around a particular topic, a significant and extended story about one’s life or the entire story of a person’s life from cradle to the present. An example of a short story could be about a meeting with a friend or the story of an event in the workplace. The second narrative type is similar to the first in that it is specific, but also significant and extended. A model of this story type is one’s life and learning at school or in this case of one’s studies at TAFE. The third idea of story is that of a more complete story – in a chronological sense from birth to present.

In stories of life, there are inevitably gaps between reality, experience and expression (Moen, 2006, p. 8). These gaps are time based and occur between the event, the formulation of story and its retelling for the purposes of research. Despite the gaps, this is how people describe their worlds through narrative interview, one with another (Silverman, 2003, p. 343). We need to acknowledge this and account for this in the analytical process (Fontana & Frey, 2003, p. 192).
Analytical approaches in narrative research

Smyeyers and Verhesschen (2001, p. 75) claim that the analysis of narrative is basically a debate over quantitative and qualitative approaches. The narrative method of enquiry is about the challenge of interpreting meaning (Smythe & Murray, 2000, p. 318) and uses both qualitative and quantitative aspects. The persuasive elements of the narrative as ethnographies operate from probabilities, not absolutes, as is the case with all science (Atkinson, 1990, p. 2).

Narrative research allows the researcher to get at information of which those involved are not conscious (Bell, 2002, p. 209) and this allows deeper analysis than that of which analogical mapping is capable (Aubusson, 2002). A typical analytical approach is suggested by Lieblich et al. (1998, p. 13) using a matrix formed from the dichotomies between holistic versus category and between content versus form. This produces the four sub-categories of ‘holistic-content’, ‘categorical-content’, holistic-form’ and ‘categorical-form’ which frames the analysis.

Narrative analysis falls into the three basic groups of structural analysis (Labov & Waletzky, 1997), category analysis (Lieblich et al., 1998) and performance analysis (Riessman, 2001). Moen (2006, p. 7) suggests that narrative analysis is a continuing process and, if this is the case, then the three general forms are unconducive to this study. The analysis of the participants’ stories needs to be progressive in nature and concerned with their learning and modelling of electrical physics. The analysis for this research is not concerned with the structure of their stories, the categories of their stories, and their performance as storytellers. The analysis needs to identify with the emotional (Hager & Beckett, 1999, p. 179) aspects of learning electrical physics within an imagination paradigm and how this works out in action. Lieblich et al. (1998) notes that the bases of any analytical approach should be: comprehensive evidence, coherence, insightfulness and the ability to provide analysis based on a small number of concepts (p. 173). To achieve this analytical approach, I have combined

Focusing narrative research data

The narratives in this project are derived from a series of semi-structured interviews with the participants over fifteen months. The interviews had two foci. The first is the bigger story of the student’s experience of learning electrical physics in a metacognitive imagination paradigm and the second focus is to create data that will provide insight into mental modelling processes within the paradigm. Semi-structured interviewing produces the opportunity for storytelling and digging down into specific areas (Fontana & Frey, 2008, p. 141).

The nature of the questions posed by the researcher affect the narrative obtained. Questions need to encourage a safe environment for storytelling (Foddy, 1993, p. 73), and to keep the question threat low and to avoid driving the agenda (p. 155). The questioning process also needs to engender appropriate reflection (Silverman, 2003, p. 140) and to encourage a level of analysis within the participants as they are doing more than telling stories. They are telling stories in relationship and this implies a level of analysis (Chase, 2008, p. 63). To achieve this, questions must be of the open type (Foddy, 1993, p. 132). A particular type of open question that encourages the participant to reflect on the thinking of others is also helpful (Foddy, 1993, p. 83). This type of open question produces strong reflection and a form of validation through triangulation.

Validity and credibility of narrative research

Heikkinen et al. (2007, p. 8) posit five principles for narrative research that encourage validity and credibility. The first, historical continuity, allows analysis from history of action. The next is reflexivity, which is the adequacy of the relationship between researcher and participants. The third is the dialectics of dialogue, polyphony and authenticity. This is the researcher’s insights, the voices and interpretations, and authenticity of
the narrative. The fourth principle is that of workability or pragmatics. This involves criticality, ethics and empowerment. The final principle is evocativeness, how well the research narrative evokes mental images and emotions related to electrical physics.

The technologies used in this research, for example, the use of digital video recording of the narratives, also affect validity and credibility (Fielding, 2007, p. 313). The narratives will still be messy and clarity will have to be pursued (Mishler, 1990, p. 417). Silverman (2003, p. 178) argues that even though video, technology may appear neutral, it is never simply an aid. It is ecological and the video approach will have ramifications. In the case of video recording, high degrees of validity and credibility can be established not just through recording, but through the availability the technology offers for easy viewing and verification (p. 186).

2.5.4 Blended ethnographies

Because different "lenses" or perspectives result from the use of different methods, often more than one method may be used within a project so the researcher can gain a more holistic view of the setting. Two or more qualitative methods may be used sequentially or simultaneously, provided the analysis is kept separate and the methods are not muddled.

(Stern, 1994 cited in Morse, 1994, p. 224)

As Morse makes clear, blending of qualitative research methods, whether by simultaneous, or sequential use, is appropriate as long as their contributions can be separated from each other. When this is achieved, action and narrative research are complementary.

The context of this research project is classroom ethnographies which includes action research (Kemmis & McTaggart, 2003, p. 340). Action research blends well with ethnography because it is inherently multi-method research, particularly in social research (Schwandt, 2003, p. 144).
The purpose of the research is not to examine a single mono-narrative, but a multiplicity of narratives that cross, connect and interact. The researcher is also engaged in these interactions. This reflects how people describe their worlds (Silverman, 2003, p. 343). It is this multi-dimensionality in narrative that captures the relationships, creates and sustains the relationships (Fielding, 2007, p. 385) and encourages blending different research methodologies.

There is a natural link between action and narrative. As action is recounted, explained or analysed via interview, a story is told (Silverman, 2003, p. 77). In the blending of action and narrative research, the narrative is more than just the outcome of the action research; the narrative research is integral to the process. This natural connection between action and narrative is exploited as an appropriate part of the blending of research methods.

A further reason for a blended approach between action and narrative research is the nature and quantity of the data represented by the number of research participants. The blending of action and narrative with just eighteen student participants will produce a large amount of rich data. The data will be created as stories are told, re-told, enhanced and elaborated. As the research moves through iterative cycles, the narrative will build and the narrative density will increase (Morse, 1994, p. 229).

However, there are negative aspects to blending action and narrative research which must be explained and managed. The most prominent negative aspect concerns validity. Thomson’s (2004, p. 17) five categories of validity – descriptive, interpretive, theoretical, evaluative validity, and generalisability provide a framework for critiquing the blending of methods. The descriptive validity is high because the data are to be video-recorded (Silverman, 2003, p. 295) during all phases of the research. Using a single researcher in this context means that blending the research methods will have little effect on the interpretive validity. Evaluative validity in the blending of action and narrative will be minimal because the
same level of evaluative validity will still apply to both, whether blended or not.

Theoretical validity and generalisability are more problematic. To obtain theoretical validity, the justification for blending must be sound and substantial. Such a justification has been outlined above. Generalisability is problematic in all qualitative research (Thomson, 2004, p. 1) and so it is here. The students of this study have a particular context within their culture and domain of electrical physics; nevertheless, some level of generalisation is possible because the domain of electrical physics is able to be generalised. Generalisations in this research use an approach that is inductive rather than conclusive (Down, 2003, p. 3) and this will aid the validity of the generalisations.

Silverman (2003, p. 95) notes that there is no perfect research approach and this section has demonstrated that the reasons for a blended approach between action and narrative research are appropriate to enhance data density, diversity and validity. The specifics of what makes action and narrative research complementary in the context of this project has also been explained in this chapter.

2.5.5 Analysis approach

Activity theory

Engeström’s activity theory examines the relationship between subject and object mediated through an artefact, and supported by a social framework of rules, community and division of labour (Engeström, 2000, p. 962).

Activity theories are derived directly from the social constructivist perspectives of Vygotsky, Leont’ev and Luria (Engeström, 1999, p. 20). These theories are concerned with the process of learning and or change which examines the relationship between the subject of the change process and the object of the change process. The expansive learning cycle created by these relationships as a collective activity system is equivalent
to Vygotsky’s scaffolding theory of which zone of proximal development is a part (Engeström, 1999, p. 34).

Later theorists have further enhanced the perspectives of Vygotsky, Leont’ev and Luria, to develop a more complex depiction of activity theory which is shown below in Figure 2.1

![Activity Theory Diagram](Engeström, Miettinen, & Punamaki, 1999, p. 31)

**Figure 2.1 : Activity theory (Engeström, Miettinen, & Punamaki, 1999, p. 31)**

Underpinning the activity theory model are rules, community and the division of labour. Rules are concerned with the community or cultural conventions. The community is those people working with and inspired by the activity taking place. The division of labour is controlled by the way labour is compartmentalised by educational disciplines, language and other social structures.

Finally the activity system through the interactions of these relationships produces an outcome. The outcome will be something new, a new intellectual tool or pattern of working together (Engeström, 1999, p. 31).
Activity theory provides a helpful way to examine imagination and the learning of electrical physics. The subject is the learner; the object is the mental modelling required in electrical physics and the mediating artefact is the metacognitive or active engagement of imagination. The outcome is new ways to learn and conceive electrical concepts. It is this purposeful changing or engaging of natural reality that makes activity theory appropriate in the study (Engeström, 1999, p. 39) as meaning is communicated about and through the object (Stevenson, 2003, p. 11).

**Tension field of learning theory**

Illeris proposes three dimensions with special interest in the emotional aspects of learning (Illeris, 2004, p. 82). He proposes that learning is essentially two different processes, external and internal (p. 81). External learning occurs as one interacts with the external environment through social, cultural and material worlds. Internal learning is the physiological processes of elaboration and acquisition as new ideas are constructed and reconstructed or incorporated with prior learning in a way that influences both.

Traditional learning and cognitive psychology have generally conceived learning, thinking, understanding and remembering as cognitive matters. Whatever the frame of reference – common sense, modern management or the latest brain research – there is much evidence that all these functions are inextricably connected with the emotions (Illeris, 2004, p. 81). Illeris explains that the theories of Piaget, Freud and Furth have demonstrated how cognition and emotions separate, but they are never isolated functions (Illeris, 2004, p. 82). Thus learning always has a cognitive and emotional dimension.

The result for Illeris (2004, p. 82) is that the learning process now has three dimensions: the cognitive dimension of skills and knowledge, the emotional dimension of feelings and motivation, and the social dimension of co-operation and communication. All three dimensions are embedded in a socially situated context represented by Figure 2.2.
As Illeris (2004, p. 83) explains:

The cognitive dimension is the dimension of the learning context, which may be described as knowledge or skills and builds up the understanding and the proficiency of the learner. The endeavour of the learner is to construct meaning and the ability to deal with challenges of life and thereby develop an overall personal functionality.

The emotional (or psychodynamic) dimension is the dimension encompassing mental energy, feelings and motivations. Its ultimate function is to secure the mental balance of the learner, and thereby it simultaneously develops a personal sensitivity.

The social dimension is the dimension of external interaction, such as participation, communication, and cooperation. It serves as the personal integration in communities and society and thereby also builds up the sociality of the learner. However, this building up necessarily takes place through the two dimensions.

Thus, the triangle depicts what I see as the tension field of learning in general and of any specific learning event or learning process as stretched out between the development of functionality, sensitivity, and sociality - which all together are precisely the fundamental elements of what we call competence.
It is the emotional dimension (Daniels, 2008, p. 104; Egan, 2005, p. 215) of Illeris’ learning theory, often lacking in similar theories that, combined with activity theory, will form a new analysis paradigm or extended analysis approach.

2.5.6 A new analysis paradigm or approach blend from Activity and Learning theory

Overview

To create a richer and more holistic analysis paradigm, I have not only blended the research methodologies of Engeström (1999) and Illeris (Illeris, 2003), but also their analysis paradigms, so as to bring multiple lenses to the analysis (Morse, 1994, p. 224). Both these analytical paradigms take a clear approach that creates colour, contrasts and exposes problems that are brought into focus by the research question— the requirement of any analytical approach (Silverman, 2003, p. 353).

Activity theory and tension field of learning have synergy at three main points. This is shown in Figure 2.3 below.

![Figure 2.3: Activity and Tension field of learning](image-url)
In the figure above, activity theory (shown in blue), the larger triangle, has three points representing subject, object and community. These three points match the representation of the tension field of learning (figure 2.10). This is represented in Figure 2.3 by the green inverted triangle. Emotion is connected to the subject because the subject is the person learning (Silverman, 2003, p. 48). Cognition is linked to the object (Stevenson, 2003, p. 11) because the object is what is being learnt. Finally, the basic commonality is context as both perspectives use community and society. It is this three-way connection that makes the blending appropriate.

Both activity theory and the tension field of learning have strong components of action and narrative. This again lends strong support for this analysis approach when combined with the methodological approach of action and narrative research as applied to the research question.

Other analysis methods have been investigated and have fallen short in matching the research methods. The other analytical methods considered were free listing; paired comparisons; frame substitution; compartmental analysis; and taxonomies (Silverman, 2003, p. 262).

**Combining of Activity and learning theory**

Combining these paradigms chronologically provides a helpful way to understand the reasons for the connections. Dewey and Vygotsky were thinking along similar but different lines at the same time, unaware of each other’s ideas. Using their works as a basis, we can examine the relationships and connections.

![Figure 2.4 Social activism theory](image)

*Figure 2.4 Social activism theory*
Dewey’s social activism theory asserted that learning comes through social experiences (Roblyer & Doering, 2010, p. 39). As indicated in Figure 2.4 above, the individual subject grows through social experiences (broken line) fostered by hands-on activities with the object (orange oval), that which is to be learnt. The outcome is contextualised real-world problem-solving. For Dewey, learning requires social interaction among students on problems that directly affect them. Learning activities should stress collaborative activities and real-world connections.

**Figure 2.5 Scaffolding theory**

Vygotsky’s original model of the mediated act or scaffolding theory (Figure 2.5 above) represents learning as cognitive change shaped by individual differences and cultural influences. Vygotsky says the individual is stimulated to learn through mediated acts which produce learning response outcomes, and all this is situated within the cultural context. This picture is recast by A. Lent’ev (Figure 2.6 below).
The common representation above (Figure 2.6) inverts the triangle to indicate social and cultural contextualisation. The subject is now the person being stimulated to solve a problem or achieve an objective. The subject learns to solve the problem through the use of a mediated artefact. The subject, using the artefact to learn in the cultural context, moves closer to the object. Once close enough, learning takes place. This proximity to the individual’s learning objective is what Vygotsky called the Zone of Proximal Development (ZPD) (Roblyer & Doering, 2010, p. 40). The complete theory is scaffolding theory, where learning works best when students get assistance from experts to build on what they already know. Also, each learner’s background shapes how they learn. In scaffolding theory, instruction should be tailored to each student’s individual needs and preferences.

The next step is to examine how Engeström’s activity theory integrates social activism theory and scaffolding theory and then extends them.
Activity theory is built on the mediated act as the subject performs an activity through a mediating artefact focused on the object of a problem, see Figure 2.7. The outcome is learning and the making of meaning. As with social activism theory, the subject learns through social experience; but scaffolding theory is more specific. Learning comes through particular social activities, however, the activity is also mediated through an artefact of some kind. In electrical physics, for example, learning of connecting resistances in series and parallel (object) by students (subject) is often mediated through the use of example resistors and a multimeter. The resistance examples and meter become mediating artefacts in learning to distinguish series and parallel. The result (outcome) is that students are able to connect many electrical components in series and/or parallel.

The learning activity is now also underpinned in the social context generally and specifically as we move towards Engeström’s activity theory (2000).
Specifically, the underpinning and social influences are rules, community and the division of labour. The rules are the social contracts within any organised social collective. Community refers to general social relationships. The division of labour is how the culture manages and brings definition and purpose to people’s lives. The learner is shaped by the culture, but the culture is also shaped by the individual learners within the collective. This is activity theory.

In learning electrical physics the rules have two levels. The first is the rules of physics, normally expressed as laws. The typical example of this is Ohm’s law, algebraically expressed as \( V=R*I \). The second level incorporates the social rules about formal learning in vocational education and training. One general example of these social rules or contracts, somewhat simplified, is that it is the teacher’s responsibility to do all the teaching and the students’ responsibility to do all the learning. In this study we moved beyond these rules into interdependent teaching and learning as a benefit to all as posed by part of the research question in relation to learning collectively.

Community and culture has many dimensions as it underpins learning, formally and informally (Eisner, 2002, p. 74). For this study and in learning electrical physics, the community of learning in a class is primary. A secondary but significant community is the workplace to which these students are strongly connected as full-time employees and through making many workplace visits during their two year training program.

Part of the workplace community is the division of labour which forms the third dimension supporting activity theory. The division of labour in this learning context affects the way the learner is valued. Different occupational levels have varying assigned values ranging from teacher and manager at the higher end to trainee or apprentice at the other. This is how culture and society manage their members.

The sides of the prism have been explained according to activity theory – that is, if you view the activity theory Figure 2.8 above as a flat two-
dimensional polygon and fold the apexes of artefact, rules and labour together, it will form a triangular prism whose sides are activity theory.

Forming the base of the new prism or paradigm is Illeris’ tension field of learning (Illeris, 2003), which has two dimensions in tension. The first is internal, between one’s emotion and cognition (Figure 2.9); in the second, external society pulls, not in an opposite direction, but perpendicular to the internal dimension (Figure 2.9).

![Figure 2.9 Tension field of learning, part 1](image)

The internal tension between emotion (subjects) and cognition (object) produces learning and creates meaning. As the subject’s emotions work to find solutions using cognition posed by the object, internal meaning is created (Egan, 2005, p. 214). At this point, internalisation has no context outside the subject. Because of its non-sensory nature, in learning electrical physics, students often experience fear as they attempt to form mental models without trying them in the external world. The tension or fear expresses itself as a wondering about having correctly understood an electrical concept.
The model’s second dimension, see Figure 2.10, is the external world as perceived through the senses using imagination (Eisner, 2002, p.4). It is in adjacent tension with the internal. Society is involved, interacting with the internal to produce a tension learning field where meaning is contextualised and learning is expressed. As already mentioned, once the student has the opportunity to try the newly learned or formed concept externally, by physical experimentation or in the social interaction of talking with others (Brookfield, 1987, p. 211), when this learning conformation occurs, fear is released and meaning has been made.

Tension field of learning theory, through its attention to the place of emotion in adult learning, an internal learning process, enhances the application of activity theory by added depth of analysis.
Now the connection between activity theory and tension learning theory can be made. Figure 2.11 above demonstrates the connections between the two learning theories.

The green triangle, representing the tension field of learning is now placed inside the activity theory diagram. Society and community align because there are close parallels in both theories. Emotion and the subject are similar because emotion is part of being a person (subject). Cognition and object align because this is the intersection of problem-solving, sense-making, meaning creation – and the outcome is learning.

With the two learning theories connected, a few more steps are still required before a new paradigm is established. The first is to understand that emotion must do more than just connect the theories. Emotion must now reform activity theory. Emotion reforms activity theory by impacting on rules, division of labour and mediating artefacts, this is represented in Figure 2.12. Emotion re-forms and refocuses the rules by redefining them in terms of what enables or limits learning. Emotion re-forms the division of labour in terms of interpersonal and learning relationships (Taylor, 2009, p. 13). Finally, emotion re-forms the mediating artefacts and refocuses these in terms of effectiveness and motivation for learning by being sensitive to what it is to be human.

Emotion affects the rules in that the rules are challengeable and context-sensitive. Now, using emotion, wisdom becomes part of rules. Wisdom does not change the rules, but perceives the rules as enabling rather than restricting. For example, in most learning situations, if students are given no rules for a learning activity, most respond with difficulty. Apparently, freedom is not so easy. A few rules give undergirding support and direction and reduce the emotion of apprehension and encourage the emotion of creativity. Conversely, too many rules bring back uncertainty, stifling creativity and so it is that wisdom is required.

Emotion affects relationships by making the learner aware that there are relationships in the first place. Emotion reforms the division of labour again
by bringing wisdom into the context. Simply put, not everyone can be the manager. Wisely understanding your relationships with self, your present skills and another is an emotional skill.

Emotion will affect a mediating artefact: what, where, with whom and why it is being learnt. Emotion will re-form learning preferences and therefore the artefacts used. For example, the emotional state of a class after lunch is often one of sluggish depression. Using the artefacts of pen and paper to write may not be appropriate. The artefact of drama or role play to achieve the same end will probably be more effective and so emotional mood may direct and alter the choice of mediating artefact.

![Figure 2.12 Effect of emotion combining activity and tension field of learning](image)

The last step in the new prism paradigm is to take the new re-formed aspects of activity theory—effectiveness of community, enablers of learning and interpersonal relationships—into the apex of the prism. As this is done, tension field of learning forms a new base while a re-formed activity
theory becomes the face in the new prism paradigm indicated in Figure 2.13 below that will appropriately engage the research question with regard to learning and imagination in the context of TAFE.

![Diagram](image)

**Figure 2.13 Final combining of activity and tension field of learning**

2.5.7 Sample size

The literature is not clear on what is considered to be a valid sample size in qualitative research. Clearly the sample size will depend on the context in which the research is being conducted and the degree of agreement with participant responses. The acceptance of the research outcome will also have a relationship with the sample size. For example:

> A study of 25 interviews may suffice for certain small projects but invites scepticism when the author's claims are about, say, human nature or contradict established research.  
>  
> (Charmaz, 2006, p. 114)

There is no agreement on an optimal sample size that fits the size of this study and the sample size is usually limited by time and resources available. Thompson (2004) compared the sample size of fifty research studies and concluded that;

> The average of all fifty studies was 31. After removing the one study with a sample size of 350 the average was 24; the range became 5 to 93. Seventeen of the studies used sample sizes
between 20 and 30, seventeen used between 10 and 19, eleven used over 30, and five used under 10. ... As demonstrated by the literature review saturation normally occurs between 10 and 30 interviews.  

(p. 13)

Silverman (2003) writes that:  

A single case may be sufficient to display something of substantive importance, but Morse (1994) suggests using at least six participants in studies where one is trying to understand the essence of experience. Morse also suggests 30-50 interviews for ethnographies and grounded theory studies.  

(p. 274)

In this research a single class cohort was used. This consisted of eighteen students who were interviewed at least twice over three cycles resulting in one hundred and eight interview transcripts.

2.5.8 Ethics  

Ethics, in the context of this ethnographical study, is concerned with the treatment of people within the research process. The treatment or concern for people’s wellbeing is that which relates to their physical, mental, emotional and spiritual states (Smythe & Murray, 2000, p. 314). Ethics is also concerned with people’s ownership and recognition of physical and intellectual property. All these aspects then combine and inform one’s right to reasonable privacy.

The ethics of research are managed through obtaining open, free and informed consent. The problem is what is meant by open, free and informed (Smythe & Murray, 2000, p. 313). The process of being open and transparent is not difficult, but the researcher must not only be open, but seen to be open. Being informed means that participants must be aware of all parameters of their involvement in such a way that all perceptions of deception must be actively eliminated. The larger problem is that of freedom, which has both a logistical and a power dimension. The logistical problem relates to the research participants giving consent to something they probably have not experienced before (Silverman, 2003, p. 88; Smythe & Murray, 2000, p. 321), so they do not know what significant information
may be missing. The power problem is one of relationship between the researcher asking and the participant being asked. In this study, the researcher as teacher has a position of power in relation to the participant who is a student. All these issues can be minimised by managing the relationships appropriately at all times and at all levels (Smythe & Murray, 2000, p. 313).

An important component of ethics is privacy. This is managed by separating out personal data or masking it through the use of aliases (Smythe & Murray, 2000, p. 314). It is important that participants are not viewed simply as sources of data as these data reflect their identities. They must be honoured and the participants appreciated for the data they will produce (Smythe & Murray, 2000, p. 317). In the process of collecting personal narratives through deep interviews, the researcher will have to be constantly aware of the ethics of what can and cannot be asked (Silverman, 2003, p. 91).

Ethics affecting the participants are important but so are ethics affecting the context of the study. This study must respond to the ethical requirements of any institution from which the participants are drawn (Silverman, 2003, p. 54). In this case the institution is a large registered training organisation in NSW. The process of gaining consent from the institution and managing the inherent bureaucracy will be a process of negotiation and information (Smythe & Murray, 2000, p. 330).

Once the ethics of consent, interviewing, recording and context have been addressed, then the ethics of interpretation of the narrative data must be considered. There needs to be a balance between the researcher’s interpretive authority (Smythe & Murray, 2000, p. 325) and ensuring the voices of the participants (Fielding, 2007, p. 344) are heard. This connection is managed through strong relationships between researcher and participants.

An external ethical concern is that of research sponsorship (Fielding, 2007, p. 341). The sponsorship can take many forms: money, time and people,
for example. In such cases, researchers must ensure it is clearly declared and that any external requirements and conditions are clearly represented. There are no external sponsors of this study and no incentives have been offered or accepted. However as a university student, limited support has been provided from the Research Council of Australia through university processes.

The outworking and implications of ethics for this study and their management are to be found in the next chapter (pp. 93-122).

2.6 Contributions to the formative cognition of the participants and imagination

2.6.1 Treatment of imagination in much of fictional literature

Literature, fictional or otherwise, is an obvious product of the imagination. In many cases it works to exorcise it from the ‘real lives’ of individuals of five year plus. Examples of this are the stories of Henry or Peter Pan or the ordinary boy in ‘Once Upon An Ordinary School Day’ and Randolph in ‘Randolph’s Dream’. The over-arching narrative in these stories is contradictory as they use imagination to marginalise imagination in the adult and children’s world. The reason for this illustration is to demonstrate that much of the literature of my students’ younger formative educational years has worked to marginalise imagination in their thinking. To illustrate this narrative and marginalisation process an analysis of the story of Henry follows.

**When Henry Caught Imaginitis**

Henry is portrayed as a very serious boy who likes doing sums and straightening things that are wonky. The choice of black and white graphics consolidates this image. One day, Henry has a thought that does not make sense and he is suddenly carried off into the world of sailing ships. He is very confused. At this stage in the story coloured illustrations are used to
represent the change that ‘imaginitis’ has on Henry. That night at dinner
Henry has another silly thought about a red dragon and he climbs under
the table to fight the silly thought. Henry’s silly thoughts continue to get
bigger and bigger. Henry’s solution is to read the *Big Book of Sensible
Things* in an effort to eliminate the silly ideas. Henry decides there is
something wrong with him and again consults the *Big Book of Sensible
Things* which indicates that having silly thoughts, indicates that he has
cought ‘imaginitis’. The only cure, the book says, is to wait until he grows
up.

Henry knew just what to do while he waited.
He built a wonky castle, fit for an imaginary king.
‘But just until I grow up’, he said.
And that, Henry thought was a very sensible idea.

(Bland, 2008, p. 31)

The emphasis in the concluding pages of the book is “Just until I grow up”.
This beautifully illustrated and imaginative children’s book unfortunately
teaches that, in Western culture, imagination is the domain of children only
and that this childhood disease will be eliminated by maturity, by growing
up.

A number of such children’s books convey the same irony in so far as
authors of creative literature write about imagination as abnormal. There is
also a contradictory thread in the way we categorise narratives as fiction or
non-fiction. Books of fiction invite the reader to exercise his/her
imagination, where as the term non-fiction implies strict adherence to
truth. The category of non-fiction infers a lack of the value of imagination
to the point of marginalisation. In fields such as drama or art, imagination
is valued. However, young children are often taught that imagination and
facts or fiction and non-fiction are mutually exclusive. In fact it is not only
children because these are the very categories of all our libraries, fiction
and non-fiction. The message is clear: imagination has little relationship to
reality. My study provides support that this is not the case.
Ralston-Saul makes the point this way: ‘Think of the two words: fiction and non-fiction. Or fiction and fact. By opposing these two categories, we tell ourselves that fiction is not factual and is therefore not true, but is ‘imagined’ and is thus somehow cut off from reality’ (2001, p. 205).

2.6.2 Narrative and imagination
Narrative takes several forms and styles. Lieblich proposes eight forms of narrative: ascending, descending, constant, moratorium, trial and error, slow ascending, risk and gain, and risk and descent (1998, p. 95). The participants’ stories show many of these characteristics. For example narratives of risk and gain are quite common as are small cycles of tension and release, which Quin (2005, p. 44) identifies as characteristic of trial and error narratives. There is also an aspect of improvisation (Brown & Duguid, 2000, p. 126) that is based in imagination. This is to be expected as narratives are inherently multilayered (Bell, 2002, p. 210). The classic narrative genres of romance, comedy, tragedy and satire (Marshall, 2005, p. 44) used by the participants will be limiting in the sense that these styles do not account well for the pedagogical aspects of mental modelling in electrical physics.

Narrative is relational as it requires a storyteller and a listener (Jarvis, 2006, p. 57). Teaching and learning is, thus, a narrative relationship (p. 64). Embedded in the idea of relationship and learning is that narrative conveys and creates meaning as a way of understanding (Clancy & Lowrie, 2010, p. 2). Narrative, by its very nature is abstract, since the experience being conveyed must be at least one step removed from its original context. The meaning of narrative is also an abstraction. More than this, it is the demonstrational ability to do (Stevenson, 2003, p. 19). Narrative is about making sense and meaning (Daniels, 2008, p. 99; Mishler, 1990, p. 430). Once a story is told, meaning arises (Tredinnick, 2006). This is the reason that narrative enquiry rests on the epistemological assumption that this is how humans make sense (Bell, 2002, p. 207).
Chase (2008), explains that narrative not only creates meaning but, in doing so, has a social dimension and is present in all ages, places and societies (Chase, 2008, p. 57). The social dimension of narrative ranges from metanarrative to a story between two people (Willis, 2007, p. 369). The social dimension of narrative is seen in national stories that bring together diverse personal narratives (Beautell, 2000, p. 37); so these narratives are a co-production of the culture (Fielding, 2007, p. 390; Marshall, 2005, p. 39). Narrative meaning is socially constructed, negotiated and can change over time. It is a way of defining reality, not necessarily truth (Daniels, 2008, p. 364; Morse, 1994, p. 39).

Narrative is concerned with learning and this occurs through social interaction (Down, 2006, p. 153). Narrative assists and facilitates social learning because it has the capacity to deal with much complexity (Down, 2006, p. 50; Quinn, 2005, p. 10; Smeyers & Verhesschen, 2001, p. 77). This becomes most obvious in game play that focuses on learning (Clancy & Lowrie, 2003, p. 6; Quinn, 2005, p. 15). Sandberg (2000) provides an example of the nexus between narrative, learning and complexity when he describes photo-copier technicians telling stories at break times. In this example, the shared stories were formalised into a data base so all technicians could benefit from the narratives that helped solve complex problems (p. 65).

Narrative is an imaginative task (Marshall, 2005, p. 41). Pink (2005, p. 16) explains narrative as requiring design, story and symphony. It is the symphony that uses the imagination as part of the narrative process. Pink (2005, p. 17) argues that life is more than philosophical argument; it is story. The ability to perceive the difference requires imagination. Narrative not only creates with imagination, but it is imagination that often fills in the gaps in a story. Turchi (2004, p. 43) makes the point in explaining the use and development of maps used in train carriages to list stations on each line. They have little detail and have only rough geographical accuracy. Travellers use their imagination to fill in the detail and amend the geography and so the diagram is able to convey the story of travel.
Bell (2002) notes that the analytical approaches to narrative are varied and allow the researcher to access information that is not consciously available to the participants (p. 209). In education, most narrative research studies have focused on teacher education and stories that inform teachers’ practice (p. 208). This study focuses on both. Various narrative approaches are built on the assumption of social construction of meaning, even though there are different versions of social construction (Fielding, 2007, p. 338; Moen, 2006, p. 2). As narrative is a strong way by which we produce meaning socially, it is appropriate for investigating ethnography (Atkinson, 1990, p. 128). Even in the process of narrative analysis, storytelling will not replace analytical thinking. Rather, it supplements it by allowing the use of imagination to preserve new perspectives (Pink, 2005, p. 26). The various approaches to narrative analysis are basically concerned with form or content (Lieblich et al., 1998, p. 113). For this study, the form of the participants’ narratives is of little importance and the content is only indirectly interesting while the opinions and thinking that have produced the content are highly significant. So a new paradigm is needed to assist in the narrative analysis. To this end I have proposed the connecting of activity theory and tension field of learning theory as explained in the next chapter on (pp. 93-122).

2.6.3 Metanarrative and imagination

Worldview and metanarrative may be inseparable (Parks, 2000, December, p. 2; Thompson, 2005, p. 23) but the intention here is to examine general narrative aspects. Thompson (2005) notes that the culture does not produce the metanarrative but, rather, the metanarrative shapes the culture (p. 63). Hence, it is important to explore metanarrative from the story perspective. The narratives that shape culture operate primarily at a national level and then within the sub-cultures of a nation. There are also cross-cultural metanarratives that shape communities, for example, science communities (Pedynowski, 2003).
For my nation of Australia the metanarrative seems messy. The authors of *Imagining Australia* (Duncan, Leigh, Madden, & Tynan, 2004) have suggested the Eureka over the ANZAC story. Jenson (2005) disputes this as these narratives are illustrative and are short on imagination (p. 20). Each focuses on justice, a fair go and the values of egalitarianism. These are the spiritual concerns of the nation and this is what a national story does (Duncan et al., 2004, p. 51). The current narrative is mainly secular and humanistic rather than Christian as it once may have been. However it is interesting to note that Duncan, while talking about national growth, unwittingly references the Bible (Duncan et al., 2004, p. 177).

Metanarratives, like all narratives, create meaning, and this meaning carries authority because metanarratives are unifying (Pedynowski, 2003, p. 744). It is this authoritative aspect that creates conflict when different metanarratives interact. When this happens, the challenging narrative is a counter-narrative until, as often happens, the counter-narrative becomes the metanarrative (Li, 2003, p. 183).

Examples of other metanarratives and counter-narratives are the science metanarrative (Pedynowski, 2003, p. 745) of modernism and the counter-narrative of social Darwinism. A sub-narrative of these is technicism (Thompson, 2005, p. 74) and Arnold Pacey in his book ‘*Meaning in technology*’ (1999) explains that this has been historically the case. It must be remembered that none of these narratives are neutral (Edlin, 1999, p. 28; Pacey, 1999, p.171). They all have underpinning assumptions and agendas – that is what a metanarrative is (Grenz, 2000, p. 237; Pearcy, 2004, p. 114). For me as a researcher in TAFE there is also conflicting metanarratives of the TAFE, that historically were once used to set the training agenda and now that narrative often conflicts with the national training agenda set by industry skills councils. The metanarrative conflict being that, TAFE the narrative has been one of technical constant improvement in an upward direction, while the new story is on of minium qualification and minium competencies that satisfy the production needs of industry.
Imagination and metanarratives are often found together in the literature. This is a reflection of the way imagination is generally treated in any culture. The authors of *Imagining Australia*, call for the use of imagination in building nationhood; ‘If Australia is to fulfil its potential, we need to rejuvenate our imagination’ (Duncan et al., 2004, p. 3). The result is that we are all in the construction game, whether scientist, politician, theologian or philosopher (Grenz, 2000, p. 248). This construction is not only the intellectual-rational, body-sensual but also the [metaphysical area of the] emotional-affective (p. 171).

2.6.4 Metaphysics and imagination
‘The metaphorical exists only within the metaphysical’ (Ricoeur, 1997, p. 280). If this is so, then there can be no doubt that the metaphysical is real because we use metaphor every day.

The metaphysical is connected to narrative and metanarrative because all are concerned with relationships (Ralston-Saul, 2001, p. 256). That is the way we as humans connect things to make sense or meaning and therefore knowledge. This knowledge is then remembered in a relational fashion (Jenson, 2007, p. 67). The direct links to the sensory world are concrete knowledge. The indirect links and interconnections are the abstractions of metaphysics. The ‘how and why’ of these connections is the unfathomable part of metaphysics. Depending on whether we believe we are created in the image of God or are the result of a big bang, what forms in our minds is our reality (Kirk, 1992, p. 20).

The reason for the consistency of our reality is demonstrated in Bell’s theorem (Capra, 1975, p. 346), that is, that the cosmos is fundamentally interconnected, interdependent and inseparable. It is this consistency and interconnectivity that requires and empowers imagination, giving us the ability to imagine the possibilities (Ralston-Saul, 2001, p. 171).

The relationships of metaphysics are all-encompassing and are not restricted to sensory apparatus or the neural paths of the mind, but also...
connect to the emotional world of love, kinship, friendship and sex (Schwandt, 2003, p. 317). This holistic view expresses what it is to be metaphysical. If not for the metaphysical there would be no imagination or requirement for it. It is the metaphysical that allows us to abstract and the imagination is the glue that links the complexities of stories together.

2.7 Consolidation
This literature review has ranged across a diverse profusion of domains as the investigation into imagination and electrical physics has no single niche in the literature.

Research into electrical physics over the past thirty years has focused on DC with very little research into the learning of AC. Most of the studies over this period have investigated more the aspects of problem-solving using standard modelling systems, the most common being algebra in the learning of electrical physics rather than the physic or the phenomenon itself. Only one major study of this period examined electrical physics in relation to mental modelling and that study has provided some signposts. The literature provides no mention of the nexus between electrical physics and imagination.

The majority of research around mental modelling and imagery is found in the domains of graphic and performing arts and in written expression. The use and understanding of imagination is limited by the narrow definitions that result from the underpinning assumptions of most of the major metanarratives or worldviews.

A significant amount of research work in electrical physics examines conception and misconception. Important in this area is research which investigating anecdotal concepts of electrical physics using an ‘interview of instance’. Other significant research examines ‘learning from doing’ as opposed to ‘learning by doing’.
At the centre of the imagination study literature review are the eight definitions developed for imagination, a reminder of the complexity and diversity of imagination. From these definitions are derived ten imaginative skills categories.

As an approach to research methodology and design, an appropriate ethnography has been determined to engage and answer the research question. The blended approach of activity theory and tension field of Learning theory in concert with action and narrative theory allows the student participants to express the stories of their learning.

The final domain of formative literature of many of the participants and imagination is significant because the assumptions or worldviews created that will impact the engagement of imagination. The literature surveyed indicates that imagination is commonly seen as the realm of children with little part to play in adult education.
3.1 Introduction
This chapter discusses the three main areas of research organisation: typology, methodology and design. The typology examines the nature of the research and appropriate approaches given that this research is essentially ethnographic. The methodology involves a new analysis paradigm and its application to the analysis of narrative data. The design includes the recognition of the synergy between participant action and narrative research in order to create both student engagement and narrative data.

The research reported in this thesis results from the following research question:

*Will being metacognitive about imagination, individually and collectively, assist TAFE electrical engineering students in their learning and application of electrical physics?*

The research design deliberately encourages the participants to be co-researchers, responsible for their own learning and acknowledging the reasoning behind learning from an imagination paradigm. The research is designed to generate and capture qualitative data that can be analysed by the methodology and the overall process to answer the research question. This will be achieved by the parallel blending of narrative and participatory action research.

The research methodology and design was developed to encourage the active engagement of the participants over multiple cycles. This would give the opportunity for new insights by the researcher and participants to be explored, refined, exploited and recorded. For me, as formal researcher, all this was to give greater understanding in the light of the relevant literature.
3.2 Typology of the research

3.2.1 Background to the research approach

The phenomena of electrical physics are not constructed but discovered. The representation systems used to understand and manage the phenomena are constructed and form our knowledge of the phenomena.

The research approach is not concerned with the particular representational systems of electrical physics (for example, algebra, geometry, analogy and metaphor). It focuses on how electrical students may use imaginative skills to enhance the constructive mental modelling systems of algebra and metaphor to better learn electrical physics.

The research approach is based on a social constructivist and cognitive constructivist approach to teaching and learning as expounded in the literature review (p.26). These two approaches are chosen predominantly for their strong synergies and because learning of electrical physics is equally declarative more often than procedural.

The declarative aspects of electrical physics are well accommodated by a cognitive approach to learning through memory schema and other cognitive approaches. A constructivist paradigm is well suited to the procedural elements of electrical physics through the processes of mental model construction and re-construction. Neither approach on its own is complete.

The research question (p.93) has driven the choice of research method, not vice versa. The question was developed during the candidature process in order to formalise the focus of the research, and the research process was developed as the one most suited to illuminate and resolve the question. This research addresses learning of the phenomenon of electricity and the theoretical representational systems used to describe it. Therefore the research is largely qualitative, examining the themes of the participants’ thinking as they attempt new ways to learn about electricity.
3.2.2 Qualitative research

Electrical physics and education are very different paradigms. The first is concerned with understanding the physical world often through empirical means, whilst generally education is concerned with how people understand the world socially. Hence in research concerning electrical physics education both quantitative and qualitative approaches will intersect with the emphasis on qualitative.

Electrical physics is framed by theories, rules and laws. This is the world of empirical science where the rules are fixed and there is only one correct answer. This is the quantitative world where most things can be counted and measured with a reasonably high degree of accuracy and consistency. Smythe and Murray (2000, p. 318) argue that no research approach is completely quantitative or qualitative. To expand, all research has a proportion of both aspects. This doctoral study for example is largely qualitative as participants opinions about their learning are investigated and examined. But at the same time, there are supporting quantitative aspects to the study, and these are not as predominant. An example of this is the use of simple statistics to indicate how often a particular theme is indicated by the participants.

In this doctoral study, quantitative approaches are used as a way of indicating the depth and breadth of the data without having to quote all the data to bring a point or theme into focus. The quantitative aspect of the study involves the use of some simple numerical quantities and ratios for descriptive purposes and to make the large quantity of data manageable for the reader.

However this study is basically about a field of electrical education, which is that of social science. It draws on the perception of people in social learning contexts. Its salient foci are, firstly, social and cultural aspects of learning electrical physics and, secondly, how people may be supported in constructing mental representations of electrical phenomena.
Qualitative research design approaches in social learning which have guided this study are discussed in chapter 2 (pp.12-91). It is this common qualitative basis that allows the approaches to work together either simultaneously or sequentially.

The overall approach to the research design focuses on theory grounded in educational practice. The research seeks to determine a link between the development of imaginative skills and efficacy in learning electrical physics. To achieve this, the participants applied imaginative skills to their learning and reported on their perceptions regarding the effectiveness of this strategy.

This research has not investigated existing practice already found in the educational environment of electrical physics and abstracting this practice into a theory. Instead the research focuses on whether or not improving metacognition skills can increase learning efficacy.

3.2.3 Research focus
The research aims to improve students’ abstract electrical modelling skills through improving imaginative skills. This involves the students understanding how they learn and strategies that can improve their learning. Therefore the focus of this research is metacognition.

Metacognition is students becoming responsible for their own learning/thinking through awareness, evaluation and regulation of this process.

Awareness relates to the students’ consideration of where they are in the learning/problem-solving process and what has and could be done in order to successfully complete the task. Evaluation refers to judgements students make about their own thinking processes, capacities and limitations. Regulation occurs when students draw upon their own knowledge and skills: for example about themselves and their strategies, to direct their knowledge and thinking in pursuits such as planning, self-correcting and setting goals.

(Wilson & Wing, 2008, p. 5).
An understanding of metacognition enables students to become responsible for their own learning by being aware and to better engage in metacognitive strategies such as the use of imagination, abstraction and mental modelling during both formal and informal learning. In the context of this research, formal learning is that undertaken in guided groups and includes specific imagination skill development. Informal learning occurs during work, self-directed learning and other self directed study.

Individuals will learn electrical physics and in the process use imaginative skills to enhance that learning. The process is one of engagement with imagination in order to become independent thinkers in the electrical domain. The students will participate in most imagination activities collectively. This will result in a social and community aspect to learning and learning interdependently.

3.3 Methodology

3.3.1 Construction of research paradigm
The research is underpinned by an understanding of learning that is shaped by activity and tension field learning theory. This is an important part of the research design, so what follows is the rationale for adopting and connecting these particular learning theories which enable a holistic analysis of complex learning contexts.

Activity theory offers a framework for the analysis of relationships among people, context, learning objectives and subsequent activity. Tension field theory enriches the analysis possibilities by focusing on fields of emotional state, social context and learning cognition. Connecting these two paradigms yields a third paradigm that is well suited to answering the research question holistically.

Combining Engeström’s (2000) activity theory and Illeris’ (2003) tension learning field theory which have been outlined in the previous chapter
produces a paradigm that is represented in Figure 3.1. The paradigm also incorporates both Vygotsky’s scaffolding theory (Stone, 1993, p. 170) and Dewey’s social activism theory (Elkjaer, 2009, p. 74) as explained below.

The new methodological paradigm can be viewed as a triangular prism. This prism is built up by superimposing the ideas of Vygotsky, Dewey, Engeström and Illeris. Connecting these paradigms chronologically provides a helpful way to understand the reasons for the connections. Dewey and Vygotsky were thinking along similar but different lines at the same time, unaware of each other’s ideas. Using their works as a basis, we can examine the relationships and connections.

Dewey’s social activism theory asserted that learning comes through social experiences. As discussed in chapter 2 and indicated in Figure 3.2 below, the learner’s immersion in social experience fostered by hands on
experiences results in learning. The outcome is contextualised real-world problem-solving. For Dewey, learning requires social interaction among students on problems that directly affect them. Learning activities should stress collaborative activities and real-world connections.

In the composite diagram Figure 3.1 Dewey’s social activism theory is represented by the base of the red triangle that forms on the side of the prism.

Vygotsky views learning as cognitive change shaped by individual differences and cultural influences. He maintained that the individual is stimulated to learn through mediated acts which produce learning response outcomes, and all this is situated within the cultural context. Leont’ev (Langford, 2005, p. 150) furthered the ideas of Vygotsky by introducing the concept of an artefact. Thus the learner makes sense of his/her situation through the use of a mediating artefact. This artefact enables the learner to move into the ZPD (Down, 2006, p. 84) where learning can take place.

The complete theory is scaffolding theory, where learning works best when students get assistance from experts to build on what they already know. Also, each learner’s background shapes how he/she learns. In scaffolding theory, instruction should be tailored to each student’s individual needs and preferences.

Activity theory is built on the mediated act as the subject performs an activity through a mediating artefact focused on the object of a problem. The outcome is learning and the making of meaning. Engeström’s version

Figure 3.2 Social activism theory
of activity theory specifies the role of the social context by including rules, community and the division of labour as categories for analysis.

The rules are the social contracts within any organised social collective. Community refers to general social relationships. The division of labour is how the culture manages and brings definition and purpose to people’s lives. The learner is shaped by the culture, but the culture is also shaped by the individual learners within the collective.

The sides of the prism have been explained according to activity theory – that is, if you view the activity theory in Figure 3.1 above as a flat two-dimensional polygon and fold the apexes of artefact, rules and labour together, it will form a triangular prism whose sides are activity theory.

Forming the base of the new prism or paradigm is Illeris’ tension field of learning (Illeris, 2003). There are two significant tension fields concerned with interaction of and cognition. The first is internal, between one’s emotion and cognition, in the second, external society pulls, not in an opposite direction, but perpendicular to the internal dimension Figure 3.3. This result is a weaving of the learning tending on the emotive factors present.

![Figure 3.3: Tension field of learning complete](image)
The green triangle, representing the tension field of learning is now placed inside the activity theory diagram. Society and community align because there are close parallels in both theories. Emotion and the subject are similar because emotion is part of being a person (subject). Cognition and object align because this is the intersection of problem-solving, sense-making, meaning creation – and the outcome remains learning.

With the two learning theories connected, a few more steps are still required before a new paradigm is established. The first is to understand that emotion does more than just connect the theories. Emotion reforms activity theory by impacting on rules, division of labour and mediating artefacts. Emotion reforms and refocuses the rules by redefining them in terms of what enables or limits learning. Emotion reforms the division of labour in terms of interpersonal and learning relationships. Finally, emotion reforms the mediating artefacts and refocuses these in terms of effectiveness and motivation for learning by being sensitive to what it is to be human.

The impact of incorporating emotion into activity theory is shown in Figure 3.4.

Figure 3.4: Effect of emotion combining activity and tension field of learning
The last step in developing, and understanding the paradigm that underpins this research is to visualise the reformed aspects of activity theory–effectiveness of community, enablers of learning and interpersonal relationships–as the apex of the prism. Thus, tension field of learning forms the new base, while activity theory becomes the faces in the representation of the composite paradigm, as shown in Figure 3.5.

![Figure 3.5: Composite research paradigm](image)

The composite paradigms enabled the analysis of data or narratives using an expanded matrix as the mediating artefact. Activity theory proposes five principles contrasted with four questions. The reformed matrix now posits six principles with six questions.
<table>
<thead>
<tr>
<th>Principles</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity system as a unit of analysis</td>
<td>Who are learning?</td>
</tr>
<tr>
<td>This principle is applied into the discussion on who are the learners and what are their contexts.</td>
<td></td>
</tr>
<tr>
<td>Multi-voicedness</td>
<td>Why do they learn?</td>
</tr>
<tr>
<td>This dimension explores the learning communities’ reasons that are underpinning their learning.</td>
<td></td>
</tr>
<tr>
<td>Historicity</td>
<td>What do they learn?</td>
</tr>
<tr>
<td>The window of historicity examines the underlying concepts of what is being learned.</td>
<td></td>
</tr>
<tr>
<td>Contradictions</td>
<td>How do they learn?</td>
</tr>
<tr>
<td>This view explores motivation using those ideas that are not obvious or seem counter-intuitive.</td>
<td></td>
</tr>
<tr>
<td>Expansive cycles</td>
<td>What is driving and thriving in the learning processes?</td>
</tr>
<tr>
<td>Learning usually involves several cycles and or layers. Expansive cycles encourage the exploration of the learning layers and connections of learning.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Principle</th>
<th>Additional Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal learning relationships</td>
<td>What have been the catalysts and responses to learning change?</td>
</tr>
<tr>
<td>The opportunity generated here is the introduction of what effect do emotions and affections have on learning?</td>
<td>How are the underpinning assumptions being challenged/changed/affirmed?</td>
</tr>
</tbody>
</table>

The addition of personal relationships now accounts for the person and the emotion of learning through relationships. The two additional questions...
create a rich dimension allowing for emotional responses to learning, change and personal assumptions.

3.4 Design

3.4.1 Research design basis

The research design is based on the paradigm outlined in the previous section.

The rationale of using PAR is two-fold. The first element is to encourage the participants’ involvement in improving the learning of electrical physics through actively participating in imaginative skills activities and exercises. The second is to provide participants with formal points at which to stop and reflect on their practice in learning electrical physics, and how this may have been influenced by the imaginative skills engagement. This then produces the content of the students’ narratives.

The narrative research, operating in parallel with action research, encouraged participants to record their stories by means of semi-structured interviews. At the middle and end of an action research cycle, participants were given open questions to assist their reflection about imagination and learning electrical physics. Participants had two or three days to reflect on the questions before video interview. This was repeated for each action research cycle. Other data or parts of the participants’ stories were collected incidentally in response to significant incidents as part of the overall narrative. In addition written responses were collected when appropriate.
Figure 3.6 Complete representation of participatory action blended with narrative research.

The above diagram (Figure 3.6) represents the processes and shows how the first three participatory action cycles were designed and conducted. Participants are represented by thick black horizontal lines moving from left to right indicating the transition of time.

The horizontal green broken lines indicate the participants’ stories as they develop through the action research process. The vertical red lines and
arrows represent the participatory action cycles. The oblique blue lines indicate the narrative research as it pervades the entire research process. Finally, the letters circled A through to F represent the six main phases of the parallel blended research approach.

3.4.2 Participatory action research design in detail
This section breaks down the overall research design into six phases and outlines the activities within each phase.

Phase A. First participatory action research cycle 1
The first activity of this cycle was to seek students’ consent to participate in the study. The process for this consent is outlined later in section 3.5. Permission was also sought from TAFE and the students’ employer, who approved a weekly four-hour tutorial for participating students to undertake imaginative skills activities. Once the students understood the research process and their engagement in it, the weekly four-hour tutorial was devoted to undertaking imagination activities. One imagination activity was pursued each week.

In this first cycle, the researcher explained and discussed with the participants particular imaginative skills activities from a pre-formulated list constructed around the ten imagination categories. These were displayed on a poster in the classroom and the activities’ purpose and rationale are detailed in section 3.4.4. A discussion with the participants about metacognition and their need to manage and be responsible for their learning is also part of this cycle.
Part way through the first cycle, students were given some open questions about their learning in preparation for the video interview. Students made a video-recording based on the open questions. This process was then repeated at the end of the research cycle. Each research cycle was of twelve weeks comprising one TAFE term and four weeks work placement. Figure 3.7 shows this in diagrammatic form.

**Figure 3.7 Participatory action research: Cycle 1**

**Phase B: Second participatory action research cycle**

Following the approved ethics process, students’ consent was again sought for their involvement in the study. A similar process was followed as for
cycle 1, as the research approach is a rolling one. In cycle 2 these students chose how they would like to engage the imagination activities. Students individually chose activities from the poster, the order they would be undertaken and how each activity would be used to improve imaginative skills as they became more aware of the new learning processes. This encouraged a higher level of engagement and ownership of the link between imagination and the learning of electrical physics. This instead also encouraged a metacognitive approach to engaging imagination.

Again, students were provided with open questions and subsequently videoed half way through the cycle and at the end. Also at the end of this second cycle, participants were asked if they would like to generate their own imaginative skills activity or select one from the list that they felt would assist their learning. Their choices were implemented in the third cycle. This is shown diagrammatically in Figure 3.8.

![Figure 3.8 Research Phase 2: Cycle 2](image-url)
Phase C. Third participatory action research cycle

Participants’ consent was again sought. In this final cycle participants were expected to drive selection and/or development of imagination activities, and to be responsible for engaging the rest of the cohort. This gave participants metacognitive control and responsibility. In this cycle the researcher was not only the facilitator of the process, but a participator in the activities with the students.

Again students received a list of open questions and undertook video interviews, approximately half-way through, and at the end, of the third cycle. On completion of this cycle, when returning from end of term work placements, participants completed a Likert scaled survey (See questions in appendix B). The survey sought student opinions on the use of imagination within their learning over the course of the study thus far. See appendix B.

These stories formed the data for the narrative analysis, using the composite paradigm detailed above. This is shown diagrammatically in Figure 3.9.

![Figure 3.9 Participatory action research: Cycle 3](image)
3.4.3 Narrative research design in detail
Phases D and E. Participant narratives produced from video interviews

To this point the narrative component sought to encourage participants to reflect on their practice in learning metacognitively and record their stories as they continued through the action cycles. Phase D, consisted of a video editing process, from the three action cycles. At this stage the semi-structured video interviews were transcribed and integrated into eighteen stories. Each story told the imagination and electrical physics experience of a single student.

In each narrative, the story of subsequent cycles overlaps with previous cycles to capture the participants’ reflection on learning practice in relation to using imagination. Phase E then created transcripts of the edited video narratives. The eighteen transcripts formed the data base for the narrative analysis. Four representative transcripts are given and discussed in chapter 4. Figure 3.10 shows the research process to the end of phase E.

![Figure 3.10 Narrative research: Phases D and E]
Phase F: Participant narrative analysis

In the final phase, the data of the eighteen participant narratives was coded into themes and analysed through the composite analytical methodology discussed above. The coding process used the social science research software NVivo. This is represented below in Figure 3.11.

![Figure 3.11 Narrative research phase F](image)

3.4.4 Examples of imagination strategies

The research strategy introduced participants to a range of activities intended to make them aware of, stretch and improve their imaginative skills. The ten imagination skill areas have been developed in part from the literature, from definitions of imagination and from the researcher’s experience in teaching electrical physics. The ten imagination categories have been introduced in the literature review.
I now provide an additional explanation of the ten categories with typical examples of related activities. No one activity fits perfectly into any single imagination category. Rather, activities tend to straddle a number of imagination categories.

The ten imagination categories are:

Problem-solving;
Spatial;
Visual;
Conceptual abstraction;
Psycho-motive;
Mental modelling;
Metaphysics;
Story-telling;
Gaming and History.

**Problem-solving**

Imaginative skills of problem-solving involves the ability to make realistic estimations, the ability to genuinely consider multiple and/or alternate solutions (Brookfield, 1987, p. 8) and the ability to project likely consequences of actions (Brookfield, 1987, p. 132). An activity to enhance these skills used in the project was scale model bridge building.

Participants were given limited resources and strict specifications to apply to building a bridge. They spent the first half-hour discussing their ideas through concept mapping. The remainder of the four hour tutorial was used for the actual construction and discussion of the model achieved. Resources provided were: a large bag of paddle-pop sticks, elastic bands, a roll of sticky tape, a model truck and a two-litre bottle of water. The specification is that the bridge must be to the scale of the model truck, span 800mm and self-support two kilograms at the centre – hence the water. Another activity used to enhance imagination in this area was to
build small plastic model aeroplanes without the instructions. This activity encouraged students to build on previous problem-solving skills.

This activity and all the others follows Brookfield’s (1987) principles of critical thinking as an imaginative task: Rejects standard forms of problem-solving; interest in a wide range of related but divergent field; can take multiple perspectives on a problem; view the world as contextual rather than universal; frequently use experimentation with alternative approaches; change is embraced optimistically as valued development and have self-confidence in their own judgement.

**Spatial**

Spatial skills are imaginative from a cognitive perspective. Imagination is often used in electrical physics. For example, drawing circuit diagrams involves being able to visualise the necessary representations and spatial relationships before translating to paper. Cognitive spatial skills are used to determine the placement of appropriate electrical symbols on the paper and knowing what the symbols represent. When symbols are connected with lines (representing conductors) the completed diagram is readable. It is laid out spatially to make the diagram meaningful. Such visual literacy depends on the possession of imaginative spatial skills.

One activity used to improve participants’ spatial skills was to take a printed circuit board physical component layout and, working backwards, produce the circuit diagram. This activity enhances the participants’ spatial imaginative skills from a visual and cognitive perspective.

**Visual**

Visual imaginative ability is used to produce or explain symbolic representations. In electrical physics there are many ways of representing circuits. All these involve visual imagination (Pacey, 1999, p. 43).

An activity used to encourage visual imagination was for students to develop a representation of Ohm’s law that did not use algebra. The participants were provided with only A3 paper, sticky tape, pencils,
drawing pins, scissors and string. The participants then chose the resources they needed. Finally students presented and explained their representations to the class followed by a general discussion on the exercise. An activity also used to enhance visual skills was small teams instructing a second team to draw chalk images on the concrete bellow the library balcony. The team on the balcony with a copy of an image had to instruct the team on the concrete below, to reproduce the image without telling the drawers below, what it was they were drawing.

**Conceptual abstraction**

In electrical physics all representations are abstractions because of the phenomena’s non-sensory nature. The reality is two, three, sometimes four times removed from the final effect of electrical current flow. Listening to cricket on the radio from England in the 1930’s provides an analogy. Alan McGilvray would receive ball by ball telegrams and re-synthesise the commentary with sound effects using a pencil (Sengupta, 2012, p.1). The cricket game was happening in real time, but the Australian listener was receiving an abstraction four steps removed from the reality. When a light globe is activated, current passes through an element. The element heats until it radiates photons as visible light. The electrical current is two steps removed from the emission of light and three steps removed from its perception.

A Morse code activity was used as an abstraction activity to improve this imagination skill. Participants constructed a full-duplex Morse code set using push buttons and LED indicators. Over a distance of fifty metres, students sent back and forth small messages which they actioned. The process of encoding, transmitting and decoding messages provided three steps of abstraction.

Another activity was an interview of instance (Osborne, 1980, p. 214) centred on a temperature switch. Participants constructed the switch, from the circuit using Vero-Board, rather than a printed circuit board. This exercise was completed whilst the students were on work placement.
When they returned, they were video interviewed explaining the operation of their device. Using this ‘interview of instance’ enabled the students to become more skilled in explaining conceptual abstraction.

**Psycho-motor**

All the more practically oriented skills in electro-technology have a strong psycho-motor component – for example, mounting components into a printed circuit board and soldering them in place.

Work placements were used to extend the participants’ psycho-motor skills. After each work placement period participants then gave short verbal presentations of their experiences in the workplace, explaining the types of work activities they undertook. By the third work placement students had access to ‘point of view glasses’\(^1\) and could use these to video data obtained to illustrate their explanations.

**Mental modelling**

Mental modelling is the imagination skill of constructing a representation of an abstract concept in electrical physics. It is not the construction of any particular mental model that is at issue. What is important is the imaginative skill of being able to construct and reconstruct these mental models.

An activity which was used to encourage participants to construct and reconstruct mental models is a story-telling approach using only closed questions. Participants received the very end of a complex story as a group. They could ask as many closed questions as they would like to reconstruct the narrative. This forced participants to select an idea from the little they had been told and then pursue it. As the fragments of the story were progressively uncovered, mental models were created and re-created. Eventually, one of the participants put all the fragments together to create the complete story. Another example was the use of small Lego models. Students were required to sit back to back, one with the model parts and

\(^1\) Point of view glasses are spectacles that have a small video camera built in.
the other with the instructions. The student with the instruction was then required to ‘tell’ the student with the parts how to put the model together. Again this activity is designed to enhance metal modelling, because of the familiarity students have with Lego as a toy.

**Metaphysics**

Metaphysics attempts to answer higher order questions. Why is the whole greater than the sum of its parts? What is the purpose of life? How do we define love? What is it to be human? Imagination itself has no single simple definition, but is a complex part of what it is to be human. Imagination, therefore, is a metaphysical entity and often referred to as moral imagination (Pacey, 1999, p. 149; Lau, 2001, Par. 1.). Metaphysics is intrinsically bound up in narrative as a way of making sense or meaning.

To encourage participants to explore imagination from a perspective beyond themselves (metanarrative), they were asked to complete a worldview survey. This helped them to identify their worldview and challenge underpinning assumptions of that particular metanarrative as a place to begin transformative learning (Taylor, 2009, p. 3). Participants also completed a Myers-Briggs personality instrument. This also challenged their thinking about how they and others may learn as a tool to bring some disequilibrium.

**Story-telling**

Story-telling for communication or entertainment is an imaginative task (Eisner, 2002, p. 16). To take information and events and craft them together into a sense-making narrative requires imagination at many levels. An imaginative aspect of story-telling is the capacity for managing complexity. This aspect was used to enhance participants’ imaginative skills in understanding metaphysics.

Participants critiqued ‘Road Runner’ cartoons in order to understand how complexity is conveyed is such a story. These cartoons have simple plots.

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2 Myers-Briggs is a test instrument for determining sixteen personality types.
but convey complexity by their means of applying ‘rules’ – ‘rules’ of physics in the Road Runner’s world, and ‘rules’ of the cartoon itself. ‘Road Runner’ cartoons have nine rules which hold the complexity of the narrative. The students critiqued up to fifteen cartoons (obtained free from the internet) in order to discover the nine rules and gain an insight into the complexity and the meaning narrative can carry.

**Gaming**

The use of games (or gaming) encourages participants to improve their strategic skills in an engaging way. Strategic skills require imagination for reflecting forwards and backwards. It is the ability to reflect and make informed assessments that produces strong strategic ability.

As the participants’ strategic skills improved so do their imaginative skills. Chess, Scotland Yard, Risk and Balderdash were provided and participants were encouraged to suggest their own strategy games.

**History**

The imaginative skills of history are skills of reflection. Reflection on the history of electro-technology gives electrical physics students much prerequisite knowledge for further learning. The reflective and imaginative skill of extrapolation uses history to predict or suggest possible future scenarios and or consequences (Smith & Smith, 2011, p. 212).

To develop this skill, participants selected and researched the life and work of a well-known contributor to electro-technology. They then produced a poster showing how their work impacts on our present practice.

The poster, Figure 3.12 below, was developed for display in the participants’ classroom. It links imagination activities to imagination categories in an attempt to help them see or imagine the future.
<table>
<thead>
<tr>
<th>Imagination activity or exercise</th>
<th>Problem Solving</th>
<th>Self</th>
<th>Visual</th>
<th>auditory</th>
<th>Psychomotor</th>
<th>Non-Sensory Modelling</th>
<th>Sensitivity</th>
<th>Story Telling</th>
<th>Gaming</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>White board pictionary</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blind Lego construction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic drama</td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wordsearch survey</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<td>Ping pong pyramid</td>
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<td>Resistor Colour Codes to a Story</td>
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<td>Using Story Book 3 software to explain electricity</td>
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<td>Use digital cameras “Explanation of AC theory”</td>
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<td>1912 Overture, reflection on images produced</td>
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<td>Learn to draw, seeing relationships (Little Edwards URL)</td>
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<td>Metaphor log on the class website</td>
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<td>Drive a plan of the campus or home from memory only</td>
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<td>Creative drawing in groups of 2-3</td>
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<td>Technology innovations using digital key rings</td>
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<td>Scenario game: Clock &amp; Ticket company, new logo URL</td>
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<td>Poster on logocentric smart thinking</td>
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<td>Poster using reflective wheel</td>
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<td>Role model &amp; great communicators: Mind map</td>
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<td>Silent silent flight activity</td>
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<td>Collaborative drawing with BIC chalk</td>
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<td>Leaves dropping using sound from video only</td>
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<td>Visual problem solving using triangles</td>
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<td>Flats from solid 3D shapes</td>
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<td>Mood music to pictures</td>
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**Figure 3.12 Imagination project classroom activity poster**
3.4.5 Semi-structured interviews

Semi-structured interviews are used for guidance, not absolute control. They encourage participants to relate their experiences in learning electrical physics as imagination is metacognitively engaged.

In this research study, guidance was given by means of a set of questions provided to the participants a few days before their video interview. Participants were expected to use these questions as a guide not an absolute.

In the first action research cycle, participants told the story of their experience of that cycle. The second cycle interviews encouraged participants to reflect on their learning (and the role of imagination within it). In the third and final cycle, participants recorded their reflections on the two previous cycles and analysed their learning in relation to imaginative skills over all three cycles.

Activity interviews

The participants were interviewed (on video) during or after the imaginative skills activities to provide a record of their reflections on the activity. These recordings give further depth and colour to each participant’s narrative.

3.5 Conduct of the research

3.5.1 Ethics

As a requirement of the candidature process, ethics approvals were obtained from Charles Sturt University, TAFE Riverina and the participants’ employer. Copies of the ethics applications and approvals are in Appendix C that are provided on the memory card (MC).

The planned ethics process was to obtain consent from the participants before each action research cycle. This gives participants the option to opt in or out in an informed manner as the study proceeds. All participants continued in the research process apart from two students who withdrew.
from the course. All students gave their consent for all phases of the research.

Participants received extensive written information about the proposed study, including contact details of TAFE and University employees managing the study. The nature of the study and the anticipated level of demand on them as participants were clearly explained. The collection of data by video, its storage and use, were also made clear.

Special attention was given to the video recording process. Participants received initial training in the process that alleviated apprehension about being video-recorded. Participants had opportunity to view their recordings each time. After viewing, the participant had the ability to delete the recording, modify it by partial deletions, or have it re-recorded.

Ethics approval was received by the University on 24th of April 2009, approval number 301/2009/02. TAFE approval was received on the 14th of April 2009. The employer’s approval was received on the 6th of April 2009.

Copies of the ethics proposals and approvals are contained in Appendix C on the MC.

3.5.2 Participants
The participants for this study were eighteen full-time Diploma of Electronics and Communications students employed with Airservices Australia. These students attend thirty five hours per week in the electro-technology department, at the Wagga Wagga campus, of the Riverina Institute. For the students, their participation in the study commenced after they had completed twelve weeks of the two year program.

Participants come from a range of backgrounds. One third were recent school leavers from year twelve. Another third had completed or partially completed tertiary studies. The remainder were mature age students recruited by Airservices Australia.
The electro-technology teaching staff also agreed to participate for purposes of triangulation and clarification. This involved six full-time and five part-time teachers who provided further feedback on the students’ learning performance as required.

3.5.3 Data collection
As described above most of the data were collected through video recordings of semi-structured interviews. These were edited and collated into narratives describing individual students’ experiences throughout the study. Additional video data were collected of the students undertaking various imagination activities and through the participants’ survey responses and artefacts such as posters and summaries.

Edited video data were transcribed into Microsoft Word documents and imported as base data sources into the NVivo 8 social research software analysis tool. NVivo did extract the themes in the data and was used in the analysis phase.

3.5.4 Sample size
The sample size of eighteen participants was considered adequate given the large volume of data collected. Each participant provided at least six interviews of six to ten minutes duration. An average fifteen minute interview provided a thousand word narrative. This meant that each student narrative averaged six thousand words, generating approximately one hundred and eight thousand words. As predicated within the literature review this proved ample for analysis purposes according to the methodology chosen.
3.6 Consolidation

This thesis centres on perceptions, feelings and opinions of student participants learning electrical physics. This invites a qualitative approach, noting that all research lies on a continuum between purely qualitative and completely quantitative. This study is at the qualitative end, its smaller quantitative aspect employing descriptive statistics. The qualitative aspects result from investigating and examining participants’ experiences in enhancing their imaginative skills to better learn electrical physics. Their experiences will form the story of the imagination study.

The analytical method used blended activity theory and tension field of learning theory, as developed by Engeström and Illeris respectively, to produce a composite theory. Their individual theories are examined from the literature. Using this composite theory, an analytical framework of six principles against six questions generated thirty-six questions. The thirty-six questions became the mediating artefact in answering the research question.

The imagination study relates directly to the non-sensory, abstract nature of electrical physics. The study design sought to encourage students to improve imaginative skills and thereby their abstraction skills. With these, in turn, they will enhance their mental modelling ability; thus improving their use of, and engagement, in abstract modelling systems used in electrical physics.

The research process used both PAR and narrative research. This was possible as they operate synergistically. This has been discussed earlier in this chapter. Using both PAR and narrative research enabled data from multiple sources to be collected and analysed.

The next chapter discusses student narratives and the process used in the preliminary analysis.
Chapter 4

Data Chapter

4.1 Introduction

This chapter provides a ‘snap shot’ of the narrative data produced by the students who participated in this study, not only as providers of data, but also as co-researchers in participatory action research. Clearly it is impractical to provide all their complete stories here. All the narrative video clips and narrative transcripts are available in Appendices D an E provided on the accompanying MC.

However the snapshot is also accompanied by some initial analysis based on typical themes covered in the narratives. These themes denote common strands found in the participants’ narratives. Whilst this analysis lacks the rigour of further analysis documented in chapter five, it enables an initial identification of the key concepts identified by the research. In this way a ‘grounded theory’ (Atkinson & Delamont, 2008, p. 301) approach has made a contribution to the shape of this research.

The narratives chosen for this discussion are typical of the complete set of narratives. The first student moved from absolute scepticism to complete acceptance of the imagination approach to learning electrical physics. The fourth student’s mild scepticism was unchanged throughout the study. The other two stories represent a range of acceptance and integration of imagination into their learning. Note that for the purpose of anonymity, the real names of the students have not been used.

The first student, Mal, completed an electronics trade qualification in Sri Lanka. He migrated to Australia and is now in his late twenties. At the beginning of the study Mal had definite views on how he liked to learn. He
was quite adamant that imagination played no part in his learning and certainly not in learning electrical physics. In his final interview Mal stated:

> Since the electricity is something that we cannot hear, smell, see, touch and taste except the effects and reactions, the language of everyday life is no longer up to the task. Some of the fundamental characteristics, how it reacts in some particular situations cannot be described with ordinary language. But since we use our senses to develop our vocabulary and talent, they are not necessarily appropriate tools for understanding what our senses cannot perceive. To understand these new concepts, we must turn to another language, and the language of imagination is perfectly suited to the task. In fact, it is fascinating to discover the ability of imaginations to extend our senses. It could even be said that imagination constitutes a kind of sixth sense. That’s the reason why I call my story “The Language of Imagination – the Sixth Sense.”

Mal’s story reveals a shift from scepticism to acceptance, understanding and insight.

Neville provided the second story. As he was growing up he spent much of his time taking gadgets apart and eventually completed a diploma in Information Technology. After this he worked as a photocopier repairer and thus has a strong background in DC electronics. During the study Neville moved from being interested and open to the concept of using imagination to learn electrical physics. During this study this interest developed into a growing engagement with the concept as he explains in the following excerpt.

> Imagination activities really do help. I reckon in the second lot (Cycle 2), that was driven by you; but we still used our imagination in it. Like doing the blindfolded activities – that also helped. You physically had to imagine where things would go without looking at it and how the circuit would be in your head. It was more of a clicking point. I think the penny had already dropped but that reinforced it a lot more and more awareness about it.

Doug’s is the third story. A mature age student, he had worked in retail for the previous eight years. He came into the electronics and communication program with very little background in electronics. His understanding of
electricity came from the little covered in secondary school. Doug began as a mild sceptic; but by the end of the study, Doug had become enthusiastic in using imagination to support learning.

The things we have been learning, like at the start, you can’t see it, you can’t taste it, you can’t touch it, you have got to look at it from a mathematical point of view. I find that pretty hard, some of the things you just can’t do that. ... So I have found those things to be good. That’s more imaginative, I suppose, than just memorising a picture of a way a circuit is supposed to look and then if they change one thing and not knowing what it is, so that’s been pretty good.

Doug has come to understand that electrical physics is more than just mathematics and dealing with circuits. It involves imaginative tasks.

In the final story, Steve has struggled with electrical physics. His current employment is more a necessity than a career choice. He has also had difficulty with the concept of using imagination to learn. Concerning the use of imagination, throughout the study Steve has been either disinterested or mildly sceptical. The following quotation is indicative of his thinking.

So I think Cycle Three affected my learning in a minimal way. I got the impression that some of us were slacking off a bit — taking it a bit more relaxed, not really thinking of that one so much. That said, for some of us it might have helped. I don’t know — I need to be driven personally, I think, or else I can get a bit off track, not focused.

The next part of this chapter presents the stories of Mal, Neville, Doug and Steve. As a technical note, the bracketed numbers ‘(#)' embedded in the text, represent the video interview clip numbers. If the clip number is absent then the quote is from a student’s written work. The video clips and written work may be found in Appendix D and E on the accompanying MC.
The next part of this chapter discusses the common themes of narratives of Mal, Neville, Doug and Steve. The common narrative themes are:

initial thoughts about learning and using imagination;
learning approaches begin to shift and change;
imagination in learning is accepted;
significance of imagination;
work placements;
self reflection about learning; and
final thoughts.

4.2 Initial thoughts about learning using imagination
The initial thinking of many of the student participants about the imagination study varied from bemusement to scepticism via ambivalence. In the example that follows Mal is sceptical about the project because he has already attained the skills he thinks he needs to learn electrical physics. He recognises that his previous learning was concerned with the acquisition of “direct knowledge”. He implies that imagination is not directly helpful and is inefficient. In the initial stages of the study, Mal indicated that he tolerated the imagination activities and rationalised them as useful as a way of thinking differently and working with others in constructive ways.

In the beginning I thought the [imagination] project would not help much because my previous learning styles that I had back in my own country. I came up with a set of skills that helped to understand electrical physics. I thought this because electronics is very theoretical and my previous experience and studies were directly to the point and gave me only what I need to know. Here, when we had group activities, we had to use imagination to learn and improve and understand electrical physics with imagination. The first couple of activities we did ... [built] up to more complex activities. So through all these activities we began to build a greater team work orientation, thinking outside the box which I began to find more interesting. This interest grew and by the end of the project I appreciated the group activities more.

(Mal #41).
Most of the participants’ definitions of imagination were narrow. As shown in the quotes below initially Neville and Doug believed that the use of imagination in physics was restricted to graphic-based visual presentations.

Term two was a little easier, but it got a bit full on because everything was just thrown at us. We had new subjects as well and learning about transistors and everything like that. You already had the knowledge. That grew as well. The previous study helped in learning, and tuition, and just going over things. I always [thought that imagination] was a visual thing, like when we had circuit diagrams. I always trace where electrons would go and I suppose that’s how I have learnt the most. So that was my picture of imagination I guess. What would happen if you put current this way through it and how much current through like a transistor. Like picture the NP junction and will it pinch off and things like that. I use that model, I guess.

(Neville 16)

Doug concurs when he writes:

My learning style is generally visual. I like looking at things and doing a demonstration on how things work and someone shows me how it works on a diagram then that seems to work better than if I just read a written description of how something operates or whatever. So it’s a bit of a visual type demonstration, I guess.

(Doug 6)

A further indication of narrow imagination is Doug’s comment ‘My learning style is generally visual’ in the second quote. He is restricting his preferred learning approach to visual graphics.

Early in the study the students used the imagination exercises as a way of learning differently. Their transcripts indicate that initially they did not link the imaginative skills with learning electrical physics. In the example below, Doug indicates he benefited from a ‘spin off’ effect of learning how others learn.

Imagination exercises have given me a better idea of or better appreciation I suppose on how the different ways people will learn. So what will work for me won’t necessarily work for other people and so when it comes to team work and things like that, it’s good if you have people with different learning styles. You often learn off each other a better way

(Doug 5)
While Mal, Neville and Doug accepted the imagination tutorials with open minds, Steve was very forthright in expressing what his view of imagination was at the beginning of the project. For him imagination was about daydreaming with no connection to learning electrical physics.

Back there [imagination] was just my day-dreaming or something. Or it was how you envision things without actually seeing it. Someone would describe someone to me and I would imagine this person. When you meet them they are completely different, simple things, just thoughts, more towards the abstract side of thinking. That is how I always thought it was. I [am a language and arts person] more than the others. Particularly in languages, it [imagination] helps. If you try and associate and sort of imagine words that sound like words you know in English, particularly one of the languages I have studied (Japanese); it’s alphabet is completely pictorial. So it really helps to imagine the symbols looking like what they represent.

(Steve 16)

However, he makes an unwitting, and insightful, comment about the ‘abstract side of thinking’. It is this abstract dimension that the imagination activities are all about and this is what he has initially missed.

4.3 Learning approaches begin to shift and change

By the time of the second action research cycle, all the participants had begun to shift their thinking in relation to learning electrical physics. Mal begins to admit that imagination does directly help and is becoming aware of imaginative skills that he already uses unwittingly. Neville’s mind is ‘opened’ to new learning possibilities and imagination is giving him the ability to perceive the overall concepts. For Doug the shift is the realisation that the imagination study has given him some new learning tools. Steve begins to change his inclination to imagination as he suggests that imagination is about better perceptions rather than making it up and this improves his knowledge.

The following examples show that Mal is shifting his opinion about imagination within learning from not helpful to a clear affirmation that ‘yes
it did’. His example of the use of imagination is the ability to transcend a connection diagram into a circuit diagram.

So as far as imagination goes I can’t say not, yes it did. The PCB to circuit, blind circuits, I loved those ones. Before I had done some PCB to circuit thing, I needed to plan, therefore I did better. I like those. I learnt new things. I learnt to go from connection diagram to circuit diagram. The blind circuits, when you can’t see something, basically you can’t see electricity, you can’t feel it or touch as I have said before, so we have to imagine, so actually by doing blindfolded connecting series circuits we are limiting our minds to connecting the circuits. So you see it by touching and it was very helpful.

(Mal #11)

The second aspect for Mal is the metacognitive realisation that to some extent he had always used imagination within his learning. Mal is now aware of this imagination ability and is beginning to use it to enhance his learning.

Then when it came to Term Two we started doing a bit more hard stuff, doing more theory stuff than practicals. In that case it’s a bit hard for me because I like to do more practical things. My mind moves more smoothly with those things. Because we were doing more theory stuff I have to think of a way to remember those things. Actually at that time I used imagination without knowing I was using it. When we were studying applied electrical and how the transistor works and all the electrons flow, there is no way you can see how they flow from collector to emitter or how the base current flows. So we have to make a model in our minds, you have to imagine some sort of dots or something in the way it goes with the emitter/base current flows.

(Mal #26)
Neville describes how using imagination enables him to open his mind a little more and examine other learning possibilities. This enhances his metacognitive skills as he is made aware of his learning and enables him to envisage where his learning fits into the bigger picture. This explanation below shows this transition in his narrative.

Imagination in Terms Three and Four (Cycles 1 and 2), it opened my mind a bit more [because] I was just on the one track, where I didn’t look at other possibilities. So I would get a picture and follow that through and that could be wrong or could be right. I would never segregate it off and go to another track. See how it went that way it’s just the way my mind sorted it. [My shift in imagination is] just more aware of a lot of things that are going on. Just taking in the big picture, I guess.

(Neville #17)

Doug recognised that the imagination activities undertaken have produced new learning tools which enhance the possibilities for learning.

What the imagination and learning activities have done for me, is given me more choice in the way that I choose to learn stuff. If we are presented a concept that we are supposed to learn, if my learning style previously, like if I couldn’t grasp the concept or whatever I would probably just beat my head up against the wall until I got it. But I suppose with the imagination exercises it has given me more tools I can use to try and actually remember what we have learnt, so it’s a bit better.

(Doug 14)

Doug also recognises that he needs to use mental modelling but at this stage acknowledged that he was still struggling with this concept.

It’s hard to visualise something that you can’t see like electricity which is where I am having the problem with AC. You can’t see it, you can’t feel it, you can’t do anything with it; so it’s just a matter of using your imagination, which is hard when you’ve got no reference for what it should be like. So that’s probably the limiting thing that I’ve got. If I can’t see it, I struggle with it.

(Doug 19)
At this stage Doug is still assuming that learning is inquisitional and has not yet recognised the ‘application, connection and transcendence’ (Gott et al., 1996, p. 260) process which learning entails.

At this early stage of the research Steve’s thinking about the use of imagination in learning electrical physics is still naive but there is evidence of a slight change of attitude in the following extract.

I guess for me, in particular, the way that current flows throughout a circuit because you look at a circuit - you can’t actually see that. So for me it has always been trying to imagine where it is going. Now I can see that’s there and that’s there, so the current is going to go that way or it’s going to split. Just working out how, that has to be the most troublesome part of it. You really do have to imagine where it’s going rather than [make it up], it really helps to know the knowledge and all that. In the end, I am still sitting there imagining the little bolts of electricity travelling around the circuit as I look at the picture. I occasionally draw the arrows on them to what fits. Even in AC circuits I will still do it, even though I know it’s going back and forth, but I am still drawing the [current] path on it.

(Steve 10)

4.4 Growing acceptance of the use of imagination in learning.

As the imagination study progressed the students not only shifted their learning towards using imagination, but most also accepted that a metacognitive imagination did enhance the learning of electrical physics. Mal acknowledged that his learning had improved through use of imagination to produce better mental models and he ‘now use[d] it a lot’. Neville reported using imaginative skills to reduce his learning load (Sweller, 2008, p. 2) and that it helped him ‘work out what was going on’. Doug has accepted imaginative skills as a way to tailor learning to the individual and has recognised that this produces better understanding. Steve acknowledged that some imagination activities had been beneficial and others not. For Steve there was a shift, but not complete acceptance.
In the example below, Mal linked imagination and mental modelling. Commenting on the subject *Data of Communications* he indicated that the subject was mainly theoretical with little practical work.

So it’s a matter of modelling of the imagination because it’s like that video tape of warriors of the Internet. It helps me understand how the data packets flow around a network. It’s very helpful for me. So even though it’s not real but when you make a model and imagine it that way then it’s very helpful to understand how it works inside the network. Actually I use it a lot of times, even in amplifiers, when we draw the AC equivalent circuits (Thevin’s) high frequency equivalents. It’s not actually there so we have to imagine the presence of the components.

(Mal 27)

As noted below Neville has recognised that imaginative skills can be more than just handy tools.

The three cycles of the imagination project have been full on. I think the imaginative skills have helped me understand circuitry a bit more. I think it has lessened the load so there is less work, working out what’s going on. Sharpening the imaginative axe has allowed me to chop through the work easier.

(Neville #25)

Imagination allows the active learner to personalise his/her learning and to challenge existing models to envisage things differently.

Imagination which is good because it helps you work out a way or better way of learning that is more suited to the individual person instead of having the teacher preach to you up on the board, this is the right way to do it or read it out of a text book, everyone has their own way of learning and explaining how things work. So I find now, having to work things out on my own a little bit more has given me a better understanding of how things work. Imagination has helped as I said before. Mainly because if the way I think of something or the way it works is not really true, or I can’t use my model of things to work out what we need to work out during the exercise or whatever, then the imaginative project has helped me come up with different ways of looking at things and helped me learn more.

(Doug #39)
Steve continues to be uncertain about the benefits of using imagination. He acknowledges that the imagination activities have not hindered or reduced his learning and concedes that may help a little.

As far as the learning goes, a few more of the electrical concepts, I can’t just accept them as is or isn’t for a lot of them. A lot of electronics is on or off, it is or it is not. But I get visions of like on or off but it might have a little switch or something, even though it’s not really. It’s that’s how I am imagining it. It’s just somewhat flicking a switch, a bloody fast switch but nonetheless a switch. [Imagination and mental modelling activities], some projects [helped] yes and some not so much. Some activities where we have been asked to design or put together things, even if we already have the drawing of it, it’s placement or space management. I know it’s spatial skills but I would have thought that was part of the imaginative thought process. Some of them have not really taught or reinforced imagination, I would have thought. But it might have for others, I don’t know. I know, for me in particular, whether it’s physically actually improving my imagination or just because I’m understanding my circuits more by practising it, I felt it’s helped.

(Steve #36)

4.5 Significance of imagination
For all the participants the imagination activities and skills have had positive consequences. This part of the narrative data examines the significance of imagination in enhancing learning from the perspectives of Mal, Neville, Doug and Steve as representative views of all the participants.

Whilst all participants acknowledged the usefulness of employing imagination within their learning, significant improvement varied over the cohort. For Mal, the relationship between imagination and the mental modelling of electrical concepts is most significant. Repeatedly he makes a link between the value of the imagination activities and his mental modelling skills, as the extract below indicates.

The next one I will talk about is physical modelling. This one was an eye opener for me to think outside the box. In this activity we did electron drama that was modelling Ohms Law. So when it comes to Ohms Law and Kirchhoff’s Law, we had to imagine how
the electron travelled through a conductor and how the resistor restricted obstructed the current flow. The sum of a current coming into anode is equal to the sum of current out of the node. So while we learnt these theories we did some physical modelling activity as well. Actually these activities played a big role when it comes to understanding this concept. These activities express a thousand words and can easily be grasped. So as we did them in conjunction with theory classes I developed kinds of modelling skills at the same time understanding the hard concepts.

(Mal #45)

The imagination activities assisted Neville to visualise his thinking in ways that were not supported directly by his sense of vision. It was this aspect of his emerging imaginative skills that he recognised as a significant turning or 'clicking' point.

Imagination activities really do help. I reckon the second lot [of exercises in Cycle 2] that was driven by you but we still used our imagination in it. Like doing the blindfolded activities that also helped. You physically had to imagine where things would go without looking at it and how the circuit would be in your head. It was more of a clicking point. I think [the penny] had already dropped but it reinforced it a lot more and more awareness about it.

(Neville 34)

Doug recognises that the imagination activities have had a positive effect on his learning. Imagination for Doug is ‘a pretty important skill to have’, which is at odds with the cultural values he associates with imagination. So Doug is articulating the conflict with his own opinion about imagination and a conflict he perceives in the culture about imagination as another layer.

[As for the adult learning culture generally,] well I think in general I suppose as adults we are not discouraged in using our imaginations, but a lot of the time through day to day life you are just not required to use your imagination, which is kind of a bad thing because it’s a pretty important skill to have. But most people throughout their day to day life, I suppose you wake up,
you go to work, pay your bills and you’re done. It does not take much imagination to do that, depending on the job that you are doing or what your other interests are. So as a general thing I think imagination it’s not frowned upon it’s just not required, so I suppose a lot of us lose that skill as you get older.

(Doug #42)

Steve understands that electrical physics concepts require imagination as he makes clear in the first part of the extract below. Steve then suggests that others have this ability and imagination is significant because they can ‘just see and do’. He cannot, and tries to justify his position by stating that some subjects do not require imagination. Finally he admits that whilst imagination is significant for mental modelling electrical concepts, it does not work well for him.

[When I think of Imagination and Culture,] I personally find that a lot of the concepts, particularly whether something is on or off, or even your basic Ohms Law, requires some degree of imagination. Maybe not some vivid image in your head, but something simple will suffice as long as you can understand. I get the feeling some of these guys just look at it and understand it. I don’t think they even compare it to anything else. They just see and do. Good on them, but I can’t handle that. There are some things, parts of the subjects, that don’t particularly require imagination. Some of them for me, is you have a formula which applies to this, as long as you understand it, for those, there are concepts are you have to have a mental image - wasted on me and sometimes I try to form a mental image and it just doesn’t work and I don’t get it.

[Culture and imagination] In general I am quite reserved, so I tend not to; I shy away from anything that might be considered out there or radical. Just by nature - it’s something I know; it’s not a great thing. It’s not exactly bad either, but it’s something I would rather get rid of, I would like to be able to speak my mind more.

(Steve #30)
4.6 Work placements
An important part of the full time Diploma course is the work place components. During all the TAFE holiday periods the students were employed in Airservices depots all over Australia. During these placements the participants not only engaged in the workplace but also undertook TAFE assigned projects. The benefits the participants reported varied, as they used their developing imaginative skills to enhance their specific learning issues and needs. During work placements participants undertook different work place activities depending on the location, the actual work performed and the purpose of such activities. This meant that their imaginations were used, and consequently strengthened in different ways.

Work placements gave Mal an opportunity to apply and contextualise his learning.

I also fixed the oscillator in an old mast marker beacon. Another fault happened with temperature stability. It worked at normal room temperature, but did not work at another temperature. We first confirmed the problem by putting it in different temperature conditions. I replaced a transistor and after the alignments it worked well. I also worked on Doppler VOR and the antenna-switching control module. I modified it according to the new standard by putting high voltage protection devices and a gas arrester to the inputs and outputs.

(Mal #22)

The work placements were an opportunity to relate what the participant has learnt at TAFE to real work situations. Neville found the opportunity to work on actual in-service equipment and the processes involved excited him and encouraged further learning on his return to TAFE.

The most memorable [activities] were the ones that were related to my learning here (TAFE). This was ILS because we had to do a PI on the ILS. The test equipment that they used, it just gives you modulation and the modulation frequency; it does not really display anything like that, referring back to our radio course on modulation depth and frequency. ... We did a twelve monthly on a Doppler VOR which was pretty good. I got in and got to measure
a fair bit. A lot of the PIs are reading off the sheet and doing what they say. If there are calculations involved, they actually give you the formula and what to do. It’s good stuff.

(Neville #22)

Doug reflects on building the temperature switch project, which was a TAFE assignment whilst he is on work placement. Doug enjoyed the hands-on aspects of the workplace, but struggled with the concept of the temperature switch project. When reporting at this stage he is still a little negative about the imagination study.

The third week, we started building our temperature switch projects. So I used my imagination a lot for doing that. We also did ILS performance inspections and some work on the voice switch and tower audio systems. On the project, not having a component layout was a bit of a challenge I suppose, having to do it all from scratch. So, I used my imagination to think how much better it would have been to have a component layout.

(Doug 24)

Steve’s experience of work placement was restricted. His persistent ill health and lack of commitment meant that the benefits of work placements for him often had little to do with learning and working within the field of electronics.

[As for new skills,] the strange one would be when we went up to the radar. They made me drive up to it and then they decided that was a really bad idea, because I had not done any four-wheel driving ever. They only have a two ton ute for me to drive up there in. They didn’t do that again. I want more off-road driving skills. That is what I would really love to get into for future travel I think. Other than that, in general more experience, more knowledge in just about everything.

(Steve #24)
4.7 Self reflection about learning
A strong component of the research question is the ability of students to be metacognitive or self reflective about their learning. As part of the participant’s journey within the study they were encouraged to be actively reflective. This was encouraged through activities that forced participants to engage their own learning and thinking process.

The Myer-Briggs (McCrae & Costs, 1989) personality instrument and associated addendum on learning was an important way for Mal to be self reflective. He enjoyed discovering and premeditating weakness or under emphasis in his learning.

And finally, the [Meyers-Briggs] test accurately told me how I am. What kind of person I am, I actually like that very much. I kind of knew I was a person like that but I didn’t know the weaknesses and strengths of those. Now I know my weaknesses so it will help me to fix my weaknesses.

(Mal #30)

In the following extract, Doug reflects on how imagination is treated within societal contexts and how important imagination is in the learning of electrical physics.

As far as the culture here I don’t really know. As I said before imagination is not something we all consciously thought of throughout the course and things like that. I won’t say that it’s discouraged here because a lot of the times the material we are learning you need to use your imagination a lot. So I think that’s where I find it useful in getting someone to explain something a different way to the way I would think of something. That’s them having to use their imagination. Luckily, people have imaginations here otherwise I wouldn’t be able to learn as much as I did, I think.

(Doug #42).
Not all self reflection by participants was positive. For example Steve’s introvert personality meant that his self-reflection was largely discouraging and related to how he thought others would view him.

I have been told a couple of times I am an introvert. That really wasn’t a surprise, the ‘P’ [Myers-Briggs category] that was about being pretty indecisive, that’s me. I did not know where I was going to sit ... [in relation to] the others and on my profile I was fairly close. One of them was fairly close, one I had to go a long way because I was in the middle. I got sensing and thinking - I think that I think. I don’t know if [the instrument has] helped because I try not to think about these sorts of things. I feel that if I fuss about how other people view me I am just going to look like a bit of a twit. I definitely do [have some issues] with taking risks, I would rather go the tried and tested [way].

(Steve #20).

4.8 Final thoughts

The final thoughts of these four participants summarises their opinions with regard to imagination and learning, demonstrating the shifts and changes that have occurred. For the entire cohort of participants the changes have been in the positive direction only.

For Mal the changes have been large. He has changed his opinion about imagination and learning from negative to very positive. As Mal points out below the process was gradual, activity by activity.

Finally, I understood the impression that I had early when I first started was unacceptable. The development of our imagination in the electrical physics is a gradual process. Every activity we did so far would account for this gradual change. With help of those activities I suppose now, I am a different person with having a broad view and vision, not only in the field of Electronics but also in the community as well.

(Mal)

In his summing up of his experience as a research participant, Doug acknowledges that the nature of electrical physics makes learning in this domain difficult. He concludes that using imagination is an appropriate way to learn in this area.
The things we have been learning, like you said at the start, you can’t see it, you can’t taste it, you can’t touch it, you have got to look at it from a mathematical point of view. Which I find that’s pretty hard, some of the things you just can’t do that. So that where the circuit activities have come in pretty handy for me because often I would look at a circuit and if it was not drawn the same way as in an example, in a text book or up on the board, I would not be able to recognise that is what it was. ... So I have found those things to be good. That’s more imaginative I suppose than just memorising a picture of a way a circuit is supposed to look and ... so that’s been pretty good.

(Doug #48)

The narrative constructed from Steve’s video interviews did not reflect a chronological development as did the stories of the other participants. The final thoughts of Steve accurately reflected the data collected from him throughout his narrative. His perspective on learning has remained shallow and related to memorisation rather than contextualised learning. Nevertheless, he records that the imagination study has been of some assistance to him:

Some of [the imagination activities] have worked more on my ability to recall information. I have found it’s been more about what I can pull back from my memory. Whether it’s short-term stuff or whatever, it’s been an interesting test for my memory. For example, the one where we were blindfolded and asked to do the circuits: I just tried to memorise where I had laid out the stuff and what had gone up on the board and then repeating it as quickly as possible. At the same time, it was the hands-on of getting used to where they were physically as I plugged them together, as I tried to remember this plug there and that one is not that one at all. It’s been more of a memory exercise for me.

(Steve #5)

4.9 Summary
The themed stories of Mal, Neville, Doug and Steve are a window into the eighteen stories that form the data for this thesis.

Mal came to the imagination project with little hope that the imaginative skills activities would be of any help. On completion of the project, he had
not only learnt a new way to learn electrical physics but had gained an insight that will serve him his entire career.

Neville engaged the imagination project and activities with an open mind and improved his physics skills beyond many in his class. After the imagination project, Neville continued to actively use imaginative skills in his learning at all possible levels.

Doug has used his imaginative skills whenever he has found that his standard learning approach has been inadequate. He has used imagination to challenge and focus his learning and has improved his learning outcomes considerably.

Steve has attempted to engage the process and activities of imagination with little shift in his application or understanding. Steve continues to struggle with the higher electrical physics skills beyond DC, particularly in AC, analogue and radio.

All the student participants’ stories are located in Appendix E on the MC.
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Chapter 5

Analysis

This chapter provides a detailed analysis of the eighteen participants’ stories during the course of the imagination study. The analytical framework applied here is described in the previous chapter and is derived from blending and extending activity theory and tension field of learning theory. The result is a matrix of six principles and six questions. They are tabulated below (Table 4.1).

5.1 Introduction

The principles of the analysis are activity, multi-voicedness, historicity, contradiction, expansion and learning. **Activity** is the larger picture of the overall system. **Multi-voicedness** is derived from the differing participants’ stories both individually and collectively. The context and past experiences of the personal, local and the wider context are addressed through **historicity**. Much is revealed by the analysis of patterns of disequilibrium, discontinuity and **contradictions** which are present in any collective human activity. Creativity as a facet of imagination offers an **expansive** window into many aspects of learning. The final principle is the **learning** relationships that are part of the essence of being human.

In the left column of the analytical matrix is a series of six questions that probe the principles explained above. It is this probative value that brings new knowledge and understanding to the metacognitive use of imagination in the learning of electrical physics.

Asking **who is learning** provides a focus on not only the obvious learners, the participants, but also on the less obvious people whose contribution to the learning may otherwise be easily overlooked. Investigating **why they learn** furnishes the motivation and passion for learning in the domain of electricity. The question of **what is being learnt** delves beyond the obvious
to the learning engendered by human interaction. The learning change that is occurring is explored through the determination of the catalysts of, and responses to change. The fifth question, how do they learn, is one of the most significant for this thesis. Response to this question clarifies whether and how imagination has played a role in the learning. The final question challenges the underpinning assumptions of learning and in a predominantly abstract domain.

The key words bolded above relate to the row and column headings in the following table (Table 5.1) This represents a matrix which maps the six question (rows) against the six principles (columns) which is the basis of the data analysis process.

<table>
<thead>
<tr>
<th>Activity system</th>
<th>Multi-voicedness</th>
<th>Historicity</th>
<th>Contradictions</th>
<th>Expansive cycles of creativity</th>
<th>Learning Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is learning?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Why do they learn?</td>
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<tr>
<td>What do they learn?</td>
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<tr>
<td>What have been the catalysts and responses to learning change?</td>
<td></td>
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<tr>
<td>How do they learn?</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>How are underpinning assumptions being challenged/ changed/ affirmed?</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The colours of the rows in Table 5.1 use the metaphor of the refraction of light through a rectangular prism. The narrative data of this research can be visualised as the white light that enters the prism. The prism is the composite analytical framework used for the analysis and the spectral
colours each relates to a basic analytic question that has been explored. This is represented diagrammatically in Figure 5.1 below.

![Figure 5.1 Analytical metaphor](image)

In the following analysis, the thirty six cells of the matrix are investigated separately. To guide the reader the six by six icon is used to inform the reader as to which particular combination question and principle is being analysed. This is done by whiting out the particular cell as shown in Figure 5.2.

![Figure 5.2 Analysis Icon](image)

In this example the whited-out cell is in the second row and fourth column. The relevant analysis will ask the question, why do they learn?, against the principle of contradictions. This actual analysis is found in section 5.2.2.4.

Throughout the analysis text a proportional scale is used to indicate the coverage and depth of the students’ comments. Using this scale 1.0 would be used to indicate complete coverage by all students and 0.0 used to indicate no coverage. Thus a scale of 0.4 would indicate forty percent coverage.
5.2 Matrix analysis
This section documents the thirty six analyses generated and extracted from the data material which answers the six questions according to the six principles.

5.2.1 Who is learning?
This section contains the six sets of data filtered out by using the six principles against the first question, who is learning.

5.2.1.1 How does the activity system affect who is learning?

The main learning activity system in this study was comprised of a full-time electronics and communication diploma course, and the eighteen students participating in the class. Whilst the immediate activity system impacting on this study is the daily direct interaction within the class of students and teacher, this activity system is embedded in other activity systems.

The analysis in this study focuses on the students, their work places and their classroom, whilst still being cognisant of the multiple layer and dimensions of activity systems, such as the Riverina Institute of TAFE, the Australian VET system, Airservices Australia, the Electro-Communication and Energy-Utility Industry Skills Council, and the social and domestic activity systems which impact on the students.

In considering the students as learners, I have examined the students’ past experiences as learners and then their present experience in learning electrical physics at TAFE for themselves and their employer.
Considering the nature of the students previous learning and motivation aspect of learning within the TAFE system, provides insight into the learning activity system from the students’ perspectives.

Previous formal learning of electrical physics for the students is categorised by institutional type (school and university) and by subjective experience (positive or negative).

The students’ school backgrounds are significant because all eighteen participants make mention of their school experience as it relates to the learning of electrical physics. What is also notable is the balance of positive experiences with negative experiences. There is a ratio of approximately two to one in favour of a positive school experience with electrical physics.

The following example is typical of positive reference to school experiences (Coverage 0.7);

I had a very basic understanding of it (electricity) from Physics in high school. I knew what volts were, what amps were, what Ohm’s were, knew basic circuitry, just parallels and series...

(Dillon #4)

whilst the following example shows a more negative experience of school (Coverage 0.3).

...by comparison, I am doing a lot better than I did through school. That’s because this is more hands-on stuff. I never did really fit into the school kind of mould...

(Darren #8)

Five of the eighteen students attended university before starting their studies at TAFE and only one completed a degree course. All five students made some negative comments about their university learning experience.

The following is an example of a positive comment on learning by Josh when he wrote (coverage 0.3):
I think when I was doing electrical physics [at university], everything was explained in a completely different fashion. So I had concepts and ideas on how everything worked and that wasn’t a problem.

(Josh #17)

A typical example of a negative comment is given by Dan when he stated that (Coverage 0.7):

To be honest, even after uni, I couldn’t grasp even the concepts of a parallel circuit properly, I don’t know why but I guess it’s their teaching style.

(Dan #3)

Learning at TAFE from the students’ perspectives is the third facet of the learning activity system that adds to our understanding of learners. Approximately one third of the participants’ responses made mention of this. For the student, the formal learning is corralled by the walls of the classroom and their perspective is important because this classroom is their life for thirty five hours per week over a protracted period. The relationship between the student and the classroom context, over such long periods influences the activity system, just as the system impacts on the students’ learning. These multi-level interacting relationships provide the picture of who is learning in the activity system.

The first aspect is how the students view the learning system at TAFE and how this compares with their previous learning experiences.

I found that coming from university, and high school before, that [TAFE was] almost a mix between the two.

(Josh #34)

These students do not understand the movement from school to university to be a simple continuum. For them, learning at TAFE is not just half way between two extremes; rather TAFE is a blending of the two. It is this insight that tells us a little more about who is learning; that is, students from other learning systems.
The classroom activity system does not operate in a vacuum. These students, as learners, are tightly connected to the social structure of the class as a group of people. This section explores the relationships between students as they relate to who is learning. The main perspective is that of social interaction (Coverage 0.6).

Interacting with others has helped me to learn a lot, because you can share the knowledge, skills, learning styles and different ways of doing things...

(Mal #37)

Not only does the TAFE system not operate in a vacuum, but neither do the students. The comments above clearly demonstrate that the learners learn in community. Not only do they learn in community but they are aware that this community relationship is vital as it brings meaning to who they are as learners.

5.2.1.2 What are the points of view of those learning?

A particular point of view involves norms, expectations and underpinning assumptions. In this section, I explored the expectations of the participants, their families, learning institution, their employer and the researcher. I have identified two sub-dimensions that carry the most meaning for this study. These dimensions are expectations of culture and self. The data show that these had a strong influence and, therefore, used as a tool for the learning of electrical physics.
Cultural expectations (Coverage 0.55)

These expectations are grounded on the ethnic culture of the students and expressed in their familial expectations. Four of the eighteen study participants were from an Asian culture (India, Sri Lanka and The Philippines). The remainder of the participants were raised in Australia and represent a Western culture. The Asian participants recognised the influence of their family culture and learning background when they made the following comments.

When I was younger, I had a stronger Indian culture but not so much in my teen years. In that culture the kids, even though they are in primary school, they still pushed to do it like a robot. Basically, that’s the best method, very goal-orientated, very regimental. Nothing that may help just get what you need to know.

(Dan #44)

Because I have grown up in different cultures, I think my culture is very strict with learning styles and imagination was not a focus. It did not regularly encourage or discourage me. It is more focused to the theory focus, no matter whether you use imaginative skills or not as long as you get the correct answer.

(Mal #38)

These students’ points of view about how to learn are strongly, and directly, influenced by their cultural worldviews. These worldviews encourage learning ‘like a robot’, ‘strict learning styles’, and regimentation because ‘this is the best method’. They are pragmatic, having little regard for the learner or the process of learning. The students appear to see themselves as products and the process is just a part of mass production.

Cultural expectations also echo through to students’ perception of imagination and therefore their perceptions about learning. The following quotation is indicative for most of the students, whatever their particular ethnic culture.
In terms of my cultural background, being part Indian, Indian culture frowns on imagination...

(Dave D #43)

The third theme of adult learning culture kind of links to theme two, I think my culture and imaginative skills for learning in adult learning its sort of more to the facts and like we’re doing the more maths and physics.

(Adam #34)

It is also important to note that those students from a more Western perspective reflect a culture where the norm is to minimise the importance of reflecting about learning (Down, 2006, p. 49; Gott, 1995, p. 13). This assumption often leads to them thinking that learning is the same for all of them, but this is not the case. Learners who have an understanding of their learning preferences learn more effectively (Smith & Dalton, 2005, p. 6). Simply put, not every one learns the same way.

Generally, the students’ point of view reflects a dualistic and scientific positivist understanding. This is dualistic because imagination and learning are in the personal domain and are features only the person can bring to the process. Where as, scientific positivism in electrical physics is the water they swim in. The students do not consciously think about it, but this is part of their assumed worldview.

**Expectations of self** (Coverage 0.6)

Stop, rewind, pause and play
My life about a year ago today
Learn, act and think with constriction
Everything in line with an implicit convention

(Dom #36)

In this extract Dom gives a strong picture of the students’ self learning expectations: that is, there is only one way of knowing that is valuable and that is scientific positivism.
The first stanza talks about the old me before the program (Imagination in Electrical Physics). I haven’t really thought of Science as an area where you could just freely imagine and come up with random ideas. To me, it has proofs, rules that are tested time and time again and that these rules can’t be disobeyed. Science warrants data that backs up the talk and that what has been said in publications are always right and so just do it as they would do it. I was content with that and never really cared to venture to the other side.

(Dom #36)

Dom recognised, before participating in this study that he has experienced only one approach to learning and was therefore ignorant of other approaches.

This singularity was a common assumption by the participants at the start of the research. After at least thirteen years of schooling the students had built learning expectations that had served them well and were not going to be easily changed or adjusted.

Last three terms I have been more open-minded towards learning rather than use the old methods. Open up a little bit and try to embrace new techniques of learning such as the learning cycle in particular and even the story telling. Incorporate that into learning. It’s been a sort of a change for me.

(Sam #41)

Left unsaid by the students was their expectation that appropriate learning support would be provided to them. Therefore it was their responsibility, through engagement in the learning to complete the course. Three of the students did not complete the course. For two of these it was their disengagement from the learning at an early stage which led to termination of their employment. The third participant recognised his difficulties in learning the level of electrical physics expected and negotiated his transfer to a lower level course.
Although the students’ points of view were diverse, they were all focused on completion of the course and starting their careers as radio technicians. These diverse expectations were to a large extent influenced by their family’s cultures and expectations of success. They appeared to define success as having a respected career and adequate financial remuneration so as to provide for their families.

5.2.1.3 How do historical contexts affect those who are learning?

History is about people so it follows that it must be oriented around people. People use historical narrative of their past experience when making meaning. The learners’ historical contexts are investigated and reported upon here. It is these histories that give further insight into the participants use and association with imagination.

The personal histories of the students revolve around their education to a large extent. This occurs because of their age range. However their geographical location in cities, regional towns or rural settings and, previous employment also impact on their historical narratives (Coverage 0.9).

Most of the students’ personal histories are relatively short. Each of the following excerpts from the students’ narratives demonstrates their geographical context and a little of their personal history.

I grew up in the rural areas near Wagga on my parents’ farm. This is where my first interest in electrical things started.

(Adam #1)
I am from Townsville. I was born and bred in North Queensland. My interests are in electronics – there is no question about it – and I have always liked it since I was a kid.

(Neville #1)

I am originally from Canberra. I am nineteen years old. I graduated from Marist Brothers College Canberra last year [2008].

(Mort #1)

The students’ interest in electronics before commencing the Diploma course was strongly linked to their educational backgrounds.

Those who had completed only secondary education before starting the course and those who had undertaken previous TAFE studies and or work had a reasonably superficial interest in electronics. The students who had undertaken university studies expressed a much stronger interest in electrical physics.

Previous employment is also a relevant aspect of the historicity that participants brought to this research. The students, who came directly from secondary education, had virtually no part-time employment. Those from TAFE or university typically had part-time work or were involved in traineeships combining work and study. The final category was those coming directly from the workforce who had been employed in industries other than electronics, often retail sales. The geographical historicity of the students is diverse, ranging from remote rural to city contexts.

The analysis was unable to make any specific links about the student educational, employment or geographical historicity and their participation in the study apart from common employment by Airservices Australia.

It is probably relevant to show how my historicity has led to my undertaking of this research study now in my early fifties.

I have had a long interest in electrical/electronics from pre-school days of playing with electrical torches, to pulling electric toys apart in primary
school, to construction of radio transceivers in high school. My major interest in my childhood was all things electrical and electronic. This was fuelled by my parents and grandparents with electronic magazines and kits as birthday gifts.

All the employment positions I have held have been electrical/electronic in nature from beginning as an electrical apprentice at seventeen until today, now teaching electrical/electronics engineering. My employment in the electro-technology industry as an apprentice; tradesman; supervisor; in-house industry trainer; project engineer and sole trader has led to the direction of this study as I observed others struggling with what appeared obvious and straight forward to me. I have always wanted to know why.

Running concurrently with my interest in electro-technology has been my involvement with the Scout Association, first as a youth member and then as a leader for some forty plus years. Scouts have influenced my thinking with regard to teaching/learning from an innovative perspective and as such it has influenced this study and my approaches to teaching.

A direct influence of this study also has been my experience as an Industry trainer. This began informally in the late part of my apprenticeship as many of the first and second year apprentices would come to me for tutoring with their TAFE work. This was then a natural progression in other employment contexts as I assisted apprentices and tradespeople alike. A typical example was the teaching of trades people how to engage workplace specifications appropriately in an effort to improve quality. As these workplace skills improved I became a company trainer, writing, producing and delivering technical courses (PLC mostly) nationally and internationally.

A further impact on this study is the phrase ‘Semper Reformata’, which comes from my reformed Biblical Christian worldview. Since I was about eighteen this perspective of reformation: “Reformed and always reforming” has driven my life at all levels. The direct effect on this study is my application of this to my teaching. I strive to always critique my
5.2.1.4 What are the contradictions that influence who is learning?

The contradictions that occur for those who are learning are diverse in each of the categories of student, employer, TAFE NSW and researcher. The analysis of this question will focus on the student primarily, with the employer and TAFE NSW in a supporting role. The students experience contradictions inherent in learning content and context change, contradictions within themselves and contradictions in using imagination as a learning tool. I, as the researcher, also experienced learning contradictions as I increased my understanding of teaching theories or approaches.

Changing learning styles is about reflexive change. As mentioned, all the students of this study have had an extensive education before starting the Diploma of Electronics and Communication. As such, they have their own particular ways of learning that have been established by at least thirteen years of schooling. The aims of the imagination study was to challenge and enhance their approach to learning electrical physics, in particular by using and developing imaginative skills. This imaginative skills approach, in combination with new content and context, has magnified contradictions in learning (Coverage 0.8).

These contradictions arise because of tension, risk and doubt connected with moving from established methods, processes and systems to new paradigms. Associated with this is the movement away from dominant metanarrative and established societal expectations. After thirteen plus
years of formal schooling the participants have been conditioned in particular ways. To introduce the participant to the concepts of competing narrative, alternative ways of doing things and the idiosyncratic nature of an individual’s learning, is to take him/her from a climate of certainty to one of disequilibrium (Mezirow, 2009, p. 22).

Sam gives a tentative indicator of the students’ change in learning approach.

Last three terms, I have been more open minded towards learning rather than use the old methods. Open up a little bit and try to embrace new techniques of learning such as the learning cycle in particular – and even the story telling. Incorporate that into learning. It’s been a sort of a change for me.

(Sam #41)

The contradictions in approach to learning electrical physics have been bidirectional, oscillating between students’ traditional approaches and tentatively trying a new approach. The expressions ‘...been more open minded (e.g. Sam #41)’ or ‘...open up a little bit (e.g. Neville #14)’ are indicators that the new approach is contrary to their traditional expectations. Most of the participants experienced contradictions as they experimented with different learning experiences (Coverage 0.7).

Another indicator of contradiction is risk – for example, the risk of changing approaches to learning in an attempt to learn better.

It was a complete shift in thinking from DC voltages, to the codes and what all the gates do and things like that. It was a lot to take in when I had not done any of it before. But now I recently did my catch up test for digital two and realised it was not that difficult.

(Greg #29)

Thus the contradiction for Greg is internal, involving his perceptions of his ability to learn and to explain that learning.
Dan is a university graduate in teaching science but, within his new context of TAFE, he is experiencing internal contradictions in his ability to explain a relatively simple DC process using a circuit diagram and the actual components in this case.

I think that pulsating DC, the whole aim of the circuit is to convert AC to DC for that every component needs it. So after this first stage where you have the diodes and centre tap, we have this pulsating DC coming out.

(Dan #7)

The above example indicates the internal contradictions experienced by Dan as he undertook a make-up⁴ test and realises that the content was not very difficult. The contradiction in his thinking was sufficient to hinder his first attempt at the assessment.

In the following examples from Greg a contradiction in his thinking is exposed when he restricts the usefulness of imagination to learning about amplifiers, but later within the same interview transcript he acknowledges a wider use of imaginative skills.

Amplifiers that was really the only class; I mean Term 3 of last year, it would be the only class where I used imagination at all.... The [imagination] classes have given us the skills and tools to aid us in these subjects, just the way to look at things, the way to picture how code and programs work. It’s good if you can just organise it in your mind using your imagination.

(Greg #46,48)

Greg’s opinion of the imaginative skills has widened and become more positive. The contradiction occurred because the learning approach is very new and is counter cultural to the student’s traditional way of thinking about learning. The result was that he vacillates about how he thinks about new concepts.

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⁴ A make-up test is undertaken when a student has failed to achieve competence in an Assessment. Thus undertaking a make-up test the student has demonstrated that he/she has experienced difficulties in learning.
The contrast between teacher-led learning and student-responsible learning produces contradictions caused by who is responsible for what in the learning process of learning in the community of the class. Here, there are three main relationships, those of student / teacher, student / student and student / self. As the student starts at TAFE, the strong frameworks and content often give the new student the impression that much of the learning is the responsibility of the teacher and those strong frameworks somehow convey that message to the student. Normally, by the end of the first term, the students have learned that a far greater portion of the responsibility lies with them as learners. This is generally in contrast with their previous learning in a school-based environment. The following quotation makes this apparent as they contrast TAFE with other learning experiences based in work and university (Coverage 0.9).

Learning at TAFE, it’s a pretty open learning environment. To a certain extent, it’s your own learning abilities and your own pace [that make the difference]. If you don’t put in, you don’t get anything out.

(Neville #24)

The students involved in this study were aware of the concept of preferred learning styles and discussed these in their personal narratives. All the participants mention the way they prefer to learn or not learn.

But, at the same time, I think it’s things I hear I tend to retain better as well. I am not sure if everyone is the same, but hearing is generally the best for me.

(Steve #8)

In most cases, the participant’s preference was for hands-on learning. This actually reflects their preferred content type rather than a preferred learning style. This misunderstanding on the part of the student results in contradictions within their narratives (Coverage 0.85).

From a learning styles perspective, I understand that I need to be doing things rather absorb them from books.

(Jeff #13)
Here, Jeff suggests that he prefers to learn through listening when a difficulty arises. When Steve and Jeff make it clear that reading is not their preferred learning approach, they are thinking in terms of written text. This produces a contradiction when the “reading” under discussion refers to the interpretation of a diagram (visual literacy). Again the contradiction is in the content and context of what is being learnt.

From the above there is clear a theme, which the contradictions discussed arise because of change in the learning process. So, the who is learning in this analysis refers to those participants who are enhancing or changing their patterns of learning.

5.2.1.5 Who is learning with expansive creativity?

Continuing with the two categories of student and researcher as who is learning, I now analyse these perspectives from an expansive creativity perspective. ‘Expansive’ means increasing (in this case, one’s learning) and ‘creativity’ involves expanding learning with approaches that are beyond the learner’s normal approaches. For these students, the imagination study has provided a creative approach to learning electrical physics and provided unexpected challenges to their learning. The employer in this case has also been creative in solving the problem of adequate shortage of radio technicians. As the employer approached the problem creatively, TAFE was led to find creative solutions as the partnership grew. Finally, the researcher has been creative in selection and execution of the imagination thesis.

Students were asked to learn via a creative perspective, consciously improving their imaginative skills. There have been three responses to the
direct request to learn creatively: trying something just because it is new, 
changing an old approach because of the weakness of the old approach 
and engaging the imagination approach as requested (Coverage 0.6).

Trying a new way to learn, Keith discovered a metacognitive technique he 
was not previously aware of:

I think it’s helped a lot because it makes you think about thinking. 
Before, I would be narrow-minded but here I can take a step back 
and think what I have done in the past – so I am using past 
experiences too.

(Keith #24)

Even though he was engaging in imagination activities, his response at this 
stage was centred on a new approach to learning rather than specifically 
about the use of imagination. Later in his narrative Keith reflects on 
challenging the old ways of learning.

I would say [imagination] has increased the risk but I think that’s a 
good thing, because sometimes you have to take a risk to get a 
profit. ... It puts you out of your comfort zone, which I think is a 
good thing and expand what you are all about.

(Keith #37)

In his narrative Doug mentioned that the absence of the expected 
challenged old ways of learning.

With the PCB to circuit exercise, it was not laid out. There was no 
circuit diagram, so it was a challenge as far as how things were 
connected up together... I did not go very well at it because I had 
never done it before.

(Doug #15)

Imagination activity is, by its very nature, intrinsically linked to creative 
expansion. The following students give a positive picture of learning using a 
creative imaginative approach which has helped them to connect things 
together.
Using imagination ... [has] been most helpful with mathematics class. It allows many avenues for the use of imagination, specifically the types used in electrical physics. ... Computer studies, I did not touch on that in last term, but it requires the use of abstract theories and use of programming languages that rely on the imagination heavily. The [imagination] classes have given us the skills and tools to aid us in these subjects – just the way to look at things, the way to picture how code and programs work. It’s good if you can just organise it in your mind using your imagination.

(Greg #48)

My shift in imagination is a bit of a tool, so you consciously think about, then you will go about it sort of using the skills that you learnt. ... So you had to use your imagination of how the circuit would integrate into the resistors and how you could simplify it to make it simpler.

(Adam #20)

In the following excerpt Dom recognises the need for the rationale of learning strategies to be articulated and that this disengagement from learning often occurs because students do not know why they are being asked to use particular strategies.

I think learning a little bit more about history, although it might be boring for some, and learning where to apply these things would be good learning. I think learning something, without knowing what it’s for or where it’s from, it’s kind of hanging; it leaves me asking “So what?” I think I will remember it better if there is connection to everything.

(Dom #14)

The expansive creativity of the individual student has been increased but not in a linear or uni-directional way. For most students, the imagination study has fostered expansive creativity in multiple dimensions. The creatively expanded dimensions, identified by the participant, included context; connection; perceiving the whole; and producing new learning tools.
This research study has proved to be both creative and expansive. The expansive component was two dimensional. The first expansive dimension was my knowledge and understanding of learning systems. The second was my increasing understanding of what imagination is, how it can be used, and why my culture and others reject imagination as an adult learning method.

5.2.1.6 What are the relationships between the learners?

For the purpose of analysis, who is learning and through which relationships, again follows the larger categories of student and researcher, even though the employer and TAFE have some significance. The analysis focuses on three key relationships: student with self, student with other students, and the student with teachers.

**Learning relationship with self**

The self learning relationship entails two key elements: one’s own personality and the capacity for self reflection. Key development areas of the participants’ ability to self reflect were the use of the Meyers-Briggs personality test and being asked to reflect on their learning in a semi-structured interview process. Sam’s response is typical of participants’ reflections on their inner-relationships (Coverage 0.6).

I found out that I was the Introverted, Sensing, Feeling, Perceiving person. This information allowed me to better understand my identity and gave me the opportunity to reflect on my strengths and weaknesses and improve from there.

(Sam #47)
As the participants realised that they could reflect on their personalities and so use this to assist their learning, the participants became more metacognitive in their approach. They began to view learning as making sense of phenomena rather than memorisation of known facts. This is shown in the following excerpt from Mitch.

I did not really think about that imagination was something that we all do that adults do as well. Though I have also realised that we do it subconsciously without thinking, I don’t know like making stuff up. Like here now I am using my imagination to talk about what I have learnt and remember stuff.

(Mitch #26)

Although Mitch is effectively using imagination in his learning, he is still uncomfortable about using imagination in an adult world (Coverage 0.67).

**Learning relationships with others**

Learning relationships are complex, diverse and can be both positive and negative. In their narratives, the participants noted four aspects that represent the complexity of the learning relationships.

In the following example, Adam indicates that relationships are good, reducing the need to rely on texts and teachers and thus making learning more flexible.

So I guess that’s good because most people are learning at the same time and if they do grasp it then they will be able to simplify it a little bit for you. Which I think is really good, so you don’t have to rely on the text book and the teacher all the time.

(Adam #33)

The second aspect, identified by the participants, was assisting each other with difficult or missed concepts. The following extract is illustrative of participants learning together.

...social interaction in class: it’s really good because if I don’t get a concept or I get a concept we tend to bounce ideas off each
other’s heads as we march on through the course. So I guess it’s been very helpful.

(Dillon #36)

Another aspect identified was flexibility within social learning. Students need to be able to find a balance between individual and collaborative learning. Some relationships are advantageous but others may only distract. The student demonstrates both choice and judgement as the following extracts show.

I am learning better [in class] this year because I am sitting next to Dom and I am not sitting next to Josh and Dan. I used to talk to them a fair bit. I am pretty sure I am learning better.

(Greg #40)

I find that people can confuse me if they don’t exactly know what they are talking about. If they had a definitive answer that would probably help.

(Keith #34)

Participants did not specifically refer to the relationship between students and teachers. However, their narratives often mentioned one of the electronics teachers who had a good interpersonal style and a very high level of understanding in a specific area of electronics. It is this combination of interpersonal style and technical ability that contributes to forming a social learning context that the students appreciate.

In this study the researcher has a dual but interconnected relationship with the students; being both teacher and researcher. As the student comments below indicate, the relationship between student and researcher-teacher has grown from tentative to strong.

Ken’s been doing some of this imagination stuff with us; so I learnt a different way of doing the same thing and bonding our knowledge a bit more. ... Just a deeper knowledge of it, I guess.

(Adam #7)

Then [...] Ken Meyer came up with an idea of challenging the way our minds think and the way it is programmed. I think he believes that by doing activities that “strains” our mind, our brain will work
hard to get us out of the strain and as a result the brain comes up with various ways and new ideas.

(Dom)

As the researcher has observed the students moving from tentative scepticism to embracing the concept of imagination in some form, it has become clear that the participant cohort has become more interactive, cross-reliant and more cohesive as a group. The research study has given them a common purpose or goal in addition to completing the course.

5.2.1.7 Who is learning?

The previous six sub-sections have discussed the question of ‘who is learning’ against the six principles of the composite analytical framework. It has also identified the different perspectives of the student, researcher and, to a lesser extent the TAFE and employer workplace environment.

The narratives have identified that those learning through the research study involve all the participants, the researcher and other teachers associated with the Diploma program. The selection of the participants was initially undertaken by their employer although some students have left the program because it did not fit with their need, abilities and/or application.

The students have recognised that they are learning both individually and collectively, and the balance between this is impacted upon by the historicity, multi-voicedness, inherent contradictions, expansive tensions and relationships which are concomitant working within a group. As their teacher I have observed that involvement in the study has increased the participants’ awareness of the process of metacognition and formed them into a cohesive and mutually supportive group.
5.2.2 Why do they learn?

‘Why do they learn’ is a question about motivation. The motivation to learn comes from an identified need to resolve an issue (problem-solving) or to attain a currently unattainable goal (specific development). The participants in this study are all undertaking formal and workplace training to become a radio technician (developmental motivation). In order to achieve this they need to learn to resolve the issues, complexities and challenge they meet on the way to their goal. These lie on an overlapping continuum between internal and external motivation – overlapping because there is originally always a mix of internal and external motivational factors that determine the problems to be solved.

5.2.2.1 Why do they learn in this activity system?

For this study, the activity system is the formal TAFE learning environment and those who inhabit this learning context. This activity system involves the classroom, tutorial, homework and self-directed learning related to electrical physics.

The motivation to learn depends primarily on the learners’ expectations but is also affected by those of the employer and TAFE teachers. Internal motivators include self-interest and survival expectations (income production).

The participant narratives indicate that there are three general external adult learning motivations or reasons why these students learn within the TAFE activity system. The first is the social norm of how adults are expected, or not expected to learn. The second is the need for general social support or acceptance. The third reason is that of specific, individual, learning support.
The coverage for these reasons are: adult learning expectations (0.55), need for acceptance (0.45) and specific learning support (0.67).

The participants recognise that adult norms take learning seriously. The next narrative extract, portrays a rejection of adults doing childish things while learning and, in this context, the use of their imaginations is regarded as childish. The participants’ understanding of adult education is basically anything that is not ‘acting like a kid’.

For me I have been brought up that as you get older you have to become more serious and stop acting like a kid. I think that’s where my view on imagination is, it’s childish. If not imagination I would prefer to call it using your mind or something, mind power or thinking.

(Mitch #42)

Another motivation to learn is matching the achievements of the majority of the class. This quotation is all about being there for the purpose of learning.

Here at TAFE is pretty similar to how I spent the two years before I started TAFE. For years eleven and twelve because we had a really big school and it was a very adult learning environment. If you weren’t there to perform, you were basically kicked out; they did not want to teach you. [So] I like this kind of learning environment a lot more. Because I suppose if someone breathes down my neck I tend not to do the work at all, I rather do it in my time.

(Jeff #30)

These motives to achieve, and achieve at a similar pace, are externally imposed by the activity system investigated by the study. Specifically it is the rules, community and division of labour which shapes the class culture and in turn, the educational delivery system of TAFE. This delivery of education is sequential in nature. This is because of the volume of learning undertaken and the inter-relatedness of the electrical/electronic concepts. That is, some concepts of electrical physics are essential to learning others.
The internal motivations to learn are many and varied. The internal or external aspects of motivation raised in the participants’ narratives were largely confined to wanting a qualification, general interest, the production of an income, and enjoyable learning.

Obtaining a qualification is clearly connected to income, but many participants recognised it was even more strongly connected to self-image and self-worth. The production of income relates to Maslow’s (Maslow, 1943) hierarchy of needs: the need for protection, food, help and support.

Everybody knows each other and if you need help, it’s always there.

(Josh #34)

If I do need help will turn to a couple of guys close to me who seem to have a pretty good grasp on the topic.

(Mitch #38)

General interest is seen by participants to be related to curiosity. The origins of this curiosity often derive from family contexts and natural skills and inclinations in science.

My interests are in electronics, there is no question about it, and I have always liked it since I was a kid. I use to rip a part everything I owned. It got the point where mum was buying me clear see through toys so I would stop pulling things apart to see how they work.

(Neville #1)

Similarly Mort’s motive came from his fascination with how things work. This has resulted in dismantling gadgets to find electrical components. This has then led to building electronic kits in an attempt to learn more. The result is a strong interest in electricity.

I have always had interests in electronics, taking things apart and seeing what’s in them and seeing how they work, things like that. Always played around with electronics and built things of my own and I built some computers as well.

(Mort #3)
Enabling students to understand, and become skilled in a range of learning approaches and styles is also motivating because learning becomes a joy.

My learning experience at TAFE this year can be characterised as “fun because, it’s easy to say the course has been intensive or been really interesting, that’s all good, that is probably common to everyone.

(Dan #41)

Jeff also echoes the perceptions of many: the learning approach at TAFE has a strong practical or hands-on component. It is the hands-on and ‘learning by doing’ that many students enjoy and so are motivated to learn.

The way I learn best is definitely the practicals. I can’t sit in front of a book. [The practical is] just being able to see it, [not] reading about. Talking about it does not mean much to me at all. It goes straight in one ear and out the other. [Learning by doing], I really like that.

(Jeff #12)

Steve’s need for acceptance within the learning group is typical of the participants’ narratives.

[The social aspects of learning] have been finding it incredibly vital. I believe if I could not talk to the other guys I would have failed long ago, I would have dropped out.

(Steve #29)

The participants of this study regularly took advantage of the bi-weekly tutorial sessions. The students indicated that the specific electronics tutorial was of particular benefit with regard to learner support.

I used to go to tutorials; I found some of the other guys would go regularly like Neville. We used to help each other out very much there.

(Sam #42)
The students’ expectations of qualification, interest and income were closely linked to the question ‘why do they learn?’ For example, Neville’s expectations are linked to the effort he applies to his learning.

Learning at TAFE, it’s a pretty open learning environment. To a certain extent it’s your own learning abilities and your own pace. If you don’t put in you don’t get anything out. Like you guys won’t chase us up for it. I think it’s more of a mature learning place.

(Neville #24)

Some motivation can be misdirected. Steve had not been able to keep pace with the course delivery. As time went on, this became worse. His motivation to achieve led to his self exclusion from work placement in order to complete the required work.

I stayed back at the TAFE instead of going on placement, on the spring September-October placement. I stayed back for an extra month and it was just a basic battle to catch up back to where I was, rather to where everyone else was.

(Steve #33)

Steve was strongly motivated to ‘catch up’. By excluding himself from the work placement, he lost the opportunity to ground his developing learning in the process and context of work as a radio technician. It is debatable whether or not he placed himself even further behind the group by his actions.
5.2.2.2 How does multi-voicedness impact on why they learn?

Not only do different students describe events in different voices, but each individual can view his/her world differently depending on which category of self identity is upper-most. Thus each participant variously speaks as TAFE student, an employee, male or female, an adherent to a particular worldview and a member of a specific culture. The narratives of the participants contained strong elements of their identities as TAFE students and adherents to particular worldviews.

As TAFE students, the participants recognise three aspects: firstly, as general learners of electrical physics; secondly, as aware students cognisant of the impact of their social, emotional and cognitive environments on their learning; and thirdly the impact of recent transitions between school and TAFE and or changes in employment.

Participants are critically aware of their primary purpose; that is, to learn electrical physics (Coverage 0.8). They expressed their preferences for learning in particular contexts with particular content types. Josh stated:

A lot of the time, I don’t understand things straight away. A lot of the time, when I am teaching myself, I don’t understand and I will give it a couple of days. Then I will start to understand. I just think all day. So, after a while, it starts to make more sense. Normally, then, I will go back and read it again and it will sink right in. Then I’ve got it.

(Josh #15)

All the participants acknowledge that they enjoyed and engaged with the integrated theory practical approach of TAFE. This student involvement ranged from open learning, which is being responsible for one’s own learning, through to the more hands-on practical units. For these
participants it is important that theoretical and practical learning are integrated with each other and with workplace applications.

... rather than doing some theory, the some practical and then doing some theory, more or less [integrated theory practical]. So getting used to having to remember what you have done in theory and then to do it in practical and now it’s you only did the theory ten minutes ago.

(Josh #26)

Three students came from university to TAFE, and again the blend of theory, practical and work context was important in their point of view as learners. The quotation below sums up their unanimous opinion.

On the pros, the way its [electrical physics] being taught, is pretty good. I think that just the TAFE system, the way the TAFE does things. I think if this course was taught by a uni it would not be as good.

(Dan #10)

These comments give a strong picture of the student’s response to the TAFE learning environment. For them, being a student is about being an adult learner and that requires a particular teaching approach and a particular learning context (Coverage 0.9).

Learning at TAFE, it’s a pretty open learning environment. To a certain extent it’s your own learning abilities and your own pace.... I think it’s more of a mature learning place.

(Neville #24)

TAFE is not like school as it is a different environment. It does not try and pour the knowledge into your mind like in schools. So you have to grasp it with your own effort but the teachers are here to help us. I found it a very positive, welcoming and safe environment.

(Mal #35)

Adults rarely learn just for the sake of learning, but more often learn to solve problems or surmount difficulties. For the participants the rationale is
to learn electrical physics as it applies to air navigation aids, so they can maintain their employment with Airservices (Coverage 0.64).

The next participant’s comments indicate the importance of relevance to the workplace. If the students connect the learning to their future workplace, then they become better students. They see the learning assisting them in solving problems and thus supporting their incomes.

Our work here (TAFE) helped with that so we knew how to fix those faults and solder (at work).

(Adam #26)

One of the imagination activities was to investigate one’s own worldview using a survey specifically designed for this purpose (Montoya, 1996). All the students participated and determine their own worldview. In the ensuing discussion participants were not required to disclose their particular worldview. However from the class comments, I judged that most of the participants would be naturalistic scientific positivists.

Cultural heritage influences a worldview. The underpinning assumptions about qualifications are very strong in an Indian culture. As an example:

In terms of my cultural background being part Indian, Indian culture frowns on imagination. They are very, know what you have to know, get what you have to get. Get that diploma, get that degree, and get that pay scale.

(Dan #43)

Here cultural heritage and its related worldview make qualifications pre-eminent and imagination is marginalised as a skill.

Considering how people think has changed the participants' awareness of difference. For many the common assumption is that most people think the way they do.

So being able to stand back and see that not everyone else here is exactly like me. It was good to get an appreciation of how people think and why they do certain things they do.

(Keith #26)
The next student realised, during a history exercise, that one of the founders of electronics had a particularly strong worldview. The student was able to bring his own worldview to bear and critique the worldview of William Shockley and justify his own point of view.

I did a poster on William Shockley. He invented the transistor and the transistor is everywhere and everybody uses it. ... He was pretty crazy, his ideas I guess. Like to sterilise people that did not have an IQ over one hundred so that they could not breed any more. ... He reckoned that they should be pretty well wiped out. He had a different worldview and he was not frightened to express it.

(Neville #18)

As a result of the worldview exercise, Doug realised that challenging one’s own point of view (or voicedness) would result in learning.

I challenge my preconception all the time now. Because, as I said before, if I fully understand something works, I find it easier to apply what it is we need to do to that. ... If the way something works does not necessarily help me understand it then I am more than willing to go and find another way of thinking to help me understand it.

(Doug #50)

5.2.2.3 How does the student’s historicity affect why they learn?

History is about the ability to critically reflect and find meaning that will enhance present understanding. The word is derived from the Greek ‘ἱστορία – historia’, meaning, ‘inquiry, knowledge acquired by investigation’. In the case of the participants, the historicity they bring to the study has several dimensions. The first is their own experience of
learning electrical physics, and the meanings they have constructed through this process. This encompasses appropriate conceptions that can be built upon through to misconceptions that will have to be challenged and reformed. The historicity they bring to the study is also shaped by their prior experience of learning both in formal and informal situations. This historicity may include negative experiences which limit their ability to recognise learning as meaning making.

When we first started this project, I thought that this would not help much. Because with my previous learning style that I had back in Sri Lanka, my mind came up with a set of skills that help to understand the electrical physics and I thought this because electronics is very theoretical and my previous experience and studies were directly to the point and gave me only what you need to know.

(Mal)

The history of general electrical physics has, in the same way shaped the way physics is understood, written about, taught, and learnt today. This external history reaches back to prehistoric people trying to understand lightning and static charges, on to the eighteenth century and the discovery of the link between bio-electricity and chemical electricity by Ludwig Galvanini. In the nineteenth century, electricity and magnetism connection were discovered and, in the twentieth, the discovery of semi-conductors and electronics became the foundation of today’s electrical technology. The external history of electrical physics is important to students’ learning because it produces context, gives students a starting point for understanding the thinking process of those who have gone before and the importance of discovery.

Mental models are used by learners to internalise what they are learning. The following quotations from the participant narratives indicate how mental models were built, challenged, and changed over the course of the study.

So I guess doing a lot of the picturing stuff in your head really helped ...

(Dillon #31)
...you have to think in my head how do I re-arrange that to see what’s in series,...

(Keith #24)

Mal is quite gifted; he has the gift of seeing the circuit, it automatically clicks, probably because of experience.

(Dom #35)

So as we did them in conjunction with theory classes I developed kind of modelling skills at the same time understanding the hard concepts.

(Mal #45)

I think it’s helped a lot because it makes you think about thinking. Before, I would be narrow-minded but here I can take a step back and think what I have done in the past, so I am using past experiences too. Dealing with analogue, working out your Thevin’s resistance and things like that, it’s on the paper there but you have to think in my head “How do I re-arrange that to see what’s in series, series parallel or parallel, parallel?” Because the circuits are becoming more complex you have to narrow it all down and do a bit of mental manipulation. Having that model in your head to say “If I turn it up this way, will it go like that and it all works out sort of thing...” You’ve got to step back and look at everything before you go rushing into something.

(Keith #24)

It is clear that students learn by engaging with their own thinking over time, by building on previous concepts and models (historicity) and also by challenging and rearranging older concepts and mental modelling.

Dom thinks history is important because it provides a context and connection to reality that aids current learning. This context and reality produces meaning that aids present learning:

I think learning a little bit more about history [...] and learning where to apply these things would be good learning. I think learning something, without knowing what it’s for or where it’s from, it’s kind of hanging. It leaves me asking so what?

(Dom #14)
Dillon is interested in the history of Michael Faraday because of his experimental approach which, for this student, is about starting points. That is, Faraday demonstrated that one did not need to be a mathematician to be able to start learning electrical physics.

I did Michael Faraday. [...] He was interesting because he was not a mathematician at all. He was a village blacksmith and then a bookbinder and he taught himself basic science. He had no idea about anything – he couldn’t do even calculus. But he was just a great experimentalist who was able to turn theory into hypothesis, and then create an experiment that proved it right or wrong or proved it enough for higher mathematicians to delve into.

(Dillon #25)

5.2.2.4 How do contradictions influence how they learn?

Contradiction is a key catalyst for learning because it questions learners’ existing concepts (Edlin, 2002, p. 7). Both Illeris and Engeström make this clear. For Illeris (2004) it is the tensions that are created by the contradiction, both internally and externally that motivate the learner to change. Too little or too great a tension and motivation is lost. In Engeström’s activity theory (1999) critical disequilibrium is achieved by ensuring the learner is made accountable for their learning contradiction.

The non-sensory nature of electrical physics compels learners to construct mental models. The phenomenon often behaves in contrary ways to the initial sensation-based modelling that the students have initially constructed to make sense of the phenomenon. When this happens a contradiction is evoked between the phenomena and the students’ concepts of them.
The participants indicated in their narrative that they want to align their mental modelling accurately in order to use their mental models as an effective tool for problem solving.

I found that was like imagining, mind stretching and turning around the pieces and seeing how they fit. The assignment for the six weeks the temperature switches. I was designing it, trying to make it as small as possible. I was trying to see and turn all the pieces around, move them around trying to get the best spot they could do in the small amount of room possible. I was moving them around and then it clicked that I could put them vertical mounting. Because I have only ever thought about flat mounting and then I realised I can do vertical mounting. So that changed things a lot and helped me.

(Mitch #27)

The problem is that the contradictions are often not obvious or able to be clearly identified. Contradiction is often experienced and expressed indirectly through disequilibrium, difficulty and challenge (Mezirow, 2009, p. 22). These experiences are very significant for the beginning student of electrical physics and they lessen as increasingly appropriate mental models are built, re-built and modified. The experience of disequilibrium, however, never completely departs.

Old misconceptions are very resilient and often cause the learner to ignore the contradiction embedded in them. The participants’ narratives reflect this in cases where participants cling to what they already know.

The following excerpts from Josh’s narrative indicate a shift in his thinking on the basis of contradiction, when he describes a picture that he draws to explain Ohm’s law.

My Ohm’s law explanation used the metaphor of pushing a large building with a small force. So we have a big resistance [large building], a little voltage [small person pushing building] and it’s pushing very quickly, producing a lot of current and Ohm (person observing) having heart attack.

(Josh #6, my explanation in square brackets)
Josh’s conception of voltage is a contradiction since the small and fast adjectives cannot co-exist for voltage.

Doing IT [at TAFE] is helpful for that and going through and changing setting[s] I would not normally go near.

(Josh #33)

In this excerpt Josh was changing settings using a computer and his IT understandings had enabled him to gain the confidence that he could do this without causing damage. His increasing understanding and confidence enable him to cope more positively with challenges in using electronics.

As 2010 progresses, nothing’s been too difficult to complete; some things have been challenging but not so much difficult. Some things have been quite easy, so it’s been from easy to challenging. I think things [...] should progress in a way that should not make it that difficult. From what I can tell anyway, things have worked up, and up and up and things that were difficult a year ago are now not so difficult.

(Josh #35)

Josh’s learning has occurred as he moved back and forth between conflict and the reality of electronic phenomena. This caused learning to occur.

Similarly, the following excerpts from Dan, described how he experienced a discomforting contradiction.

‘So that’s one thing I hope we do more of because, from my point of view, I am still not comfortable in sitting down and having a complex circuit in front of me, especially on a PCB, and analyse what all the stuff does.

(Dan #28)

Dan is not comfortable with the challenging and contradictory complexity that he is experiencing. His understanding of the process of challenge leads him to further learning.

I think you can take more risks; maybe you have to be a little bit careful with people you don’t know that well, because there are smaller groups in the class. It does help because when there is a task or an exercise which is complex or there is a lot of pressure, that interaction is like a valve or a stress relief, I think that really, really helps.

(Dan #52)
At the beginning of the project Dom experienced considerable difficulty in dealing with the contradictions inherent in moving from the theory, represented by calculations and circuit diagrams, to physically connecting the components in a circuit.

Imaginative skills have helped me to take a risk [...]. Some times when we are doing projects, like doing the practical, I would say to my partner “Can you do this or that?”

(Dom #34)

Here the student has used imaginative skills to move between the zones of theory and practice and has the confidence to be able to stay in the practice zone longer:

There is a big shift in using imagination now. Before, I would just take it as it is. If the book says you have to do this, then that, I would just limit myself to doing what the book says. But now I realize I can do a bit more than that. As long as you arrive at the same answer or solution, it is just matter of stretching your mind.

(Dom #25)

Students learn from contradiction in electrical physics because the contradictions stretch their thinking. The imagination activities have given the students the skills with which to stretch their thinking and the safety to play with that thinking.

5.2.2.5 How does expansive learning impact why they learn?

The use of imagination enables the learner to move away from the patterns and certainties of bounded learning. This enables learners to
consider and experiment with new possibilities and ways of thinking, and thus create meaning which makes sense to them. Such expansive learning often circumvents conceptual difficulties and provides motivation for further learning.

This question is closely linked to the previous question about contradiction. As students move up and down the learning continuum of comfort or discomfort, they move into and out of ZPD (Down, 2006, p. 84) they move between zones of ease and challenge depending on context and content. This learning continuum is multi-layered and multi-dimensional, resulting in complex zones. Students learn to some degree within particular zones but also as they cross the zone boundaries. As they cross these zones of learning, comfort, challenge, etc., contradictions are made apparent and paradoxes may appear. Learning results from the resolution of these contradictions and paradoxes. In their narratives students’ often reflected on their previous learning, commenting on how difficult they thought it was at the time, whereas now it had become quite straightforward.

‘It was a complete shift in thinking from DC voltages, to the codes and what all the gates do and thing[s] like that. It was a lot to take in when I had not done any of it before. But now I recently did my catch-up test for Digital 2 and realised it was not that difficult.

(Greg #29)

In the following excerpt Adam discusses a boundary between the process and concepts of mathematics. He recognises a boundary and that imaginative skill will assist him to cross.

But, in imagination, you can get like the concept, but you still have to know the mathematics behind it. Like Ohm’s Law, how you work out resistance and current, like, you can’t really imagine that stuff. But you can imagine the concepts that will help you with the mathematics side of it, so that probably a boundary.

(Adam #11)
The relationship between process and concept is restrained and bounded by their previous learning. Imagination allows the possibility of escaping existing boundaries and discovering new relationships.

Learning is cumulative and requires the student to construct new learning or discover new pathways. Dillon uses the creativity of imagination to gain the skill of reflection on prior knowledge.

Yeah, I think making sure that whole prior knowledge thing when it comes to circuits. ... The imagination exercises helped me with that whole prior knowledge thing.

(G Dillon #12)

Greg discusses learning by teaching others. In this case he credits imaginative skills as assisting with getting into this particular learning zone.

... I am not sure it’s imaginative, but the best way to learn, I think, is to teach someone else what you are trying to learn, even if it’s out of the textbook, just trying to teach them it, even if you’re not one hundred percent [sure] yourself. You really gain in the learning of the stuff.

(G Greg #32)

Keith uses imagination to discover new zones or ways of learning. This is not so much about crossing a boundary into a zone of learning. It is about discovering a zone that for this student did not exist previously.

Using your imagination in that sense, I think, was really good, to actually switch on. to say there is more than one way of doing this thing, and then get that part of my brain that says let’s look at it from this perspective.

(Keith #24)

Dom wrote a poem to express his understanding of the relationship between imagination and learning. He talks about learning constrictions and implicit conventions, questioning previous learning approaches. As
learning progresses some learning is abandoned, opening up the search for new learning.

Stop, rewind, pause and play,
My life about a year ago today
Learn, act and think with constriction
Everything in line with an implicit convention!

(Dom #36)

Mal uses imaginative skills as a new language, allowing him to, not only to move between zones as in boundary crossing, but to move across learning zones in ways that transcend the previous categories into which learning has been organised. Imaginative skills allowed Mal to move seamlessly into and out of learning zones as he creates and recreates new models and understandings within electrical physics.

Since electricity is something that we cannot hear, smell, see, touch and taste – except the effects and reactions – the language of everyday life is no longer up to the task. ... To understand these new concepts, we must turn to another language, and the language of imagination is perfectly suited to the task.

(Mal #49)

Not all students reported that imaginative skills have assisted their learning in all circumstances. Keith indicates that imagination has restricted his learning in the short term because he now questions the learning approach more often.

Imagination has helped in the sense that it has changed my thinking style but hindered in the fact that I would normally but it out, but it out(slog it out), where now I am standing back and take a little bit longer to process it all.

(Keith #33)

In the excerpt below Doug indicates his understanding of non-sensory zones and invisible learning boundaries.
It’s hard to visualise something you can’t see like electricity which is where I am having the problem with AC. You can’t see it, you can’t feel it, you cannot do anything with it; so it’s just a matter of using your imagination, which is hard when you have no reference for what it should be like. So that’s the limiting thing I have got. If I can’t see it, I struggle with it.

(Doug #19)

5.2.2.6 How do relationships influence why they learn?

As humans there are two main reasons to learn. The first is the inherent need to survive and learn to do so. This is shown in Abraham Maslow’s hierarchy of needs (Montana & Charnov, 2008, p. 238). The second reason is that as social beings we need to constantly learn to develop and maintain the relationship necessary for our societal survival. Marton and Booth (1997) maintain that of all the creatures in the cosmos, we are the only ones who teach and train their young actively and then expect this learning to be life-long. Relationships from the learner’s perspective can be subdivided into relationships with self, relationships related to learning and ethnographic relationship.

Relationship with self is directly connected to self-image, that is, how you see yourself. For the participants in the study how they see themselves as learners will have a significant impact on why they learn. If the students are able to manage and control their own learning, then learning is amplified with greater connection and resilience (Coverage 0.89).

Within this study the participants have reported that exploring their most effective learning approaches, there has been a corresponding enhancement of their self-image as learners. Similarly their exploration of the impact of particular personality types, through the use of the Myers-Briggs personality test has made them more aware of how they make sense of their world.
The following examples reveal students being individually conscious of their personal learning approaches. They present a positive picture of their learning approaches and how they can use these to improve their learning.

Doug has a good learning self relationship. He understands his preferred learning approach, both how he likes and doesn’t like to learn electrical physics.

> **When it comes to learning styles I am a visual learning person. I like to see a picture of it or if someone can demonstrate to me how it works, that’s the most effective way for me to learn.**

( Doug #18)

Luke was one of two participants who displayed a poor self-image with respect to learning electrical physics. Despite having the ability to undertake electrical physics he frequently found ways to negatively challenge his own learning.

> **I have no idea what my learning style is. It seems to change. One day writing something down helps, another day writing something down does not and I would not remember anything. One day reading something it will stick another is that it won’t. Sometimes the imagination exercise we have been doing will help others it won’t. That just probably means I am ... different.**

( Luke #15)

Luke departed at the end of the first year and Doug approximately six month later. It is interesting to note that the three who did not complete the entire course all displayed negative self-images.

The relationship between learners and teachers is fluid and can vary from autocratic and mono-dimensional to multi-faceted and facilitative (Coverage 0.6).

The two main teachers of this cohort were the researcher and the radio teacher. The students reported positively on their relationship with both teachers. The two teachers’ approaches were very different and this was recognised by the students. The radio teacher’s approach was teacher-
directed with lots of whiteboard notes and then practical exercises. The researcher’s approach was discussion and research focused, theory being followed with practical projects. The students reported on these projects to the rest of the cohort, who were encouraged to reflect and comment on their fellow student’s work.

The following student (one of three) reports on learning with the radio teacher. They have a strong respect for the teacher’s approach and experience in the subject.

With [Josh], he writes it all up on the board and goes through it in his own words, where you go through the text book. ... Not sure if I prefer one over the other but your way allows me to go over it in the text book and put it into my own words, where in Josh’s way we only get it in his words.

(Mort #17)

The researcher has built up relationships with the students individually and collectively. Adam’s comment provides some insights into those relationships. All noted that my approach required more effort. At the start, this was a challenge, but by the end of the study, most found it helpful and, as this became apparent, the relationships strengthened.

I do remember an activity Ken did at the start of the year. We had to run between chairs on the side. That was good understanding of how current moves and then, when we narrowed it, then we all tried to fit through it and it didn’t work that well.

(Adam #4)

I suppose that’s one thing I understand better now than I did before. The teacher helped because he can explain it to you and stuff rather than just saying that’s what it is.

(#12)

The third relationship is that of the learner in a community or class of learners. In this study, the class cohort forms an ethnographic group. The learners learn together and from each other. This creates a complex web of
learning relationships within the social constructs of the classroom (Coverage 0.9).

The first theme report by the participants in relation to learning together is that of filling the learning gaps. The students appreciate that a group approach to learning allows learning at different speeds and in different ways.

...there is always someone that will grasp it the same way you do, so you can talk to them about it.

(Mort #44)

The second theme is how have other students affected my learning? I think it’s good because, say, if you didn’t get what the teacher said straight away, you can ask whoever is next to you and they will explain, in sometimes easier ways and sometimes harder ways.

(Adam #33)

The next theme reported is that of building sufficiently deep relationships that one starts to learn how each other actually thinks and what learning processes are operating. This goes beyond simply assisting each other and is more proactive.

You can learn different ways of solving things and approaching problems from other students. Sometimes I found discussing problems with other students has helped me very much and many times, when they’re reading only the notes, actually I experience this very much.

(Mal #37)

5.2.2.7 Why do they learn?

This section demonstrated that the student appreciated the contextualisation of learning through a balance of theory and practice and such an approach motivated them to learn. It also established that the use of imagination could be a powerful motivator for learning as it gave students the ability to stretch their thinking in new ways. This section also validated that there are many ways to learn in the abstracted domain of
electrical physics and that imagination has the ability to bring to light or make more apparent new ways of learning.

Also confirmed in this section were the negative aspects to learning using imagination. Many students indicated that their worldviews about imagination were contributing negatively to this new approach to learning. This was caused because the way they originally or traditionally learnt electrical physics marginalised imagination.

5.2.3 What do they learn

Student learnt many things. The primary learning is about electrical physics. In this process the students of the Diploma of Electronics and communications learn forms of literacy, problem-solving, metacognition, and the list goes on. All this is to assist their learning of electrical physics.

5.2.3.1 How does the activity system of the learners impact on what they learn?

Using activity theory in which to envisage learning, it is necessary to consider how the rules, community, division of labour and mediating artefacts shape the learning within the system. In this analysis the ‘rules’ are those of the TAFE curriculum; the community are learners and their teachers; the division of labour is how the learning is divided and or shared; and the ‘learning artefact’ is the use of imaginative skills.
The primary rules that impact on the students are those of the curriculum. The curriculum contains a matrix of units of competence and each with their particular, essential knowledge and skills. For the students of this study, they are aware of the curriculum requirements or rules, but, on a daily basis their awareness of this is minimal. It is only as they near completion of the Diploma program that these rules become acute. As the study was conducted in the early part of their Diploma program the participants make little reference to the curriculum in their transcripts.

Participants however make mention of the community in which they were learning (Coverage 0.6). For example, in the following extract, Dan moved from an individualistic approach to learning to a collaborative one. He noted that the imagination activities assisted with this cultural change.

So as I have found now and comes out in my final report is that I have kind of seen that some of the activities we did, especially the group ones really kind of helped in that interaction. I still have some of those preconceptions however they are kind of tempered now with that other people see things differently. I think some of the exercises really helped in that.

(Dan #47)

Similarly Sam explains that the imagination activities have moved the cohort learning culture in a positive direction.

Then through out all these activities began to build a better team work orientated classroom and learning environment. I began to find the imagination classes more interesting because their obviously improving our learning so that a major point. I appreciated the group activities more because they were quite an asset to my learning.

(Sam #46)

The division of labour has direct and indirect aspects. For the students of this study, the direct division of labour occurred during joint assignments as the workloads were divided. The indirect aspect of labour division is in
the context of assisting each other with learning as the following example from Mort indicates.

I tend to keep to myself a lot of the time. If I do need help I will turn to a couple of guys close to me who seem to have a pretty good grasp on the topic. If I don’t understand it one way that I have been taught, one of the other guys may have understood it a slightly different way and then they would be able to tell that different way to me, then I would be able to get that. I think just being in that community based learning thing...

(Mort #38)

During the research project the students were encouraged to become responsible for their learning processes. This was achieved over the three action research cycles. In the first cycle imagination focused learning was teacher directed. In the second cycle the approach was more collaborative with a more equal division of labour and responsibility. The third cycle shifted the larger responsibility for learning and process to the students. During this time most of the students moved from passive consumer of content to active creators of learning.

The students demonstrated flexibility as they moved from one teacher whose pedagogical approach was content and teacher centred, to the researcher’s approach that was student centred and focused on giving students responsibility for their learning.

Over the past few terms I experienced a lot of new activities that can be used to help with day to day learning. I have developed myself as a student by using some of these methods in my study regime. This includes building my own story to remember acronyms and drawing more often to remember things. I have also started using the learning cycle on occasions to help me retain day to day information.

(Sam)

There are many mediating artefacts employed in the learning of electrical physics, such as the curriculum, the design of learning activities, and assessment. In this study an additional mediating artefact, the
metacognitive application of imagination to assist in the participant learning, has been used to improve the learning.

5.2.3.2 How does multi-voicedness affect what they learn?

This analysis examines how multiple points of view of the students affected what they learned. The participants’ multi-voicedness was derived from their roles as employees; their opinions of the use of imagination in relation to its effectiveness for learning; and the students’ general perspective or worldview as related to assumptions about learning.

As employees, the students were primarily interested in those aspects of learning that their employer deemed important, such as electrical connection skills and air navigation aids. As the study progressed the participants’ narratives present a different voice relating to their increasing wariness of themselves as learners.

The views of the participants also change over the duration of the study. Most initially were sceptical about using imaginative skills to improve their learning. The depth of scepticism varied. A small survey conducted two months after the study was completed to provide information on perspectives at the beginning and end of the study. Approximately one third were strong sceptics, about one third were mild sceptics and the remainder were ambivalent or slightly interested.

The following student comments show a shift in scepticism in all cases in the direction of acceptance that imaginative skills, actively and metacognitively pursued, did improve their learning in electrical physics. It is interesting to note the ‘pendulum’ shift in opinion: in most cases, the
more sceptical the student at the start, the bigger the shift into acceptance and vice versa.

I started out as a mild sceptic but now I would say I am a mild believer in using imaginative skills.

(Adam #41)

As I sit here and think over the last three terms, the imagination stuff that is, I would like to say up front I was a sceptic, I thought this was rubbish. But now I can tell you I am a believer now. The imagination stuff had [a] positive effect on my learning.

(Dillon #2)

As I said before, I was a sceptic about using imagination in learning electrical physics; but today I am a believer.

(Jeff #40)

In the imagination study, students completed a couple of activities that focussed on becoming aware of their own worldviews and how these affect their learning. For reasons of sensitivity, the study did not ask students to reveal what their specific worldviews were. Rather the intention was that the participants should be aware of the worldview that shapes their thinking and underpinning assumptions that are associated with a particular worldview. The students made mention of their questioning of these assumptions particularly with regard to their learning approaches (Coverage 0.45).

Dan challenged some learning-related aspects of a worldview that was embedded in indigenous culture. He then contrasted his Indian cultural perspective on using imagination as a learning tool with that of his Australian experience.

In terms of my cultural background, being part-Indian, Indian culture frown on imagination, they are very, know what you have to know, get what you have to get.

(Dan #43)
Dom expresses similar views. He is concerned that the ‘Australian way of teaching’ may be very different from the Philippino approach that he has been accustomed to.

The year started and I was very excited to go back to school again. It’s been almost eight years since my last study. But I also have fears – will I be able to cope with study and way of teaching here in Australia?

(Dom #22)

Both students learnt that knowing and appropriately challenging some learning assumptions assisted them in their learning (Coverage 0.8).

Imaginative skills have helped me to take a risk, which is good. Some times when we are doing projects like doing the practical, I would say to my partner can you do this or that? Before I would go just by the text book. It helps taking the risk, making a fool out of yourself or whatever, it’s good to explore.

(Dom #34)

Other participants used worldviews to better understand themselves and the impacts of their learning. What they learned is that not everyone thinks, learns and models electrical physics the way they do. This has had a twofold effect: first, they better understood their own thinking and managed this better; and, secondly, they came to understand how others think and were able to take on new ways to think and model. For example:

I think that’s good because I, with my personality, I think my way is the only way. So being able to stand back and see that not everyone else here is exactly like me - it was good to get an appreciation of how people think and why they do certain things they do. It helps you to get to know people too.

(Keith #26)

The following extract demonstrates that Doug engaged with worldviews and has challenged his own preconceptions. Consequently he has
developed a questioning technique which enables him to problem solve effectively.

I challenge my preconception all the time now. .... If we are given problems or equation or whatever that we need to find the solutions to, I find that if I am able to understand why things happen like that, it’s easier to come up with the answer. If the way something works does not necessarily help me understand it, then I am more than willing to go and find another way of thinking to help me understand it.

(Doug #50)

5.2.3.3 How does historicity impact what is being learnt?

The themes expressed in the students’ narrative in relation to personal historicity falls into three categories. The first is their history of interest in electronics, represented by their activity in building electronic kits during adolescence. The second is a history of interest in electricity arising from family background. The final category is history of interest in electricity through schooling.

Building electronics kits as an expression of interest in electricity developed first in the early seventies when consumer electronics became commonplace. Many of the students in this study have used this easy and cheap access to a variety of electronics kits and express their interest in a history of kit construction (Coverage 0.3).

Regarding their histories of kit building, it is interesting to note omissions from the comments. All enjoyed the process of building or construction, but none mentioned having learnt any electrical physics from the process. However this involvement did result in useful hand skills and interest in a career in electronics.
I used to build a lot of kits when I was younger. [...] it was the next step up from building a kit that comes with a PCB to building the PCB yourself.

(Dan #19)

Some students extended or augmented their interest in electrical physics when they had opportunity with school and university studies. However, the current school curriculum only touches on the complex field that is electrical/electronics. The following student responses confirm this (Coverage 0.6).

The only picture I had of electricity I got from physics and maybe early [primary school] science, which was basically voltage, current and resistance.

(Greg #2)

I went to secondary school in Wagga... Physics taught us a lot about electricity and that, about current flow and resistors and through conductors and how it varies and surface area and all that stuff.

(Adam #2)

Three students studied electrical physics at university. Dan admits that learning to teach physics enhanced the imperfect understanding he gained from his science degree.

I had a very short time teaching – about six months – but the year I had to do my diploma [in education] I did learn a bit more in terms of electricity and how to teach it. I found that was really helpful.

(Dan #3)

Keith also studied electrical physics at university but neither he nor Dan could connect a simple series circuit on commencement of their TAFE course. Both had some theory of electrical circuits, but neither could articulate this into the physical reality of a circuit.
I went to university and started [an electrical] power engineering degree. That is what ignited the electricity flame. I just wanted to learn more about that.

(Keith #3)

The final historical category concerns family background in electrical physics. Four students mentioned family background as a significant contributor to their interest and history in electrical physics. For one student the history goes back at least two generations (Coverage 0.3).

I have come from a background of technically motivated people. My dad’s an electrician; his dad was interested in that kind of stuff and most of my dad’s side of the family are that sort of thing. My uncle is a tool maker. The rest of my family are along the lines of architects and that sort of thing.

(Dan #1)

5.2.3.4 What do they learn from encountering contradictions?

Contradictions often lie at the root of a problem. In adult life problems which need resolving are usually identified as contradictions. Contradictions lie on a continuum from superficial to complex. Since a contradiction may be resolved by different approaches to thinking about it, the second aspect to be examined is ways of understanding electrical physics (Coverage 0.8).

Dillon relates his experience when he over-rated his abilities in a self assessment of his ability to relate a PCB to a circuit diagram. Recognising the contradiction meant he engaged in the problem and acknowledged his need for further learning that has been inferred from this as an imagination activity.
The PCB to circuit drawing, that was, I thought, I was good at problem solving. That showed me that I was crap at it and will have to work on that.

(Dillon #13)

Adam experienced difficulty in modelling systems. Imagination allowed him to better understand the concept as he related it to mathematical modelling.

I think there are some limiting factors like you can’t always learn about the mathematical side of it. But in imagination you can get like the concept, but you still have to know the mathematics behind it.

(Adam #11)

Josh uses contradiction as a direct learning tool, to challenge the norm and learn from the challenge of contradiction. Josh has an inherent critical learning ability that was amplified by the imagination exercises.

If I read something I will try and find a flaw in it. It may be something that’s been proven for hundreds of years I will go through and find a flaw.

(Josh #16)

Sixty percent of the participants recognised in their narrative that there is more than one way to learn or understand a concept. Therefore when a contradiction occurs, whether real or apparent they now question the learning and or concept approach by using imagination. Thus contradictions provide a catalyst for the student to change his own thinking to make sense of the phenomena of the physics involved.

Term three and four as far as imagination goes I started to think about and talk about it. But also when I came to a problem if I couldn’t see a convenient way then I would try to imagine it in different ways that we talked about. That did help with some of the new concepts like radio; it did help quite a bit.

(Mort #32)
Another aspect of what is learnt when contradictions are encountered is the value of engaging other people in the problem-solving process.

... You can learn different ways of solving things and approaching problems from other students. Sometimes I found discussing problems with other students has helped me very much and many times...

(Mal #37)

One imagination activity was to give the students the very end of a story, with neither context nor plot. They were able to use closed (Yes/No) questions to elicit snippets of information from the story teller in order to piece together the complete story. The students learnt that apparent contradictions evaporated once the larger context was understood.

As far as the imagination stuff is concerned, I liked [the] “hand in the box”. It was a good thought exercise. It made you think in ways that you normally wouldn’t. I really enjoyed that and it’s stuck with me a bit.

(Mort #15)

Keith and Doug are starting to realise that people do not all think about electrical physics the same way as they engage the imagination activities. The physics does not change but the way people think and represent physics does change. The important contradiction here is that multiple models are more likely to yield a correct result, than using just one mental approach.

So being able to stand back and see that not everyone else here is exactly like me. It was good to get an appreciation of how people think and why they do certain things they do.

(Keith #26)

Imagination exercises have given me a better idea of or better appreciation I suppose on how the different ways people will learn.

(Doug #5)
5.2.3.5 How does the pursuit of creativity influence what they learn?

In this study, the students are being encouraged to be creative by finding new ways to understand or act. They have learnt that it is permissible to challenge preconceptions, that there is more than one way of knowing something, and that creativity can be challenging.

In his narrative Dillon recognises that he already uses imaginative skills to learn (Coverage 0.6) and that he is now more aware and active in using imagination.

So I guess doing a lot of the picturing stuff in your head really helped doing that bit, the circuit analysis. Not much else I feel really helped myself. [...] I was always good at picturing concepts and that in my head, but I never put that down to imagination.

(Dillon #31)

Greg also directly acknowledged that the imaginative skills have assisted in learning electrical physics. Greg is acknowledging the link between using imagination skills and the abstract nature of electricity.

Using imagination with electrical physics has [...] been most helpful with the mathematics class; it allows many avenues for the use of imagination, specifically the types used in electrical physics.

(Greg #48)
Reporting on a particular imagination exercise, Greg recognised the need to use knowledge and to remember to actively engage skills he had not realised he possessed.

... Because you don’t have the plans there, you had to use the knowledge of what you have had before. I thought that was a really good one too.

(Keith #25)

For most participants, the use of strategy games as a conceptual skills activity was a new way to learn. The student generally found the games fun and hidden in the fun was the learning of problem solving, estimating and prediction.

The board games we played this time were completely new ones. We played the one where you had to chase the guy around the city (Scotland Yard). That was an entirely different skill set to what I am used to; to play a game.

(Josh #43)

Challenging preconceptions had fifty five percent coverage in student narratives indicating a positive impact on learning. Probably the first preconception which was challenged by the research study concerned the use of imagination in learning. In the following extract Mal acknowledged that he had thought that imagination did not have a place in learning electrical physics. By the end of the project, his conception of imagination had undergone a complete about face.

In the beginning, I thought the [imagination] project would not help much because my previous learning styles that I had back in my own country. I came up with a set of skills that helped me to understand electrical physics. I thought this because electronics is very theoretical and my previous experience and studies were directly to the point and gave me only what I need to know. Here when we had group activities we had to use imagination to learn and improve and understand electrical physics with imagination.

(Mal #41)
Participants reported that the use of creativity (in this case using imaginative skills) can be challenging (Coverage 0.37). The first challenge these students faced was to overcome cultural perspectives that at best marginalised imagination. Students also reported that re-learning to use imaginative skills was a challenge in and of itself.

Neville recognised that the need to enhance his learning skills initially slowed down his learning rate as a negative impact.

> The three cycles of the imagination project have been full on. I think the imaginative skills have helped me understand circuitry a bit more. I think it has lessened the load so there is less work; working out what’s going on.

(Neville #25)

Keith also acknowledged that creativity has helped but came at a price in the early stages but has paid off with improved learning.

> ...the work is more in depth, we have been building this term on the previous one [...] Imagination has helped in the sense that it has changed my thinking style but hindered in the fact that I would normally but (slog) it out, where now I am standing back and take a little bit longer to process it all. Probably good in the long run taking a bit longer but it makes it about patience because I am not a very patient person.

(Keith #33)

Finally, Dom’s poetry confirmed that creativity is tough and came with much apprehension.

> Winter came and brought imagination.  
> Half heartedly accepted and yes with apprehension!  
> Games, quizzes, analysis and stuff,  
> Oh boy! Imagination can be tough!

(Dom #36)
5.2.3.6 How do relationships impact on what they learn?

Relationships are not only essential for learning (section 5.2.2.6) but they also shape what is learnt. Relationships enable us to develop our expectations, learning our responsibility for learning and the learning of specific content and concepts.

Expectations may be either explicit or implicit. For example the expectations of an employer are directly imposed through workplace standards and norms whereas the expectations of family and friends are more often implied than imposed (Coverage 0.6).

The participants were in no doubt that the employer’s expectation was to learn electrical physics. For example:

Learning at TAFE is sort of a contradiction of hands-on. We joke and mess around a lot but it’s also a lot more mature than high school [...] but we know it is our job.

(Mort #42)

The imagination project has focused on how to learn using imaginative skills as they relate to the content of the learning domain. The participants were encouraged to understand how learning takes place by being critical of their own learning approaches. Once an understanding of preferred learning approaches (students called these styles) was achieved, students were encouraged to respond by expanding the use of imagination.

Students used the learning cycles as a framework for engaging in theory and practice of electricity.

Last three terms, I have been more open-minded towards learning rather than use the old methods. Open up a little bit and try to embrace new techniques of learning such as the learning
cycle in particular and even the story-telling. Incorporate that into learning.

(Sam #41)

The learning cycles of the research study had three phases. The first involves engaging with the actual phenomena; that is learning what electricity is. The second phase was working with a multitude of modelling systems and abstractions used to represent electricity. The third phase is the application of these modelling systems to produce the necessary electrical effect. The learning cycles enabled students to generalise about specific aspects of electricity.

Sixty percent of the participants commented on the concept of being responsible for your own learning. TAFE, as a learning environment, is focused on adult learning. Two of the most prominent features of adult learning are self-direction and self-motivation (Down, 2006, p. 152). Keith’s comments indicate a strong theme of personal responsibility in the learning of electrical physics.

The imagination activities have impacted me positively; they probably like actively make me think how I like to learn.

(Keith #11)

Electrical physics is learnt through multi-dimensional relationships. The first is student–content–teacher. The second is student–content–student. The third is student–content–workplace. Even this tri-dimensional picture is a simplification for the purposes of analysis. In reality all the dimensions interact in different ways in different contexts and at varying levels.

Participants noted a good example of the student-content-teacher relationship when they commented on John, the Radio teacher. This relationship is characterised by John’s vast experience with the content and his easygoing approach with the students. However John’s teacher
centred approach means that he rather than the students is shaping what is learnt.

As for next term and how I like to learn, I don’t know about learning styles. With John, he writes it all up on the board and goes through it in his own words, where you go through the textbook.

(Mort #17)

The student–content–student relationship it developed as students learn together and from each other.

Most participants’ comments indicated that they found the researcher’s approach conducive to good learning as it allows them to make sense of the material covered. Thus, what they learnt was guided by the researcher but shaped by the students.

Ken’s been doing some of this imagination stuff with us, so I learnt a different way of doing the same thing and bonding our knowledge a bit more. Just learning different ways to know what we learnt in the first two terms and so like putting that on top of now.

(Adam #7)

Students reported many strong learning outcomes after coming back from work placements. The relationship of student–content–workplace was bi-directional as TAFE learning fed into the workplace and workplace fed back into TAFE.

I got a lot of help from the ABS staff. They are all kind of kit builders; they were all trainees like us. They did help me do a bit of fault finding. Another plus would be it got me more motivated to do some kit building.

(Dan #22)
5.2.3.7 What do they learn?

As can be seen above what the participants learn has been shaped by; their activity system; their multi-voicedness; their historicity they bring to the study; the inherent contradictions encountered; their learning creativity and the relationships they experience.

What the participants learnt contributed to their understandings of the complexity and abstract nature of electricity, and the contribution made by imagination as a mediating artefact in providing skills to assist in managing these challenges.

Learning is a process of change. Whilst the participants were learning about electrical physics they were also changing and developing their attitude to and perception of the process of learning, use of imagination in that process and the active role and responsibility they needed to apply to their learning.

Learning is a holistic process (Taylor, 2009, p. 10). The participants’ narratives reflected their increasing awareness of the complexity of electronics and how apparent contradiction opened up new possibilities for understanding. They also recognised that their increasing use of imagination enabled them to construct mental models to more effectively understand the phenomena of electrical physics.

The use of imagination has acted as a mediator for the students’ learning. What they have learnt has not just concerned the content but also the process of learning, the way in which it is shaped by the factors which impact on it and the resultant flexibility in the outcomes of learning.
5.2.4 What have been the catalysts for, and responses to learning?

5.2.4.1 How has the activity system impacted the catalysts of, and responses to, learning?

The participants have acknowledged that the catalysts of their learning throughout the study have been a learning environment (TAFE), a high level of access to electronic learning technology; and a new pedagogical approach using imagination. Their responses to these changes have largely been very positive.

The activity system of the TAFE learning environment is a strong theme in most of the participants’ narratives (Coverage 0.66). The catalyst for change has been the very nature of this system. The integration of theory and practice has enabled them to contextualise and make meaning of the content. The participants’ narratives explain this as they contrast the learning activity systems of TAFE with secondary school, the workplace and university.

Students making a secondary school comparison note that in TAFE the learning was not forced on you. The TAFE environment encouraged learning as part of being a responsible adult, whilst also providing strong frameworks of support.

Learning at TAFE is a pretty open learning environment. To a certain extent it’s your own learning abilities and your own pace. If you don’t put in you don’t get anything out. Like you guys won’t chase us up for it. I think it’s more of a mature learning place.

(Neville #24)
Those contrasting TAFE to a university experience indicated that the TAFE learning activity system was somewhere between school and university. At university, learning direction is provided. However the participants lacked the learning support they needed at that stage.

I found that coming from university and high school before that almost a mix between the two. ... Everybody knows each other and if you need help, it’s always there, where at university you are in your friend groups of may be four or five and that’s your support group.

(Josh #34)

The third category, those commenting from a workplace perspective, focused on the context of learning as the catalyst. The expression ‘hands-on’ symbolises the difference. Many of the students engaged in the learning because of its practical nature. It is this part of the TAFE activity system that had influenced Dom.

Learning at TAFE is more hands-on and I appreciate all the theory and the practical component that comes with the theory part of it.

(Dom #31)

The participants, as employees of Airservices Australia, had access to state of the art electronic learning technologies. These technologies include fully integrated ‘smart boards’, a fully integrated notebook computer per student and a comprehensive set of test instruments. This set of instruments includes software training aids from circuit simulators, CAD, PCB design to word processors and spreadsheets.

The availability of technology is assumed by the students as normal. For this reason they do not often directly refer to the effect of having these things at their disposal. Luke does explicitly explain why he likes computerised things.
I like to do things computerised. If I did something physically in front of me, say building a cube out of other cubes, [...] it won’t stick in my mind.

(Luke #16)

Not only is the subject matter technological (electro-technology), but the learning approach and many of the pedagogies are also e-technological. This again is an aspect of the learning activity system that shapes the learner and the learning approaches.

Ninety four percent of the participants commented that the environment in which they were learning acted as a catalyst for learning. This environment is inclusive of the participants, their teachers, the learning design, the curriculum content and the conditions for learning and, as such can be considered as an activity system.

Activity systems shape the changes and learning within. For these participants the TAFE activity system has been far more positive than constrictive, as the following sequence of narrative clips from Doug indicate.

Imagination exercises have given me a better idea of or better appreciation I suppose on how the different ways people will learn.

(#5)

... I suppose with the imagination exercises it has given me more tools I can use to try and actually remember what we have learned, so it’s a bit better.

(#14)

As we moved through Term One or cycle three the imagination exercise began to bite. At the beginning of this story I would say that I was a mild sceptic but now I am a believer.

(#38)

All but one student reported that their involvement as students in the Diploma program has resulted in a significant improvement in learning electrical physics in the particular Diploma program of this study.
5.2.4.2 How has the student’s multi-voicedness impacted the catalysts of, and responses to learning?

The student’s multi-voicedness and its impact on their learning is apparent from the narratives collected during this research. One of the framing questions, use in the semi-structured video interviews, asked participants to report on what they thought other participants’ expectations of imaginative skills had been. The question was used to triangulate participants’ opinions of imaginative skills without their unintentionally telling me what they supposed I wanted to hear. In addition, it supplies a multi-dimension of others’ thinking about the project as a way of learning electrical physics.

This strategy also increases the participant awareness of the multi-voicedness of the student cohort. This has been discussed in previous sections where the participant narratives reflected their wariness of differences in the way others approached their learning and understood concepts within electrical physics (Coverage 0.68).

The following two examples of Steve and Keith reflect the ends of a spectrum of what classmates think about imaginative skills and their relationship as the catalyst. Steve sees the skills of his friend at work and appreciates his point of view and abilities. He recognises differences in their perspectives, responding by accepting and using a new approach.

He uses imagination just by how he explains things to me, I don’t know if this is what he is actively thinking, but how he explains things to me does show he has some degree of imaginative [ability]. He imagines things differently to how I would. After bouncing it off him I get it. If I bounce off him he gives it to me in a way that I could not have thought up on my own, then I get it.

(Steve #32)
At the beginning of the study, Keith indicated that whilst his class partner made use of imaginative skills, he, preferred to use tried and proven solutions.

I don’t think that he would think that highly of it (imagination). But I think he can see a use for it. I don’t think it would be his first port of call, he would brush it aside. With the culture he would brush it aside and it would be his last port of call to use his imagination.

(Keith #38)

Another example of how multi-voicedness provided a catalyst to learning is shown by comments made by Adam and Keith of their use of other students’ thinking processes to generate and adapt their own thinking. It is interesting to note that these learning responses relate directly to awareness of how classmates learn electrical physics (Coverage 0.6).

Also you learn how other people think as well, not necessarily yourself. So [I] like working with ...[Dan] a little bit, and knowing how he thinks and I think, would explain why some times we have different questions and quarrels I should say, so that’s fun.

(Adam #23)

Being able to stand back and see that not everyone else here is exactly like me. It was good to get an appreciation of how people think and why they do certain things they do.

(Keith #26)

Another group participant indicated that multi-voicedness caused them to not only adapt their thinking, but to change their learning approach in particular contexts (Coverage 0.6).

If I don’t understand it one way ..., one of the other guys may have understood it in a slightly different way and then they would be able to tell that different way to me. Then I would be able to get that.

(Mitch #38)
Imagination exercises have given me a better ... appreciation I suppose on how the different ways people will learn. So what will work for me won’t work for other people and so when it comes to team work and things like that, its good if you have people with different learning styles. You often learn off each other a better way.

(Doug #5)

Multi-voicedness is often a catalyst for change. Participants expressed their awareness that multiple points of view initiated new approaches and new learning. The extent of that change, its frequency and depth, is contained in narratives of the participants. Most participants indicate a change from mild scepticism to conviction that imaginative skills did assist their learning.

5.2.4.3 How does historicity affect the catalysts of, and responses to learning?

Previous analysis has indicated how the student ontology and historicity have influenced the ways in which the participants approached their Diploma studies and responded to the concept of imagination as a learning tool. This section of the analysis investigates how the introduction of specific strategies related to the history of the development of electrical physics also impacted on their learning.

During work placements, the participants encountered many experts who have engaged in the field of electronics and communication for thirty years and more. Learning from the experience of these workplace experts or mentors has been significant for many of the students. The knowledge of these experts and the experience behind that knowledge was appreciated by the students.
The participants appreciated that the experience of others impacted on their current learning. The participants’ narratives recognised that it was the historicity of the workplace which enabled the expertise to be developed (Coverage 0.3).

I worked with Ben, the stream specialist. He is a team leader who is very knowledgeable with everything. He’s been there a long time. A couple of younger guys that have been with Airservices for a couple of years they have a fair bit of experience.

(Doug #37)

Talked a lot to ..., which is one of ASA’s people to go to about satellite systems. That guy is stupidly smart.

(Dillon #22)

The students appreciated interacting with workplace experts and their history. They reported that this interaction provided a catalyst to their own learning.

The narratives indicated that the educational historicity of the participants has influenced the catalysts for learning and their responses to change. As Adam indicates below, the change from strong learning management to self responsibility has been a catalyst for learning (Coverage 0.6).

At school they would force you to read everything and do questions. Where as here its sort of have to do it your self or other wise you basically don’t learn it. Like a lot of it you still do in class like at school, but there is. At school they would always check it and make sure you did do it, where as here is just sort of assumed that you have done it and if you haven’t so!

(Adam #31)

Some of the imagination exercises conducted in this study involved the students researching and considering the history of electrical physics. As the next two students note that revealing history gives them a connection to those who have gone before and to the ways they thought and learnt about electrical physics.
Learning about how they thought one hundred years ago or whenever it was, and a bit more visual and problem solving. Quite enjoy problem solving and those circuit boards or something we will relate to or work later on.

(Adam #22)

I did Michael Faraday, the grandfather of modern electronics; he was pretty interesting. He was interesting because he was not a mathematician at all. He was a village blacksmith and then a bookbinder and he taught himself basic science. ... It just shows a practical application of knowledge that’s just amazing.

(Dillon #25)

5.4.4.4 How do contradictions affect the catalysts of, and responses to learning?

The participants of this study have reported three effects to the catalysts of learning caused by encountering contradictions: finding ways around the problems caused, resolving the contradiction or problem, and giving up.

Finding ways around a contradiction or problem was a common tactic of many students. They would seek different paths to the learning objective. Imaginative skills played a significant role in helping find available options.

Mort finds a particular process that assists his learning.

Before it had not really had any effect but now it has changed a lot more because we are doing much harder subjects and things like that. It did not affect the way I learned but it did affect the way I approach problems.

(Mort #32)
In a second example Doug speaks of changing or finding ways around his actual thinking about a particular concept.

If the way something works does not necessarily help me understand it then I am more than willing to go and find another way of thinking to help me understand it.

(Doug #50)

When a contradiction occurs, many students decide that further engagement is required. Dillon and Greg were converting a PCB layout into a circuit diagram. The first time, Dillon thought he had good skills for the task but discovered that he had done a very poor job. Six months later, after requiring a lot more spatial imaginative skills, he made the following comment (Coverage 0.6):

..., like the second time we did PCB to circuit diagram. We got it almost right and I just loved that. Being able to identify each part and be able to write it up into a really nice circuit diagram instead of lines going everywhere. So I guess doing a lot of the picturing stuff in your head really helped doing that bit, the circuit analysis.

(Dillon #31)

The effect of the imagination exercise spilt over into other subject areas. In the following extract Greg indicates that it has been useful for him in his mathematics studies.

It’s been most helpful with mathematics class as it allows many avenues for the use of imagination, specifically the types used in electrical physics. The maths required strong use of imagination and associated functions when visualising what is happening and especially with imaginary numbers.

(Greg #48)

Giving up (Coverage 0.22) is the final category of response to experiencing contradictions. Giving up covers a range of responses, from simply not trying, to abandoning a struggle with a particular concept. Students who experienced contradiction and engaged in an extended struggle usually
achieved a learning resolution, whereas those who gave up did so after a reasonably short struggle. The issue here is one of reasonable or unreasonable effort and engagement. The amount of effort or engagement is determined by a complex combination of motivation and aptitude in the domain of electrical physics.

Dan and Luke did not demonstrate strong perseverance. They isolated themselves early in the relationship-building phase of the class and, despite both having something of a background in electricity through family and interest, they did not fully engage in the learning.

Even though I have found the hands-on aspects of TAFE great fun, the physics, the maths has still continued to be more and more difficult... At the end of the day, it’s all caught up with me and I can no longer keep up or catch up and I think I will have to do something else.

(Dan #24)

So, by the middle of the last term, it was obvious to all I had given up. I delayed assessment two and three times again and again. ... In effect I was missing at least a day a week, not working when I was there and getting so far behind.

(Luke #22)

From the outset Max engaged with the learning and built good relationships in the class. Towards the end of the first year, he was offered an apprenticeship in the area of diesel mechanics.

Well, that was the end for me because, in the middle of fourth term, I was offered an apprenticeship near home as a diesel mechanic. So I had a chat with Airservices and they agreed it was an OK situation.

(Max #17)
The creative use of imagination to aid the learning of electrical physics can be described in ten categories. These categories are abstraction, history (reflection on the past), metaphysics, narrative, non-sensory modelling, problem-solving, psychomotor, spatial, strategic gaming and play, and visualisation. The participant transcripts provide evidence of how encouraging creativity affects the catalysts of, and responses to learning.

Electrical physics is not directly sensible, so the inherently abstract nature that results, make the concepts difficult for most students. Steve and Dillon recognise that active conscious use and training of one’s imagination (metacognitive imagination) does improve their abstractive skills and in doing so improves their electrical skills (Coverage 0.88).

Things like that simple things, just thoughts more towards the abstract kind of thinking. That is how I always thought it was. I [am a language and arts person] more than the others. [Imagination] in languages particularly helps, ...

(Steve #16)

The imaginative skills have given this student stronger mental picturing skills for modelling electrical physics.

I have learnt to make it (imagination) a lot more applicable to a lot more things that I originally thought it would (not) be applicable to. Like I said before I would only use it for gaming and stuff like that and now in class I will begin conceptualising and imagining things to make it easier for me to understand, trying to put it in a different light or something like that. Yea, I was a little at the start, its definitely allowed me, specially , when I sit back and think about it, we really can’t see anything we ever do in
electronics or anything so I think it’s changed from scepticism to this is definitely helping for sure.

(Dillon #26)

The ability to reflect back, making sense of the reflection and then bringing application to the present and the future, requires imagination. The student narratives demonstrated a number of different facets on which students had reflected (Coverage 0.45).

For one of his imagination exercises Adam completed an assignment on the people who discovered electricity. He became interested in how the discoverer went about thinking which has helped to make the physics clearer for him.

The history was good. Learning about how they thought one hundred years ago or whenever it was, and a bit more visual and problem solving.

(Adam #22)

In his transcript Dan used his imaginative skills to challenge his preconception of metaphysics (Coverage 0.5).

With my background I had those preconceptions and they were pretty hard to challenge. So, as I have found now and comes out in my final report, [...] I have kind of seen that some of the activities we did, especially the group ones, really kind of helped in that interaction.

(Dan #47)

Greg found that the metaphysical concept of culture actually discouraged using imagination when he noted.

I think the learning culture at TAFE, apart from your class, discourages imagination because they give out the booklets and it’s all set and structured. I don’t see how you could change it really. If people are going to use imagination or not, they may not be able to.

(Greg #41)
Participant transcripts were rich in providing example of the use of narrative or story-telling as an imaginative strategy. This was despite earlier views that narrative was not helpful to their learning and learning electrical physics in particular (Coverage 0.83).

Sam’s response to using imagination and narrative is to be more ‘open-minded’ about this new approach. He is in the process of embracing new techniques.

Last three terms I have been more open-minded towards learning rather than use the old methods. Open up a little bit and try to embrace new techniques of learning such as the learning cycle in particular and even the story-telling – incorporated that into learning. It’s been a sort of a change for me.

(Sam #41)

Jeff recognised that narrative can be much more than telling a story for entertainment. In this case, the story was a way to engage and to practise problem solving.

I liked the story one, the hand in the box. I enjoyed that one. It was just interesting. It wasn’t just problem solving. You really had to think about it, rather than have instructions in front of you.

(Jeff #10)

The students’ responses to using imagination in producing mental representations vary considerably and are not peculiar to each individual. For example, some use physical analogies; some use the abstraction of algebra; some use metaphor and others combinations of all the above. The response to using imagination has been to challenge and enhance the participant’s mental representations of electrical physics by enabling them to increase awareness and manage the mental models (Coverage 0.89).

Doug makes it clear that electrical physics is difficult to grasp, especially AC since a ‘point of reference’ or a basis for a mental model is difficult to find.
It’s hard to visualise something you can’t see, like electricity, which is where I am having the problem with AC. You can’t see it, you can’t feel it, you can’t do anything with it; so it’s just a matter of using your imagination, which is hard when you have no reference for what it should be like.

(Doug #19)

Mort expresses the importance of mental modelling arising from the nature of the physics. His response is to use aspects of imaginative skills in the areas of problem solving and spatial ability to assist with his mental modelling.

I started extending imagination using non-sensory modelling. That’s what I see is what we use the most in this sort of subject. Some of the spatial things as well. I think how the things work and go together in problem solving actually.

(Mort #34)

Imagination and problem solving are closely related. We often use the term ‘thinking laterally’ – that is, imaginatively to find solutions to problems (Coverage1.0).

All participants refer to problem solving in their transcript, Dillon’s comment is typical.

When it comes to activities to help imaginative skills I think problem solving skills. I love problem solving so much...

(Dillon #27)

Steve has also discovered that using imagination has enhanced his problem solving skills by imagining possible outcomes for particular fault scenarios.

I would have to figure out what could be a problem or what could cause that and go through a process of elimination. I think having all this as well and this can do that and this can do this and already having some of those skills already helped me imagine possible outcomes before they have occurred has helped a lot.

(Steve #11)
Psychomotor skills provide connection between imaginative skills and learning by doing. This is also a very strong theme among the students with coverage of ninety four precent.

Mort affirms this link when he says that ‘practicals more reinforce it because we have already learnt it [that is, theory]’.

The practicals more reinforce it because we have already learnt it. But we can actually see it happening practically and verify what we thought was going to happen will happen, so that’s what I like most about practicals.

(Mort #17)

Mal clearly articulates the need for imaginative skills in relation to the psychomotor skill of connecting electrical circuits.

The blind circuits, when you can’t see something, basically you can’t see electricity. You can’t feel it or touch as I have said before, so we have to imagine. So, actually, by doing blindfolded connecting series circuits, we are limiting our minds to connecting the circuits. So you see it by touching and it was very helpful.

(Mal #13)

Spatial skills were considered highly significant by the students because all made multiple comments about them. In his transcript Steve acknowledges the relationship between spatial skills imagination and electrical physics. Referring to the placement of electronic components on a drawing, he notes that the drawing will not fit on the paper unless careful consideration is given to spatial management.

Some activities where we have been asked to design or if we already have the drawing of it, it’s placement or space management. I know its spatial skills and I would have thought it was part of the imaginative thought process.

(Steve #36)
Neville notes that he uses spatial imagination when tracing out a concept of electrical physics; in this case an AC wave.

Term Three, I remember that circuit analysis one. I enjoyed doing that one I guess because it expands my imagination. Because you have circuits that you have no idea about what they do or how they work. I always use my imagination by tracing out the positive going wave and then the negative, the effect and why. I always trace that out. That is where I use my imagination. That’s what I find I have really noticed that I use my imagination, using it that way.

(Neville #33)

Most participants reported that the strategic gaming and play approach to learning captured their attention (Coverage 0.90). One student commented that they had not realised they had been learning during one of the gaming activities.

Probably it’s not until afterwards you realise that was an [imaginative] learning activity that sort of thing.

(Jeff #27)

Adam acknowledged that the games activities have improved his understanding of electrical physics.

Then we were introduced to it (imagination) in Term 3 which was good, started to playing some games I think it was. I think that was good looking at it with another perspective. I think it can add more of a physical layer to it (electrical physics) which helps myself and others.

(Adam #20)

Neville noted that while playing strategy games he was initially unaware of the use of imagination and the re-enforcement that was taking place.

You use it in other areas but you don’t think about it, it does not click that you are using your imagination. I like activities like that, that reinforce it. You actively know you’re using it. With whiteboard Pictionary [as an example] you have to draw it in a way your team will get and not the other teams.

(Neville #33)
Visualising is a strong imagination skill that was noted by ninety percent of the participants in their narratives. Greg acknowledges that linking his imaginative skills with the ability to visualise is significant.

In Term 4, I branched out from the imagination classes with the use of imagination. The skills I learnt really helped with Analogue One subject with current paths and voltage levels that can be visualised.

(Greg #47)

Dan also indicated that visualisation allowed him to discover discrepancies in electrical circuit concepts.

I think I enjoyed the blindfold activity the best. I think the PCB to circuit one, I think, maybe showed some holes in my, say, visualisation of circuits. It did not occur to me to pick up any PCB and try and transpose the circuit.

(Dan #12)

5.2.4.6 How do relationships affect the catalysts of, and responses to learning?

In this project the three main catalysts for learning have been the imagination project itself; the social and ethnographic context of the cohort; and the TAFE activity system.

For the participants themselves, the imagination project as catalyst for learning is simply assumed. As a result, there is little direct but much indirect comment about how relationships facilitate the imagination study. The students indicated that their awareness of relationships affected their
response to the study, by encouraging a higher level of engagement and interaction.

The participants of the study indicated that the nexus between relationships and learning had not been obvious until they undertook the Myers-Briggs personality test. They noted that this activity clarified the relational aspect of learning.

Sam’s response is indicative of the Myers-Briggs personality test and its effect on the catalyst of the imagination study.

I found the Myer-Briggs personality instrument an eye opener because it gave me a better understanding of myself. The personality instrument allowed me to better understand my fellow students. I had the opportunity to understand how they think and what their habits are. Also helped me create a mutual relationship with them because they understood what I am like and I understood them.

(Sam #47)

Again the participants were not initially aware that the relationships between students and teachers can act as a catalyst for learning. Later in their transcripts they acknowledge that such relationships need to be appropriately maintained or their learning will be negatively affected (Coverage 0.65).

For example Max believes that the class relationships are important for sharing conceptions and discussing (and remedying) misconceptions.

I find working in groups is good because if you miss an idea then someone else has missed an idea, but they don’t line up. You have missed something they have picked up and you have picked up something that they have missed. So then you can melt or mould it together and get an overview of everything without missing anything. That’s good.

(Max #14)
The themes represented in the student narratives in relation to TAFE learning philosophies (Coverage 0.83) are those of an adult learning environment and the blending of theory with practice.

Compared to universities the adult learning culture of TAFE encourages taking responsibility for one’s own learning and progress. Having experienced both cultures, Dillon notes that the support and content structure are far better.

> The first is the adult learning culture at TAFE is a lot better than other places I have been – for example, university. There is a lot more emphasis on them helping you, instead of you having to help yourself. ... I have found they’re always willing to help here.

(Dillon #34)

The second theme is TAFE’s general pedagogical approach of integrating theory with practical activities. This approach not only emphasises the practical as reinforcement but also practice as the source and shaper of theory. Contextualisation does not just concern the content of electrical physics, but also the application of the physics in workplace practice.

Neville highlights the theme of practicals reinforcing theory. Particularly for Neville, practicals are also about convincing him that theory is correct. There is an assumed mistrust of the theory.

> Learning at TAFE is done through theory and practical applications. The practical helps to reinforce the theory and helps to gain a better understanding of what we’ve just learnt and to prove that the theory is correct.

(Neville)

For Dom, the integration of theory and practical is about gaining context. The ‘focusing on existing technology’ and ‘how it would actually be used’ is important to many of the students as actual context.
As the activity above demonstrates, Learning at TAFE is more hand[...] and I appreciate all the theory and the practical component that comes with the theory part of it. So the adult learning culture here at TAFE is more hands-on to me.

(Dom #31)

5.2.4.7 What have been the catalysts of, and responses to learning change?

This section again confirms the predominant theme which is that imaginative skills act as strong catalysts for learning abstracted concepts. The participants’ responses indicated that not only had their learning improved, but that students now had access to different approaches to learning, new learning tools and increased use of imagination within their learning.

These outcomes were also cited by the participants with respect to responding to contradictions. That is, imagination plays an important part in finding available learning options that are not initially apparent.

The student responses provide validity to the ten imagination categories discussed above and are credited with improving learning and creativity.

5.2.5 How do they learn electrical physics?

5.2.5.1 How does the activity system shape how they learn?

The student narratives contained very few indications that the TAFE activity system shaped how they learnt in negative ways or placed limitations around their learning. However, there were indications that
limitations were imposed by the students’ expectations, their historicity, their personalities and interests.

Rules of the activity system can limit how students learn and at the same time also foster learning. One of the ‘rules’ in the electrical physics classroom that often limits learning, is the belief that the scientific method or way of knowing is the only way of knowing. Many of the student narratives reported that moving from a scientific way of knowing to other ways of knowing is difficult. For example:

In Terms three and four I started to imagine current which was helpful in doing amplifier analysis and stuff like that. The only thing I was having trouble with in Terms three and four was computers because I am not IT savvy. It’s not something you can imagine really, its set rules. Rules like syntax that I am not used to. There is a big shift in using imagination now. Before I would just take it as it is, if the book says you have to do this then that. I would just limit myself to doing what the book says. But now I realise I can do a bit more than that as long as you arrive at the same answer or solution it is just matter of stretching your mind.

(Dom #25)

Despite the tradition of focusing on knowing using a scientific method, learning by doing (Young, 1993, p. 447) or knowing by doing as problem solving (Pacey, 1999, p. 59; Pavlova, 2003, p. 55) was equally reported in the students’ narratives. Dom and other participants recognised that there is often conflict between scientific knowing and practical application. This requires a combination of imagination and commonsense (Coverage 0.6).

Mort uses the practical aspects of electrical physics as a way of reinforcing the theory. By implication for Mort, theory has the higher importance.

If I am wrong, I will tear it out and start again and try and do it from memory. The practicals ... reinforce it because we have already learnt it. But we can actually see it happening practically and verify what we thought was going to happen will happen, so that’s what I like most about practicals.

(Mort #17)
However, Mitch also reinforces the point that many of the students use learning by doing to reinforce theory and in doing so contribute to their understanding of how something works.

I had a pretty good visualisation of where AC and DC fitted in and how they worked. I found that re-reading and doing the practicals reinforced that underpinning knowledge. That helped me interconnect the two. Re-reading and doing even more practicals reinforced it. The imagination has helped [with the complexity] like imagining the concepts like phaser diagrams, imagining how they should look, and how to draw them, has improved.

(Mitch #9)

The participants of this study indicated that there are two main communities of workplace and classroom that enhance and limit how they learn. The workplace was reported as a community that sometimes limited learning because the students were not yet ready for a particular context. At the same time participants recognised the contextualisation sometimes became relevant at a latter point in their learning. Dillon indicates that the classroom and workplace community cultures of supportive critically reflective learning limited his learning at one point and enhanced it another.

So the application of imagination is seeing where it could be used, for example just looking at the amplifiers and now seeing some of the stuff I have toyed with. For example I built a FM transmitter when I was in Perth. I had no idea [of what I was doing.] I just put the pieces together, but now I am learning it and [...] am being able to see these applications of the stuff we’re learning for in the context of our final project. But now I am really thinking about designing my whole thing and where everything is going to go. So applying it, putting it all together each little bit into each bit. Seeing how each bit interacts properly to get the desired output. The whole is greater than the sum of its parts.

(Dillon #33)

The student narratives also indicated that the social aspects of community also have this ability to limit and encourage learning. In the two following
extracts Josh indicates that community helps his learning and then indicates how people can distract him from his learning.

I find a lot of them (imagination exercises) useful or anything like that, interesting. I found the Ohms Law one most interesting actually. Not so much exactly what I had done, but other people’s perceptions. I found how people think of current to be quite interesting. How everyone has this view of current, but it does not seem to be what current is.

(Josh #9)

In class I find working with some people detrimental. I just like working on my own. I moved high schools because I had a heap of friends at one and I was just easily distracted and I would miss period after period. I have had to keep myself in check constantly. So I just find I work better on my own. Then if I need help I will talk to somebody, but if I don’t, I like to at least do the theory on my own, practical work is fine.

 (#36)

A significant aspect of this study reported by the participants was the movement of the division of labour (or responsibility for learning process) over the three research cycles and how this shaped their learning. Sam indicates significant improvement in his learning as he became more responsible for that learning.

Over the past few terms I have experienced a lot of new activities that can be used to help me with day to day learning. I have developed myself as a student by using some of these methods in my study time. This includes building my own story to remember anachronism and drawing more often to remember things. I have also started using the learning cycle which we have been focusing on a lot on occasion to remember day to day information. So we have been having stressful periods of times of learning, like three tests in a week. In that case I have been … doing little by little, just using that cycle to remember and found a significant improvement.

(Sam #50)

With the learning of electrical physics there are many mediating artefacts which range from technical instruments to textbooks, to demonstration
aids. For the students of this study, these are mentioned occasionally, but to a greater extent are assumed. It is the place of imagination as a mediating artefact that has shaped how learning electrical physics has progressed (Coverage 0.9). Neville indicates the way in which imagination has shaped and assisted his practical skills of circuit connection.

With the practical side of TAFE, I use my imagination in building the circuit, as we are given a diagram with pin outs and we are to construct this ourselves...

(Neville)

Likewise, Dillon below credits imagination as having been an important mediating artefact in his learning of the concepts of electrical physics.

I have learnt to make it (imagination) a lot more applicable to a lot more things that I originally thought it would (not) be applicable to. Like I said before I would only use it for gaming and stuff like that and now in class I will begin conceptualising and imagining things to make it easier for me to understand, trying to put it in a different light or something like that. Yea, I was a little sceptical at the start, its definitely allowed me, specially, when I sit back and think about it, we really can’t see anything we ever do in electronics or anything so I think it’s changed from scepticism to this is defiantly helping for sure.

(Dillon #26)

5.2.5.2 How does multi-voicedness impact on how they learn?

The major source of multi-voicedness is the dualistic roles of the participants as full-time students and as employees.

The impact of being students who learn collaboratively is a significant theme reported in the participants’ narratives. Direct learning relationships
shape how they help each other to learn particular concepts in electrical physics. The class has developed a general attitude of assisting each other in the day to day process of learning electrical physics. Mort talks of helping each other keep up with the concepts being learnt.

The social aspect of learning, I think, plays a big role – especially in class. Sometimes there is always someone that will grasp it the same way you do, so you can talk to them about it.

(Mort #44)

Keith has developed specific relationships to assist with learning and also modified some relationships that were not assisting. The students know which particular students they can call on for assistance.

As the Term one now comes to a close I think the social aspect is important. Because you are in the same class, you know everyone and what they’re about, and you know which people to go to for help.

(Keith #34)

The imagination activities have also encouraged positive learning relationships. Greg and Dan indicate that all the class as a cohort get along and this produced effective learning.

Plus we all get along pretty well; there is not anyone in the class that does not get along.

(Greg #41)

In terms of the imagination exercise, ... However, I am finding that they do help me interact better with that partner, especially the exercises yesterday, with the blindfolding. Social skill stuff working with a partner, especially with someone I haven’t worked with before. I think that’s very good development.

(Dan #11)
Sam’s learning has been enhanced by engaging the relational aspects of learning. He has discovered that by understanding how others think, he finds further ways to learn and thus increases his understanding of metacognition.

I had the opportunity to understand how they think and what their habits are. Also helped me create a mutual relationship with them because they understood what I am like and I understood them.

(Sam #47)

Learning electrical physics by the student as employee is complex, ebbing and flowing between the learning contexts of TAFE and the workplace. The participants’ narratives indicate this complexity as they talk about TAFE contributing to the workplace learning and the workplace contributing to the TAFE learning context. Students indicated the importance of taking skills learnt at TAFE into the workplace and vice versa (Coverage 0.8).

I spent most of my time with the electricians so I did a lot of testing and tagging at the fire station. I used my learning skills I learnt to learn the procedure on testing and tagging ... I think Greg hit it in the head when he said experience and knowledge. I would like to get a bit more knowledge from experience and stuff like that. Hanging around heaps and heaps and heaps and learn all you can. Then keep constantly expanding on it, basically using experience.

(Mitch #33-34)

Mort’s learning had its origins in the workplace, was amplified and filled out at TAFE, and was confirmed again in the workplace. This continual bi-directional contextualisation strengthens Mort’s learning.

The best story of that is from my first placement I was at ... a small airport in Melbourne. The mentor talked to me about amplitude modulation ... and we had not done that in radio yet. So that went over my head. ... from that we did radio and then on my next placement in Darwin I understood so much more. ... I think that’s the biggest thing that understanding and how all the concepts come together.

(Mort #48)
5.2.5.3 How does the student’s historicity influence how they learn?

The student’s narratives indicated that their learning of electrical physics is influenced by their personal history. The impact of personal history is concerned with their ability to critically self-reflect. The students categorise what has motivated them to learn electrical physics and view their active learning skills (metacognition) and the impact this has on their learning.

The participants’ personal history of electrical physics was identified by them as a motivation for engaging in further learning (Coverage 0.77). For Mal this personal history starts with building electronics kits in his childhood.

> From the beginning of year five I have been interested in electronics [kits]. I wanted to know how things work – how a light glows. Therefore I got some of these [electronics] kits and things.

(Mal #2)

Doug’s history of curiosity of electrical devices is also a reiterated by other participants as an influence on learning electrical physics.

> I suppose when I was younger my brother and I used to pull apart everything. ... After that, it was mainly computers, the same sort of thing. Building computers, then pulling them apart. Then looking to see how they ticked and all that sort of good stuff.

(Doug #2)

A theme, involving approximately forty percent of participants, was previous employment in the electrical/electronics industry. Neville knew he wanted to be involved in electronics, but was not sure how. He started out in IT, progressed to photocopier repair, then to radio technician trainee.
Then I ended up finding photocopying because it was pretty well all electronic, so I started on that and now I have this job [as a trainee electronics technician with Airservices].

(Neville #1)

Mal’s narrative, which is indicative of thirty five percent, of the participants, is a strong personal history of managing their own learning. This is true for many students who to some extent understood their learning. It was Myer-Briggs personality test that brought this into contrast for the students.

The second last is about the Myer-Briggs. My type is ISTJ. That is introvert, sensing, thinking and judging. This activity was one of my most interesting. This activity has clearly shown my type which I did not know before. It showed us how different persons act in different situations, such as learning styles, reading, writing, studying, playing skills and possible areas of stress levels, how to deal with the stress. This activity helped me to understand others and myself as well, how to interact in different situation by knowing that. I think I can use this knowledge to understand the work groups better and help each other to improve our skills.

(Mal #46)

5.2.5.4 How do contradictions change how they learn?

The themes of the student narratives focused on both aspects of the necessity for change and opening up new options or ways to learn. Contradictions create a disequilibrium that encourages the students to safely challenge previous conceptions. This could also be understood as Vygotsky’s ZPD within activity theory.
A common theme reported by all students is that contradictions indicated by a difficulty or challenge have encouraged change by indicating a lack in the understanding of a particular concept. In the flowing excerpt Dan has understood the need for change and indicates that more practice is needed in the area of printed circuit board to circuit interpretation. This demonstrated the diagnostic aspect that contradiction can bring.

So that’s one thing I hope we do more of because, from my point of view, I am still not comfortable in sitting down and having a complex circuit in front of me especially on a PCB and analyse what all the stuff does. I recognise blocks of it, that’s the power rectifier, that’s this and that’s that, but in terms of the entire picture I reckon if you did more of that work and that is one of my suggestions.

(Dan #28)

Josh is more proactive and recognises that contradiction could lead to new learning. He uses contradiction as a learning tool by actively seeking out contradictions or ‘flaws’ and so is metacognitive in his attempt to learn.

If I read something I will try and find a flaw in it.

(Josh #16)

The combination of encountering problems or contradiction with imaginative skills has encouraged sixty percent of the students to find alternatives. Searching for alternatives has, in turn, produced learning options. Mort talks about going down different paths and being helped to learn in different ways.

I started to think about and talk about it. But also when I came to a problem if I couldn’t see a convenient way then I would try to imagine it in different ways that we talked about.

(Mort #32)

Mal links concepts of challenge and new ways of thinking and doing which are facilitated by imagination. The contradiction here is imagination itself.
In a recursive way, imagination has assisted with the contradiction as ‘new ways of doing things and thinking’ are discovered by Mal.

[The last three months] has been positive and has shown me a lot of new ways of doing things and thinking ... Even though it is sometimes challenging, I have found that mostly it’s good.

(Mal #36)

5.2.5.5 How does creativity impact on how they learn?

The imagination project has a strong element of creativity inherent in it, resulting in some difficulty discriminating between that which is creative because of the study and other creative approaches. Many of the students have indicated that they already knowingly use creative skills. For example, some students in the study are musical and play an instrument, while others are involved in drama and yet others in visual artists.

Another aspect of creativity is self-motivation. This is often not recognised overtly as a form of creativity. The participants of this study, who have engaged the learning of electrical physics well, have been self-motivated and often found creative ways to engage the learning when studying by themselves, but while working as a group, they would often default to using more traditional ways to engage and learn. The participants recognised that they used creative ways to engage in the learning of electrical physics by being self-motivated and/or by pursuing imaginative skills.

Approximately one third of the students were actively self-motivated as their comments indicate. Neville’s creativity is in his understanding of the required amount of work and its flow.
Learning at TAFE, it’s a pretty open learning environment. To a certain extent, it’s your own learning abilities and your own pace. If you don’t put in, you don’t get anything out.

(Neville #24)

Josh’s creativity affecting how he learns is in his approach to questioning the norm. By challenging the accepted picture, his learning is confirmed and enhanced. The participants have indicated that the imagination study has encouraged them to approach their learning not only differently but creatively (Coverage 0.9).

Most of the students reported, by the end of the study, that their imaginative skills had a positive impact by assisting them in their learning of electrical physics. The following student excerpts are representative of their appreciation of the imagination strategies and how the creativity of the activities assisted how they learnt. Keith acknowledged that how he learns has been positively impacted by the used of imagination activities to improve his conceptual, spatial and problem-solving skills.

Then the third cycle was really reinforcing what I had done there and expanding of what I did. I think it came to show out in that bridge building. ... So being able to think, what’s the strongest shape here? I can’t make a circle so I will make a triangle. ... So that was thinking outside the box and manipulate the physics of the triangle to best suit what we needed to do. Also the circuit design from the description (PCB to Circuit) that would be very useful out in the field actually... Then there was the blindfolded knot-tying one because that made you rely on other senses. When reaching up you won’t be able to see what you are doing, so being able to physically think in my head that this is what my brain is looking at and this is what my hands are doing.

(Keith #42)

How Josh learns has been change[d] by the imagination activities. This has assisted in his ability to conceptualise electron flow as it relates to conventional current flow.

My perception of AC versus DC may have modified a little, but I suppose it has changed a little bit in that [...] I always thought of it
as in electron flow and doing the positive stuff (Conventional current flow) instead has started to change it a bit and I have started to think in that manner now. But for how the flow actually occurs it is actual movement of electrons. So I suppose the imagination stuff has made me think about how I learn things and my learning style.

(Josh #11)

Mal is very direct: imagination has impacted his learning by given him a set of creative skills to think very differently with about electrical physics.

In the beginning, I thought the [imagination] project would not help much because of my previous learning styles that I had back in my own country. I came up with a set of skills that helped to understand electrical physics, I thought this because electronics is very theoretical and my previous experience and studies were directly to the point and gave me only what I need to know. Here when we had group activities we had to use imagination to learn and improve and understand electrical physics with imagination.

(Mal #41)

Neville’s learning is challenged and changed through the creativity of simulated sight deprivation and this has led to an improvement in spatial and visualisation skills.

Imagination activities really do help. I reckon in the second lot (cycle 2), that was driven by you – but we still used our imagination in it. Like doing the blindfolded activities – that also helped. You physically had to imagine where things would go without looking at it and how the circuit would be in your head. It was more of a clicking point. I think the penny had already dropped but that reinforced it a lot more and more awareness about it.

(Neville #34)

Finally, Jeff is appreciative of the Myers-Briggs personality test and its value in enhancing one’s understanding of personality and how this understanding challenges how you think and learn.

In Term Four, I like psycho-motor type things just because it involves doing them. I like the Myers-Briggs thing. That was good
too, I thought. I enjoyed the games but did not find it very helpful for anything. The history is good. I would like to do some more of the psychological activities like the Myers-Briggs.

(Jeff #28)

5.2.5.6 How do relationships affect how they learn?

As in the previous sections dealing with aspects of relational learning, the relationships this study has focused on are the relationships with self, within the class cohort and with teachers.

The students’ narratives exemplified the themes of self-awareness and learning awareness (metacognition) as important aspects that affected how they learn electrical physics (Coverage 0.55).

The relational aspect of self-awareness is internal and all the students indicated that it was the Myers-Briggs personality test that triggered the awareness at many levels. The particular level of being aware of one’s own learning was identified in the participants’ narratives with seventy percent coverage.

A consistent theme among the participants was their acknowledgment that being self-aware of their internal learning relationships has been a positive aspect that affects how they learnt.

Then came along Myer-Briggs and friends
It’s my personality they say towards it bends
Speak up, have courage and free your mind
Then a better version of me perhaps I will find.

(Dom #63)
Sam indicates that his self-awareness through the imagination activities has affected how he learns and this is demonstrated in his improved learning in electrical physics.

Began to find the imagination classes more interesting because they are obviously improving our learning. So that’s a major point. I appreciated the group activities more because they were quite an asset to my learning. The activities I found most appealing to myself was the Myer-Briggs personality instrument ...

(Sam #46)

Dillon highlights the connection between imagination and its impact on the learning of electrical physics which, originally, he clearly thought would not be applicable.

Between Term Two and now, I have learnt to make it (imagination) a lot more applicable to a lot more things that I originally thought it would (not) be applicable to.

(Dillon #26)

Strong classroom relationships affect how the participants learn. The participant narratives demonstrate that the imagination project has made that and those relationships stronger (Coverage 0.6). In the following extract Mort shows an understanding of the advantages of learning together as social groups and the impact many of the imagination activities had in encouraging this.

The social aspect of learning I think plays a big role, especially in class. Sometimes there is always someone that will grasp it the same way you do, so you can talk to them about it.

(Mort #44)

Greg’s opinion is that the imagination activities have affected learning by encouraging the class to work together and provided a safe place to do so.

The cultural part and social part have definitely been encouraging imagination because we are all together and playing games and
things like that. Plus we all get along pretty well; there is not anyone in the class that does not get along. It’s easy to use your imagination...

(Greg #41)

It is this aspect of corporate safety that has assisted the students to engage in learning electrical physics, using imaginative skills. The student narratives indicate that this safe relational aspect has been an indirect result of learning to work together.

The relationships between students and teachers are complex, as indicated in the above analysis and in the student narratives. The relationship between the researcher and the students and how it impacts on the learning has been mentioned by thirty percent of the participants.

Keith is learning to use his imagination and also has a strong sense of responsibility for his own learning as a result of my teaching approach. He is critically aware of my teaching style and puts a strong emphasis on this aspect of the relationship.

In electronics, use of imagination can aid in the understanding of concepts but [is] not used widely. [There is] more emphasis on the student to understand with the teaching style of the teacher.

(Keith)

Doug’s comment indicates a preference for an active and open relationship with the teacher. The imaginative skills activities have fostered this interactive relationship as a part of the researcher’s teaching style.

Imagination which is good because it helps you work out a way or better way of learning that is more suited to the individual person instead of having the teacher preach to you from up at the board, this is the right way to do it or read it out of a text book, everyone has their own way of learning and explaining how things work.

(Doug #39)
5.2.5.7 How do they learn electrical physics?

This section has described how imaginative skills feed into the students’ abilities and affected how learning takes place. One of the effects of imagination is how it assists individuals to transcend established patterns of thinking and behaviour. Through the construction of mental images or models it allows the individual’s thinking to move between abstract concepts and spatial and physical reality.

In this section, the impact of imagination is to produce a framework that does not have to be theoretically and technically correct, but still allows the student to pursue learning. Imagination produces a safe environment which allows experimentation of thinking and considering consequences. The result is improved learning.

The participant narratives confirmed that the use of imagination enables learners to move away from default patterns of learning. Often students when working in isolated groups outside the classroom default to their traditional ways of learning. The cause of this is that those traditional approaches are the common denominator and as such this is the pragmatic way to get the learning completed.

The students’ narratives demonstrate that imaginative skills had particular importance and influence when students begin learning about alternating current. The complexity of alternating current is a quantum leap in comparison to direct current. There is a large amount and depth and density here between AC and DC. The impact of imagination is to give the learner additional tools of engagement.
5.2.6 How are underpinning assumptions being challenged/changed/affirmed?

5.2.6.1 How does the activity system influence underpinning assumptions?

It is important to acknowledge that any activity system is associated with a set of assumptions. The activity system in this study is concerned with adult learning system/approach that contextualises theory with practice and which is implemented through a particular curriculum and practice. This understood, the activity system (TAFE) affects students’ assumptions from the perspectives of rules, community, division of labour and, mediating artefacts.

A predominate assumption by the students of the study is their anecdotal understandings of the ‘rules’ or laws of electrical physics, for both DC and AC. This assumption is often closely followed by the discovery that DC is not what they thought it was. Then, just as the student comes to grips with DC, the understanding of AC brings a whole new world of concepts and brings to the surface faulty assumptions.

Dom, like many other students (Coverage 0.8), assumes that DC is about voltage. The reference to ‘flat line’ is the voltage trace on an oscilloscope.

My picture of DC and AC has not changed really. If anything, it’s more distinct. Before I would say DC flat line and AC sinusoidal⁴. But now it’s more like DC flat line cannot go through a capacitor but the AC will. It’s more about going deeper; go into the components, where it will be allowed or rejected.

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⁴ A simplistic way of representing AC use a sine wave so its alternating nature whilst DC is commonly predicted by a flat line.
The second assumption in DC arises from the hydrology analogy where DC is compared with water movement in a pipe. The analogy has many advantages and works well to a point as many analogies do. The problem is that students often make the assumption that this analogy is appropriate for all DC circuits or phenomena. Doug in the following example defaults to this hydraulic analogy.

The imagination activities have not changed my picture much – particularly DC hasn’t. I still look at DC as, and will I use the plumbing, water flow as far as current flow.

(Doug #16)

There are many assumptions made by students about AC. The conceptual complexity is increased by a considerable factor. The first assumption often made is that AC is sinusoidal and only sinusoidal. Adam, like many other participants (Coverage 0.72), made this assumption about the wave shape, when talking about AC.

The move from DC to AC has been challenging. The concepts are another level of difficulty and the mathematics behind it, are just crazy! I have always thought it (AC) was a sine wave ...

(Adam #9)

The extract from Dillon and Mort demonstrate an assumption that DC and AC cannot be mixed or used together. Again this is an incorrect assumption.

So, [as] an example of the DC versus AC, [in] one of the practicals we did we are using, plugging DC and running AC signal through it. I thought this must be impossible. ...It’s just the idea that a signal, instead of being electrical power it’s a signal, I don’t know? Working on power supplies and amplifiers just plugging DC to get them to run, then changing the DC and AC conditions and
watching how it all integrates together is that, that has shifted my perceptions of electricity.

(Dillon #14)

Mort assumed that AC was always symmetrical and consistent, which is not the case.

If I was to think of it another way it would be how I view AC and DC. ... AC I think of as being constant amplitude and frequency so obviously that radio changes both. I differentiate between AC and signals, I am not sure why. I see signals as low level, low current and AC is high current high voltage.

(Mort #16)

A significant assumption produced in the student narratives is that of the role of imagination in adult learning (Coverage 0.9). Mitch, as a typical example, assumes that imagination is not part of learning for adults.

As I mentioned this earlier on that I think imagination is a childish tool. As you get older you’re discouraged to use your imagination more, though I can see uses for it in such careers like journalism or where they have to make stuff up or being an author, Because it’s not there. You have to make it up if you are an author. I think they’re quite imaginative, but me I think I am more discouraged because I tend to think of it as a childish thing. But where as if I use my mind that’s more adult and serious word for me. It works for me instead of imagination just mind powers something is more meaningful to me than imagination.

(Mitch #39)

Jeff makes a further assumption with regard to imagination, which exists but is unconsciously used (Coverage 0.70).

I was not conscious of imagination until we got into all this. But still I knew everyone had it and it is important. It effects how you do everything really, well I think it does. [In Term two] it was just there, not so much thinking about it all, but I used it without realising I was using it.

(Jeff #25)
Despite the affirmation of learners’ labour in the TAFE learning approach, few students came with this approach to their learning. Most were not prepared for a context which placed the responsibilities for learning on the learner. Their initial assumptions were that they would be taught rather than their learning facilitated.

This is demonstrated in Adam’s comments. His assumption, as a school leaver, is based on his school experience.

At school they would force you to read everything and do questions, whereas here (TAFE) it’s sort of have to do it yourself or otherwise you basically don’t learn it.

(Adam #31)

Greg had made assumptions about the amount of labour required to learn electrical physics. He had completed high school physics without much effort and assumed this would carry through to his experience at TAFE. By his own admission, his assumptions were incorrect.

I did not have any fears in Term One because I didn’t think it would be that difficult – maybe because of my preconceived notions about learning at TAFE. By the end of [Term One], that had definitely changed. It was a lot more complex than I had expected, especially Term One.

(Greg #28)

The student narratives do not often mention those things that are mediating artefacts. The very use of artefacts, for example, electronic test equipment or student workbooks by very nature are assumed by the participants.

The exception mentioned in this study is the workplace project of the electronic temperature switch (Coverage 1.0). The students assumed that the purpose of the project was to improve their electronic circuiting skills. Their assumption was correct, as the electronic temperature switch was a
mediating artefact and not the true focus of the project. As a result they do not directly mention this in their narratives.

5.2.6.2 How does multi-voicedness impact underpinning assumptions?

The multiple-voices of the students being considered by this study; are that of full-time electronics Diploma students; that of full-time employees of Airservices Australia and; that of their ethnic culture. Of these three voices, their ethnic culture and the prominent worldview of that culture is what underpins many of their assumptions. To a large extent the participant’s indicated that their worldview is that of a scientific positivist. This is, consistent with the field of electrical physics which is a science based in empirical measurement and significant in the ethnic culture of all the participants.

Dillon’s thinking, in the following excerpt, is strongly positivistic and representational of most of the cohort.

But he was just a great experimentalist who was able to turn hypothesis, and theory into hypothesis, then create an experiment that proved it right or wrong or proved it enough for higher mathematicians to delve into.

(Dillon #25)

To understand what the assumptions of a scientific positivist are, we need a description of how they view the world.

Most of the narratives indicated that the participants believed that sciences are the only way of knowing anything that is worthwhile. This assumption often marginalises the effect of relational learning. It is the participants’ view of sciences as individual and based on facts, which is at fault here. In reality scientific endeavour relies on the interchange of
experimental findings and thinking. As indicated in other parts of this study, by making students aware of their own learning relationship with the content and context, the students’ learning is improved.

Sam has come to understand that his worldview has produced a narrow way of knowing, but that the imagination activities have challenged many of his learning assumptions.

I have learnt the different methods of learning and how a person can learn and how widening one’s imagination can benefit them. I think some of the ideas are quite interesting. I might look into them later on in the future and try and grasp them. They will probably help me and make me a better person in the future.

(Sam #5)

As electrical physics is a science, the assumption is that it will result in complete truth. Paradoxically the non-sensory and sub-atomic nature of the phenomena makes them unknowable in an absolute sense. The assumption of absolute completeness affects learning through personality and attitude. This is indicated by Dillon’s comments about the university and TAFE approach to learning electrical physics: the University was more interested in the precision of a mathematical approach to the learning than in the practical application of the physic.

Which is good and another thing I have found which is better is they [TAFE] don’t concentrate on the mathematical scientific side; they concentrate more on what it will do, not necessarily like all the exact maths and all that.

(Dillon #34)

Science can predict and so can control. There is an axiom in electrical physics: that if you can measure it, you can control it. This too is a result of this particular worldview. An alternative axiom from another perspective is that ‘not all that is measurable is useful and not all that is useful is measurable’. This is where the positivist assumption falls short – that is, there is much to be learnt about electrical physics that is not measurable but is useful and appropriate.

These areas of electrical physics are often ignored by students or are assumed to be less valuable and so less learning effort is accorded to them.
This is exemplified by Dan when he sees the dominance of the workplace in relation to his learning.

Because we are in a work-related environment, it’s a bit different: we are supervised. But I think that everyone that comes here with the mindset that this is what I want to do, this is what I have to do. That’s the kind of mind set I have. I am not here to have fun, well not too much fun, I am here to do a job and I have to do it. I think that’s the adult mentality.

(Dan #40)

5.2.6.3 How does historicity impact learning assumptions?

The historicity of the participants, which impacts learning assumptions, are schooling background, family context and curiosity about electricity or technology.

The participant narratives indicated that their schooling experience would be similar to their learning assumptions at TAFE. The learning assumptions that Dillon, like others (Coverage 0.6) has brought from his schooling relate to mathematics and electricity. The assumption is that electrical physics is mainly concerned with mathematics. The assumption here is that mathematics is the physics rather than a modelling system that can be use to describe the phenomena. This is a common misconception.

I really like maths but not necessarily electricity, I always enjoyed engineering and solving problems, engineering is always maths. So I guess when I did electricity in high school, it was simply maths based there wasn’t much else about it. I didn’t have anything about electronics. We did a little bit about electricity and that was about it.

(Dillon #3)
Josh and Adam have assumptions about the strength of their concept understanding from school. Both have their assumptions challenged as they discover the finer details of previous conceptions. The reason for this is that school based electrical physics is often taught at an anecdotal level and misconceptions as a result never get challenged, rather they get embedded.

I think when I was doing electrical physics [before] everything was explained in a completely different fashion [in school]. So I had concepts and ideas on how everything worked and that wasn’t a problem. But to have it explained a different way ... But now it’s quite simple and things like voltage as pressure is a thing I have always used but I suppose even simpler words even. It’s made it easier to understand and made it more second nature.

(Josh #17)

My picture at the moment is sort of roughly what I knew then (at school), but it’s more detailed now, like I can follow a circuit diagram and know more about it, than say at that time when I was sort of a bit iffy of where voltage would be dropped at certain parts. I remember trying to work out parallel voltage and found that a real task. I just could not get my head around why it would all be the same. Like it’s all pretty easy now.

(Adam #3)

A further source of personal assumptions in the students’ narratives is found in the context of family. Several of the participants come from family contexts where their parents have an electrical background.

For Adam his rural auto-electrical context of the family farm brought assumptions of his ability to connect circuits. He knows some of the terms used and his small amount of success resulted in embedding his concepts about these terms that were not built on the basic concepts of electrical physics.

On the farm I used to wire up batteries and fix fuses and stuff on the equipment and machinery and learned a little bit then, sort of about voltage and current.

(Adam #1)
Darren’s family are all electrical contractors and Darren had helped with stage lighting for local theatre productions. His assumption was that his background in application would automatically assist his learning of the physics. The reality for Darren is that he struggled in his learning because of his assumptions, in the end his assumptions lead to the opposite result.

Before I came here I did a lot of technical theatre stuff along the lines of lighting sound equipment that sort of thing designing sound and lighting systems that kind of stuff. ...I have always had an interest in electricity because of my dad being an electrician. I sort of listened to him talking about that sort of stuff and going over it with me. He tried to teach me a lot of the like electrical physics stuff when I was younger.

(Darren #2-3)

Some months later Darren continues to struggle with the learning.

Starting something new, maths has always been my weak point. Just because I find it difficult to put it into mathematical modelling into the physical world even though it’s a huge part of it and makes a lot of sense. I have to sort of do it in my own head. I have always found it difficult to have it taught to me, like I have to go off on my own stream of consciousness. I need the question answered as it comes up. It’s not the kind of question where you can just put your hand up and ask. It’s something that does not really makes sense to me that I just really need to understand more details.

(Darren #9)

Half way through second semester, the assumption caught up with Darren and he left the course.

Even though I have found the hands on aspects of TAFE great fun, the physics, the maths has still continued to be more and more difficult. I suspect because I have used my story telling skills a little inappropriately to try and slide past many of the assessments instead of using them to engage the learning. At the end of the day it’s all caught up with me and I can no longer keep up or catch up and I think I will have to do something else.

(Darren)

Many of the participants of the study reported that curiosity in electrical things was a strong motivation to undertake the course. The assumption was that this natural curiosity would continue to motivate learning. As Jeff
reported, this shallow but successful engagement with electricity promoted interest but not actual learning about the physics.

In year nine and ten I did an electronics course. That’s just because I wanted to be able to fix things that I had broken and get inside DVD players and know what was going on. That did not take me very far. I installed a couple of car stereo systems and things along those lines. Obviously I just followed the instructions, followed the colours.

(Jeff #3)

Jeff indicates that it is the practical hands-on approach and the contextualisations of learning are now stronger motivators than curiosity.

Before it was just words, now I can see circuits and understand what’s going on. From the start of the year I have gone from knowing nothing to where we are now. I think the work placement was a big help, just working out how it all comes together in the real world. Then being able to relate back to it has helped a lot. So having things explained while we were out [on work placement] that correlated with what we had done here really helped

(Jeff #11)

Jeff indicates, near the end of the study, that the learning is more difficult and it is imagination that is assisting his learning.

Over the last term I have found that the difficulty of work has been growing but at the same time there is more imagination being used to get a grasp on various aspects.

(Jeff #31)

5.2.6.4 How do contradictions affect underpinning assumptions?

Assumptions often lead to a contradiction as has been discussed in the previous two sections. That is the nature of assumptions. This section
examines some of the learning contradictions encountered in a scientific worldview and how this affects those assumptions that emanated from the participants’ narratives. The scientific assumptions to be explored are that science is the only way to know anything worthwhile; science reveals absolute or complete facts; and science can predict and so can control.

The assumption that science is the only way to know anything worthwhile soon produces contradictions in this study as the participants are introduced to other ways of knowing.

Adam and Dillon acknowledge that there are other ways of knowing things that are not in their scientific paradigm. Both students refer to the imagination paradigm as having been a ‘different way to know’ something. These students’ knowledge shift is reminiscent of Michael Faraday’s approach to knowing as he made little use of mathematics (Pacey, 1999, p. 43.)

Ken’s been doing some of this imagination stuff with us, so I learnt a different way of doing the same thing and bonding our knowledge a bit more. Just learning different ways to know what we learnt in the first two terms and so like putting that on top now.

(Adam #7)

So I think, I definitely think some of this imagination work has rubbed off. Like for Thévenising” circuits I am able to picture it in my head now perfectly without having to draw it up and do it step by step. Just go bam, bam, that’s what it’s going to look like.

(Dillon #24)

These students have come to use the contradictions imagination produces to enhance their learning in electrical physics by challenging and changing their assumptions in a positive trajectory.

The student narratives indicated an assumption that science reveals absolute or complete facts. As electrical physics is a science, the

5 Circuit analysis technique developed by Léon Thévenin.
assumption is that it will result in complete truth. Dan is a science teacher. For him the contradiction between imagination and science is influencing his assumptions in overt ways. As an ex-science teacher he has experienced the lack of imagination and it’s now becoming clear to him.

But, once you get to high school, that’s over unless you’re actually doing imaginative subjects. It’s not really encouraged, especially in science.

(Dan #43)

For Dom science and scientific publications are always right. A contradiction about science arrises for Dom, as his belief that imagination is unnecessary is challenged.

Science warrants data that backs up the talk and that what has been said in publications are always right and so just do it as they would do it. I was content with that and never really cared to venture to the other side.

(Dom)

That science can predict and so can control is a further assumption in the student narratives. This is a result of this particular worldview that is ascribed to the participants.

The key to control, for Neville, is the word ‘prove’. His scientific worldview needs proof that the theory is correct and the result is control. The contradiction here is that of understanding and proof. Proof does not necessarily lead to understanding, nor must it lead to control.

The practical helps to reinforce the theory and helps to gain a better understanding of what we’ve just learnt and to prove that the theory is correct.

(Neville)
5.2.6.5 How does creativity impact underpinning assumptions?

Two of the themes of the participant narratives indicated that the impact of creativity on underpinning assumptions were imagination as a learning tool and the place of mathematics in electrical physics. For the students, creativity is directly attributed to the imagination activities.

In the extract below, Jeff’s assumption is that imagination is stupid, without realising that the space/time given to the imagination was enabling him to question his assumptions.

In Cycle One, I thought the whole idea was stupid really. I just went along with it because it was a bunch of games and was a nice break each week.

(Jeff #36)

Mal indicated that his prior assumptions about imagination were unfounded and that the realisation of this was a gradual change (Coverage 0.7).

I understood the impression that I had early when I first started was unacceptable. The development of our imagination in the electrical physics is a gradual process. Every activity we did so far would be accounted for this gradual change.

(Mal)

Approximately one third of the student narratives indicated a shift in the assumption that electrical physics is all about mathematics. As an example the following extract from Dillon is very pro-mathematics.

Because I am a very mathematical person, I will like, imagine it then start breaking it down into maths instead of just keeping at...
an imaginary level. I think its limiting some times, but sometimes its good and it helps me some times to work out exactly what’s going on. Being able to break it down into maths and see how this equation at this point will affect this equation at that point. Sometimes by thinking (imaginatively) that way I miss the entire big picture of the circuit. It’s limiting but it’s also beneficial.

(Dillon #16)

Some two terms later, Dillon has had his mathematics assumptions shifted by the imagination activities. No longer is electrical physics just about mathematics.

Which is good and another thing I have found which is better is they don’t concentrate on the mathematical scientific side they concentrate more on what it will do not necessarily like all the exactly the maths and all that. It’s like this will do that, I found it better that way, the way they talked about that rather than concentrating on the deep maths and equations and all that.

(Dillon #34)

5.2.6.6 How do relationships affect underpinning assumptions?

The students’ narratives in this final section indicate assumptions of a need for complete answers before learning can continue; that others must know exactly before they can assist others; that learning relationships are not necessary; and one can know everything about electrical physics.

The student narratives indicated that learning relationships affect the assumption that a complete answer or solution is needed before their learning can progress. Dillon like many others, (Coverage 0.55) is objective oriented and aware that others may be upset at his lack of a perfect solution.
In the Myer[s]-Briggs I got an ESTJ which I guessed originally from when we were just saying, what you feel like this. I already knew I was like that. I take advantage of my personality when it comes to people who fiddle fart around and just too scared to make discussions and that’s one of the things on my Myer[s]-Briggs was the type [of] person I don’t like to screw around... I tend to go, well let’s just focus on the objective here, who cares, like we’re going to annoy people or do one small thing wrong, but we’re going to get the main objective done.

(Dillon #28)

Keith is a little more direct in his need of help from those with a definite answer. This is a learning assumption on his part and will exclude some other learning possibilities.

I find that people can confuse me if they don’t exactly know what they are talking about. If they had a definitive answer that would probably help.

(Keith #34)

Dan as an ex-science teacher has assumed that imagination activities will not be of any assistance in his learning or learning relationships. In the excerpt below, Dan’s preconceptions changed and he was challenged by the learning relationships that are being developed through the imagination activities.

In terms of the imagination exercises, I can’t say they have impacted that much in terms of my learning. However, I am finding that they do help me interact better with my partner [for a particular activity], especially the exercises yesterday, with the blind folding. Social skill stuff, working with a partner, especially with someone I haven’t worked with before. I think that’s very good development.

(Dan #11)

The students’ narratives are a signpost to an assumption that they can know everything currently known about electrical physics. This assumption was not directly challenged during the study.
It’s a good way to know that you can follow instructions without having to know everything. This is important because you can’t learn everything overnight. When you read a book, you can’t learn it instantly.

(Keith #11)

5.2.6.7 How are underpinning assumptions being challenged/changed/affirmed?

This segment has examined the common assumptions about learning electrical physics reported by the students and how these are affected by the activity system, multi-voicedness, historicity, contradiction, creativity and relationships.

These assumptions on the part of the participants can produce misconceptions that are strong and persistent and difficult to change. It is imagination, in part, that gives the students the opportunity to challenge these assumptions. Such assumptions often have their roots in regular exposure to some aspects of electrical physics and rarer exposure to others. For example the narratives of many students reflect erroneous assumptions with regard to the uniformity of sinusoidal waves and that DC and AC can not be combined. Such assumptions arise from their familiarity with power grids which supply electricity and their, as yet, unfamiliarity with other forms of electricity.

The assumption of context or lack of context was examined in this section. This assumption has two main dimensions of non-sensory abstraction and application. The very nature of the phenomena creates an abstraction and therefore a removal from context that is unavoidable. It is imagination that allows the student to make some connections between abstraction and context and it is this that improves learning in this domain. The second dimension of application is the context of use. When students have some understanding of application through imagination of workplace experience then learning is also improved.
There are aspects that as yet do not have full theory or technically-based explanations. This applies to the realm of radio and electrical energy as well. One of these is how an antenna works. This section confirmed that it is imagination as a tool that allows students to make the non-theory connections that brings about further learning.

This section also established that imagination and reason have a strained relationship. The reason for this is a culture that marginalises imagination. It is this cultural attitude that produces another barrier to learning using imagination. So the student is often expected to learn about a non-sensory phenomenon without overt access to the very tools that will help him/her in this area of learning.

5.3 Consolidation
This chapter has explored the participant narratives using the principles of the analytical framework and mediating artefacts of: activity, multi-voicedness, historicity, contradiction, and creativity and learning relationships. This process has revealed that imagination and imaginative skills pro-actively assist students with their learning in the abstract domain of electrical physics.

From the six principles, there are seven clear groups or themes that emanate from the analyses of the research question.

5.3.1 The anti-imaginative culture
Social and cultural interactions have been significant in the trajectories of personal learning and institutional learning as it applies to the use and application of imagination. The personal social and cultural backgrounds of the students have brought negative assumptions about imagination, while the institutional learning assumptions about imagination have also been negative. These cultural and institutional ideas with regard to imagination have influenced many of the students’ worldviews about imagination, the result being a reduction in learning outcomes. The reason for this reduction
is that traditional ways of learning also marginalise imagination. This perspective is so entrenched that imagination is rarely the favoured approach to learning. Often students when working in isolated groups outside the classroom default to their traditional ways of learning.

5.3.2 Shifting opinions on imagination
In spite of a strong bias against imagination in learning, this chapter has demonstrated a shift in student attitudes towards imagination and its use. The imagination shift has been from a negative perspective to a strong positive perspective. The positive has led to an expansion of creativity which has opened up other ways to learn that were not obviously available, and that imagination is a catalyst to seeking or finding ways around and through contradictions. That is, imagination plays an important part in finding available learning options that are not immediately apparent. Each of the ten imagination categories find validity and relevance in this analysis as most students make some mention of each category and the creativity that they have brought to their learning.

5.3.3 Metacognition
Before the study, the students focused on what is to be learnt. The imagination project has at this point encouraged the participants to be aware of the ability to learn and the part imagination may play in this. The result of the study has shown that not only did the participants become aware of their learning approaches, but that the use of imagination has enhanced their effectiveness.
5.3.4 Abstraction without de-contextualisation
The students have discovered that by improving relationships with themselves and others, and by approaching content with imagination, their learning is enhanced. This is particularly evident as the imagination study has been a significant part of these relationships as all have come to a better understanding of how imagination can assist in the learning of electrical physics by making the relational context apparent.

This analysis has established that imagination plays a critical role in assisting students to cope with and use contradiction as a way of learning. Imagination does this by giving students the ability to stretch their thinking in new ways that bring new contexts.

Ninety five percent of participants reported that imaginative skills had noticeably improved their learning in electrical physics. In particular imaginative skills had contributed to their learning by establishing grounding or context for the concepts under consideration, and that had helped manage the learning process.

5.3.5 Imagination provides mental modelling tools
Mental modelling and its relationship to imagination has been confirmed, as participants repeatedly made comments that imagination helped reduce limiting factors that a non-sensory domain brings. That is, imagination allowed a better control of the mental modelling with regard to electrical physics. Imagination does this by producing a framework that does not have to be theoretically and technically correct, but still allows the student to pursue learning. Imagination produces a safe environment which allows experimentation and results in enhanced learning. In particular, this was clearly demonstrated when learning of students moved to the complexities of AC. The inherent intricacy of AC is a quantum leap in comparison to DC.
5.3.6 Imagination and misconceptions
This analysis has examined the common assumptions about electrical physics that create misconceptions and the part imagination plays in assisting in their elimination. An example of this has been discussed in section 5.2.6.7. Non-sensory interaction with electricity is often the reason why the students’ assumptions produce misconceptions and these are strong, persistent and difficult to change. It is the use of imagination which provides students with the tools and opportunity to challenge and re-work these assumptions.

5.3.7 Giving space to context
This discussion has demonstrated that imagination assists students to use alternate approaches to abstraction in conjunction with the use of mathematics. Using mathematics is an abstraction which is used to manipulate concepts in specific, trusted patterns. Such an abstraction de-contextualises the process and often makes it difficult for the student to relate back to the actual context of the phenomenon. Using imagination in conjunction with the application of algebra problems associated with electrical energy prevent or limit further de-contextualisation and enhances the learner’s ability to abstract without losing sight of the context.

Imagination provides a path to new or not obvious contexts. A further example of how imagination is used to enhance students’ abilities to abstract and re-contextualise occurs in the process of translating circuit diagrams into actual circuit connection.

The assumption of context or lack of context was examined in this section. This assumption of context has two main dimensions of non-sensory abstraction and application. The very nature of the phenomena creates an abstraction and therefore a removal from context that is unavoidable in the first instance. It is imagination that enables the student to retain a connection between the abstraction and the context. The second
dimension of application is the context of use. When students can have some understanding of application through imagination of workplace experience or similar, then learning is also improved.
Chapter 6

Discussion Chapter

6.1 Introduction
This study of the relationship between imagination and learning electrical physics has used a blended, ethnographic approach in method and design. The participants, eighteen full-time electronics and communication students, participated in the study over three TAFE terms. The cohort of participants was relatively small, but the quantity and quality of the data were extensive. The data, gathered from participants telling the stories of their learning experiences, support qualitative research. Both quantitative and qualitative data were collected and analysed. The quantitative dimension is based on the number, length and depth of each participant’s narrative. The qualitative aspects dominate the study. Shorter narratives were connected to produce each participant’s three-term ‘big’ story of learning using imagination. The participants’ ‘big’ narratives were thematically investigated using NVivo social science software. The resultant themes were used to inform an analytic paradigm derived from blending activity theory and tension field of learning theory. This approach produced a more complete framework allowing for emotion in learning, a significant influence on students’ use of imagination.

The importance of this study speaks to, and goes beyond, the values of imagination as a valuable tool in teaching and learning in electrical physics. This research also contributes to new areas of study that require abstract skills. It contributes new understandings in learning and teaching electrical physics, both generally and specifically. Generally, it investigates the use of imagination-based mental modelling skills for learning abstract concepts in electrical physics which is non-sensory and therefore abstract. Specifically, the study provides new knowledge in the form of teaching approaches and learning skills that assist with learning the concepts of alternating current (AC). This is significant because little or no research exists in this area. In
addition, the concepts of AC are particularly difficult because they are multi-dimensional abstractions which require high-level mental modelling skills. However the patterns identified may be applicable to other areas of learning complex concepts.

This study has contributed new knowledge in learning and teaching electrical physics through blending participatory action with narrative research. This approach was selected to answer the research question because these research approaches have a synergy with theory grounded in practice. Investigating the research question has resulted in a tentative theory in relation to imagination and learning of electrical physics. This theory, that imagination is a useful tool in andragogical instruction of abstract concepts, has been tested in practice through the study and the results examined from a social science perspective. The new knowledge is the outcome of that examination as discussed below. An indirect consequence of the research has been the development of a new analytical paradigm for narrative, blending activity theory with tension field of learning theory, delivering new facets of narrative analysis and in turn a more complete picture of the data.

The underpinning knowledge which informs this project is extensive and diverse. It does not come from any one single part of the literature; firstly because little research exists in electrical physics beyond DC or examining skills of mental modelling and abstraction and, secondly, because the field of learning using imagination to help ground abstractions impinges on philosophy, quantum physics, adult learning theories, mental modelling, artificial intelligence, metacognition and much else. This has resulted in considerable diversity, with imagination as the common thread.

This thesis is anchored in the literature review, which examines the research literature related to learning generally and electrical physics specifically. The literature review highlights the research approaches used and their analytical techniques. The method and design section (Chapter 3) explains the reasons for the research approaches and how they have been
blended to engage the research question. The analysis chapter presents an examination of the narrative data using the newly-developed analytical framework. The data section gives an analysis in some depth of the narrative data from four typical participants. The first is of a participant who experienced a large shift in his learning using imagination. The next two are from students who made significant but lesser changes in their learning. The final account is from a student who saw little imagination-based change in his learning.

Finally chapter five has provided a thorough and detailed analysis of the participants’ narratives with regard to learning electrical physics with imaginative skills. This was accomplished by combining activity and tension learning theory, by Engeström (Engeström et al., 1999) and Illeris (Illeris, 2003) respectively.

The remainder of the discussion chapter focuses on the study’s limitations, the main research findings, and the implications of the results for the individual, VET providers, workplace training, industry, and teacher education. The discussion concludes with an examination of the thesis objectives.

6.2 Study Limitations
All research has limitation, and the limitations of this research include; the definition of imagination; qualitative nature of the data, commitment to possible change; an assumption that imaginative skill and abstraction are problems in learning electrical physics and involvement of the instructor as researcher. These are discussed below.

There are multiple definitions of imagination which emanate from diverse ways of making sense of experience. In this study, the researcher has taken broad view of imagination as the ability to create possible scenarios based on fact and fancy. In contrast many limit their definition of imagination to
scenarios based in fantasy and use the term thinking ‘outside the box’ for scenarios based on fact.

The data collected over three action research cycles plus written responses from participants resulted in a large amount of data which was then analysed using specific qualitative data techniques. However as with any complex data analysis the possibility of overlooking relevant data remains. A further impact is the holistic nature of a qualitative study as this will limit generalisability (Daniels, 2008, p. 103).

The eighteen participants were all employed by the same company and undertaking similar work. The homogeneity of the participants might be considered a limitation to the study or conversely an advantage as it enabled comparison among participants with similar current work and learning experiences.

The outcomes of this study were strongly influenced by the commitment of the researcher to enhance the students’ imaginative skills. A limitation of this study is that a similar commitment and effort by other teachers of electrical physics would be needed to duplicate these results.

The study has made some assumptions which could limit its application in other situations. The study has assumed that the development of imaginative skill would help students make sense of electrical physics. This has been shown to be the case. However alternative strategies were neither identified nor implemented, and this might be considered a limitation. In other words a counter-thesis was not pursued.

Final limitations may be outcomes arising from a Hawthorn effect (Adair, 1984), in so far as the participants phrased their comments to please the researcher. As discussed in the data it was shown by numerous examples where this was not necessarily the case. Although the Hawthorn effect (Adair, 1984) must be recognised as a limitation to the study, the action research methodology used was designed to minimise this.
6.3 Research findings

In this study, theory is grounded in practice – that is, the research question articulates a problem which is investigated in practice through student participation and narrative. The narratives provide a rich tapestry of data (Denzin & Lincoln, 2008, p. 5) representing the participants lived experiences of engaging actively in the imagination project.

The findings help understand the mental modelling support electrical students need in order to form appropriate mental models of electrical phenomena. Developing and using imaginative skills does improve mental modelling, thus helping electrical students to learn and engage in abstract concepts. Whilst specific instances have been cited by the participants, within their narratives, there is no one to one relationship between the development of a particular imaginative skill and its impact on learning. That is, a range of imagination skills across the imagination categories, based on the imagination definitions has assisted these students with their learning of and about electricity.

Basis of the research

This project encouraged students in a full-time electronics and communications class to video-record their stories of learning. Participatory action and narrative research approaches were blended. The action research component encouraged students to engage in the research and simultaneously be co-researchers. This was achieved through three action research cycles which changed in focus from being researcher-driven to increasingly participant-driven. At least twice per cycle, students made a video-recording of their stories using a semi-structured set of questions. These transcribed recordings formed the narrative data.

Figure 6.1 (below) summarises the research design approach.

This Figure 6.1 is based on Figure 3.6 (Representation of participatory action and narrative research) and Figure 3.12 (Imagination categories and...
activities) from methods chapter, but has been developed into an overall summary of the process.

As the Figure 6.1 shows, narrative is central to the approach. The process of action research creates engagement with the lived experiences of the participants. This is articulated in their narratives. Around the outside of the narrative and action (in dark boxes) are the ways of collecting and categorising the data. The lighter box shows imaginative skills areas derived from the literature research. These are used to produce imagination activities selected by both researcher and participants.

Participant narratives were transcribed and connected into ‘big’ stories of each student’s imagination learning experience. These data were thematically encoded using NVivo8. The narratives and their themes were then analysed using a composite approach to activity theory achieved by integration with tension field of learning theory. Engeström’s work on activity theory has resulted in an analysis matrix by posing four questions against five principles. Combining this with Illeris’s tension field of learning results in an extended analytical matrix composed of six questions mapped against six principles, resulting in thirty-six analytical questions with which to interrogate the narrative data.
Figure 6.1 Research approach summary
The narrative data themes confirm both the imaginative skills categories and the imagination definitions sourced from the literature review. It is the relationship between these themes that forms the framework for the following discussion.

6.4 Imaginative skills
Each of the eight definitions of imagination explained in the literature review are now further explored through application examples. In order to indicate the strengths of relationship between a definition and an imagination category, a ranking is used. Thus a strong relationship between definition and category is indicated as “ST” and an “SE” indicates a secondary link or relationship. The imagination category table example is shown below in figure 6.2. Also note that the spatial and psycho-motor categories are a similar colour to indicate that, though treated separately, I now regard them as extremely closely linked with respect to imagination.

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**Figure 6.2: Imagination Category icon**

In the following discussions each of the definitions of imagination is rated according to the Likert scale discussed above. These rating are linked to appropriate aspects of learning electrical physics and other similar domains which have a strong non-sensory or abstract aspect. Finally, I give one or two examples of activities within the imaginative skills which come from the students’ feedback.
6.4.1 Definition 1
The first definition is the ability to, and process of, forming mental models or images of things not actually detectable by the senses.

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The dimension of imagination is highly significant in learning electrical physics. Since no aspect of the phenomenon of electricity is present to the senses, this necessitates mental modelling and abstraction skills as a starting point.

Non-sensory mental modelling is required in all electrical physics, but is most challenging in sub-atomic theories, magnetism, creation/storage of charge and current flow. Chemistry, too, would benefit from imagination and mental modelling skills since it deals with matter at a sub-atomic level that cannot be directly sensed.

In this non-sensory domain, the predominant skills for mental modelling are analogy, diagrams (illustration) and reasoning. Similarly the main skills of abstraction are metaphor, reproduction, reasoning, elaboration and risk. This is not to say that the skills align perfectly. Rather, the skills cross-connect and I have separated them for reasons of clarity and descriptive order.

Initially mental models are grounded in the sensible material world; this is achieved with analogies. The necessary skill set is concerned with selecting appropriate analogies and not becoming too strongly committed to them. However, as the abstraction increases, analogies are often insufficient to deal with theses complexities.

The skill of diagramming or illustration in electrical physics is important and many diagrammatic approaches are used. There is no one diagrammatic
approach that allows for all possible mental representations. The imaginative skills required is the recognition of, and competence in the range of diagrammatic forms and being able to move fluidly among them.

The skill of reasoning is applicable to most imagination definitions and categories of imagination. One of the important applications of this skill is the ability to recognise gaps in understanding and or logic, and to make accurate perception of when and how to move between different representations.

The non-sensory nature of electrical physics means that we can only understand it in abstraction. Metaphor is a strong imaginative skill, used to make sense of such abstraction. For example one of the students used the metaphor of ‘warriors’ to describe Ethernet collision detection, which is an important part of the TCP/IP protocol, to enhance his learning.

The skill of reproduction is being able to give physical reality to mental models, perhaps in a circuit diagram or by connecting an electrical circuit. Both are representational reproductions, representational because there are often many valid ways to draw or connect a circuit. Linked to reproduction is reasoning which is used to distinguish between valid and invalid choices. Individuals reason from a mental model to making a choice.

The imaginative skills of elaboration are significant in mental modelling. As students observe the effects of electricity with all their senses, they need to make reasoned guesses (elaboration) and with them adjust and confirm their mental models.

Risk as an imagination skill pervades all learning, particularly within electrical physics. The research is clear that anecdotal models are very resistant to change. Students need to become ‘risk-takers’ with regard to their learning as those mental models are challenged.

In order to improve the students’ imaginative skills a number of activities were used. Two that have special relevance to mental modelling are blindfold circuits and white-board Pictionary.
Blindfold circuits demanded construction of increasingly complex circuits without using sight. Students had to memorise a circuit for one minute of visual observation. They were then blindfolded and had to connect the circuit from the appropriate components whilst their partners timed them. Timing introduced a little performance pressure and friendly competition. The process was repeated with alternate students. In all, fifteen circuits were used with up to eight components using resistors, capacitors and a power supply. The circuit difficulty ranged from simple series circuits to complex multi-path series/parallel combinations. The game forced students to quickly develop mental models from concepts they already understood well and then reproduce the physical reality under pressure. The concept was to engage and encourage mental modelling by transferring the abstract (circuit) to a mental model then to a physical circuit while taking risks. Deprivation of sight constituted risk for most of the students while performance also involved risk.

Whiteboard Pictionary is the Pictionary board game modified. Students had to create visual metaphors and analogies to express abstract concepts. Again pressure is introduced as sides compete with each other or against time. The game encourages participants to stretch their imaginative skills of connection and mental modelling using drawing, metaphor and analogy.

Mal’s appreciation of the introduction of imaginative skills to improve mental modelling is indicative of most students.

When it comes to Term 4, as an example I can say the subject Datacom [Data of communications]. We learn only theory things; apart from a couple there were no practicals. So it’s a matter of modelling of the imagination because it’s like that video tape of warriors of the Internet. It helps me understand how the data packets flow around a network. It’s very helpful for me. So, even though it’s not real, but when you make a model and imagine it that way, then it’s very helpful to understand how it works inside the network. Actually, I use it a lot of times in amplifiers when we draw the AC equivalent circuits [Thevin’s] or high frequency equivalence. It’s not actually there so we have to imagine the presence of the components

(Mal #27)
6.4.2 Definition 2
This definition envisages imagination as the forming of mental images to facilitate the production of ideal creations, consistent with reality in language. This is the creativity in storytelling, language, drama and poetry.

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The production of a narrative based in reality requires language, plot, reflection, perception, contextualising and creativity.

Reality, in relation to the imagination definition, consists of the physical cosmos and the narratives of history. I include history because these narratives in many ways represent the metanarratives that give fundamental meaning to the physical reality.

Language is an imaginative abstraction, a facet demonstrated by the multiplicity of languages and dialects around the world and their associated vocabularies. Visual literacy is also a distinct skill. Narratives convey meaning by sequencing ideas in a plot. Creating plot is an imaginative skill since narrative meaning can change dramatically with the variation of sequence and resultant emphasis. Imagination underpins reflection skills, enabling story-tellers to think about where the story comes from, where it is to go and the meaning to be conveyed.

Importantly, in human communication, the story must help others to understand. The story-teller needs the additional imaginative skills of contextualisation to be able to shift the narrative from reality to abstraction and back to reality again for the audience. All these imaginative skills are used in conjunction with the imaginative skill of creativity. Creativity binds these skills together: there are many ways to produce a meaningful narrative, and even more ways that fail to communicate the intended meaning.
In electrical physics, narrative is an important part of learning and work. Much learning is contextualised through stories and many pedagogical associations are made using narrative. In the workplace, narrative is important in verbal communication and report writing. All other domains use the skills of narrative, for this is a natural human approach.

To improve their narrative skills, participants undertook the ‘hand in the box’ story activity in which the story must be discovered from being told the closing paragraph of an extended narrative. Participants are only permitted to ask closed questions of the storyteller (Yes/No) and piece the complete story together from these answers. Unravelling the story from fragments builds language-based imaginative skills by asking only one precise question at a time, understanding the plot sequence, and private and collaborative reflection on previous answers. Perception is challenged through the unusual nature of the story. Only by discovering the context does the story become meaningful and creativity is expanded by the level of difficulty.

In a second example of activities used to develop narrative practice, whenever participants returned from work placements they were required to give a short presentation to the class of their experience and its relationship to their learning at TAFE. These narratives form part of the students’ overall stories.

Dom gives some insight into narrative and learning:

I like to watch movies, so if somehow lessons can be presented like a movie if I know the plot, the story I would probably remember it better. I think learning a little bit more about history although it might be boring for some and learning where to apply these things would be good learning. I think learning something, without knowing what it’s for or where it’s from, it’s kind of hanging; it leaves me asking so what? I think I will remember it better if there is connection to everything.

(Dom #14)
6.4.3 Definition 3
Definition three is the skill to produce ideal creations consistent with reality in pictures. This is the art/istry of pictures, arts and sculpture.

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Imaginative artistic production skills include but are not limited to, representation/perception, design, visual literacy, invention and cultural risk. Within this research I have limited the imaginative skills, related to artistic production, developed by the participants to those most useful in electrical physics. Artistic production, by its nature, is about perceptions and representation to communicate meaning (Finley, 2008, p. 98). In electrical physics this representational aspect of imaginative artistic production is used extensively in the geographical symbols of circuit diagrams. A photo of a transistor conveys nothing of its operation or connection; on the other hand, the symbol of a transistor conveys electrical connection and operation.

Design skill operates at many levels: problem-solving, use of appropriate symbols, selection of diagram type and, finally, the production of a diagram that is correctly understood by others. A strong visual literacy skill is essential to reading circuit diagrams. The imaginative skill of visual literacy concerns the production and reading of discrete symbols and the understanding of the relationships between them. Therefore, the spatial relationships within a diagram and the diagram type also belong to the field of visual literacy. As there is no one set way to solve an electrical problem from an application perspective and no one set way to represent the solution using diagrams and symbols, invention and creativity are required.

The last aspect inherent in artistic imagination is cultural risk-taking. Imaginative artistic production, within many cultures recognised in
entertainment and aesthetics but largely ignored in learning. As I have argued earlier, the skill of risk is required to step outside cultural norms.

In electrical physics, artistic production is important for effective communication, primarily through circuit diagrams and their component parts. Other types of diagram in the electrical world also use artistic production – mechanical sketching, for example.

To challenge and expand their artistic skills, participants undertook activities in team drawing and representing Ohm’s law without mathematics. In the former activity, the class formed three groups, each of which sub-divided into parts ‘A’ and ‘B’. The TAFE library balcony overlooks a large paved concourse. Part ‘A’ of each team was given a picture of a train, a plane and a car. Each team’s part ‘B’ was given large drawing chalks on the concourse. Each part ‘A’ had to verbally instruct its part ‘B’ to draw a representation of its particular vehicle on the paving without being shown the picture. The activity expanded their artistic skills in communication, spatial judgement, colour, proportion and representation. The second activity required each student – using only a piece of A3 paper, a pencil, a drawing pin and sticky tape – to produce a representation of Ohm’s law without using mathematics. Video clips of this activity were made and are included in Appendix F. The activity forced the students into the artistic domain by excluding the mathematical domain. Most found a way to model Ohm’s law through drawing and some through sculpture. They expanded their imaginative skills by discovering that electrical physics can be represented in ways other than the traditional algebra. Adam is a case in point:

To this point, the most interesting activity I had [was] to represent Ohms’ law in some way other than mathematically. The way I did it was with a bat and ball kind of analogy. ... the balls are the six electrons, this is your starting voltage (bat), and they get smashed through (decreasing size cone), they hit the sides and stuff and stop... and there’s two left from the original five, six...

(Adam #5).
6.4.4 Definition 4
Imagination is the production of concepts not consistent with reality, being baseless or fanciful.

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When linked to learning, this baselessness concerns many. Nevertheless, this aspect of imagination does require skill and that skill can be used to improve declarative learning. Declarative learning, by definition, is arbitrary. In electrical physics as an example, resistors are colour coded to represent their value in Ohms. The colours have been arbitrarily or declaratively set and as such have no logical basis. The skills of fantasy are creativity, fun/play/motivation, breaking with tradition, risk and whimsy.

For all its poor press, fantasy requires creativity, the ability to think outside the norm. The creativity of fantasy requires oblique thought, examining problems from unusual angles. Fantasy is often equated with fun and motivation, with doing apparently meaningless things just to have fun and see what might happen. This skill of play helps students to experiment and interact with the phenomenon of electricity; it is critical for their learning.

An important facet of this learning is being able to depart from normal patterns of thought and recognising when this is appropriate. The skill is actually wisdom, knowing when and how to appropriately challenge common practice. It feeds into the skill of risk. The student can use fantasy to create safe places where risk is reduced, in which they can challenge the norms and improve their learning. The final skill is that of whimsy – that is, playing with something just because it is there to be played with. Whimsy pulls many of the fantasy skills together to encourage, risk, play, and creativity for creativity’s sake. This in turn will improve many imaginative skills.
The naming of measurement units is arbitrary, demanding further declarative learning. Most units are named after the people of electrical history. Michael Faraday, for example, lends his name to the unit of capacitance: a farad. Similarly, many medical terms are more related to Latin than English and the connections lost in translation. Learning can be assisted by using fantasy to make a connection between the name of the unit and its use.

To use fantasy skills to make learning connections, students divided into groups with two hours to develop a way of connecting the ten resistor colour codes. They responded with nonsense songs, poems and stories. Here is part of the story Sam’s group presented as a fanciful story that helped connect the declarative association of the resistor colour code system with numbers:

Our story was about coloured bandits, this is a snippet of the story example. Mr Blue who stole three orange and four yellow doughnuts is serving six years in gaol and has a job separating the red overalls from the white overalls. He earned two percent of a cigarette per day. Mr Black stole one brown and two red doughnuts and is not in gaol as he resisted arrest and was killed ‘accidentally’ with a batten and a tazer. Mr Black is now zero point zero five percent grey, zero point one percent violet, zero point two percent blue and zero point five percent green.

(Sam #26)

The game Balderdash was also used to improve fantasy skills. The game is based on creating plausible but incorrect definitions of a word or concept. These false, but creative, definitions are then shuffled with the correct definition and read to the only player who was not part of the process. This player has to indicate which is the correct definition. The game encourages fantasy through story.
6.4.5 Definition 5
This definition uses imagination as the capacity to solve difficulties resourcefully in a non-linear manner.

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The major elements involved in lateral or imaginatively problem-solving are: aims/goals/focus, procedural knowledge, reasoning/logic, ways of knowing, elaboration, risk, innovation, and creativity.

Imaginative skills for aims/goals/focus incorporate the ability to perceive what the actual problem is in a critically focussed way and then use this insight to search for non-traditional or non-standard solutions. Imaginative problem-solving requires the skill of unpacking procedural knowledge through critical reflection. It also requires the ability to de-automate the blindingly obvious and use this as part of new solutions. Logical reasoning uses imagination skill in so far as it requires a combination of reflection and connections to find applicable solutions.

As an extension of logical reasoning, ways of knowing is also an imaginative skill. There are many ways of knowing and being able to understand and use these is an imaginative skills. For example, the chef who can taste and tell whether the roast was cooked in a gas oven, an electric oven or a microwave oven has used imagination to link taste with methods of cooking.

Elaboration is an imaginative skill that takes associations of the past, views them in a new light and re-works them in new associations and relationships. The process is not static but dynamic, is reflexive and investigative. It results in improved ways of solving problems.

Derived from lateral approaches to knowing and elaboration, the skill of risk taking is important to imaginative problem-solving (Brookfield, 1987, p.
Acting outside the relevant norms entails risks and, therefore, imaginative problem-solving, is inherently risky. The resulting solutions are considered innovative if they are effective – aesthetically, ergonomically, or in reducing energy use. The imaginative skill of innovation broke/creativity is more than a collage of randomly associated ideas; creativity is an interactive, flexible framework representing a way of knowing, explaining and communicating.

Many aspects of electrical physics require imaginative problem solving – most prominently are those of design, application, and protection. Design requires imaginative skills in all the processes from problem perception through to algebraic representation and finding solutions. These solutions may then become part of the physical outworking of further problems as designing circuits is intended to lead the production of circuits. Further imaginative problem-solving is then required in the selection of components, connection methods and component placement for most effective connection. Imaginative skills in the electrical domain move from abstraction to physical application through many aspects of problem-solving. In electrical physics problem-solving is highly significant in the protection of people and property. Imaginative problem-solving in this area is vital. By way of illustration the earth leakage circuit-breaker developed twenty years ago and mandated some five years later, protects human life. Lateral thinking and imaginative problem-solving are relevant across domains requiring high levels of abstraction before finding applied solutions.

In the course of the study, many problem-solving activities were used. Two activities whose primary purpose was to stimulate imaginative problem-solving were ‘PCB to circuit’ and ‘bridge building’. In the first of these, students received a complete small electronics project (sound generator). However, the circuit diagram was withheld. From the circuit written description for operation and construction, the component list and printed circuit board lay-out, the circuit was to be re-created. This activity stretched their abstraction skill by their having to work backwards. Their
spatial and psycho-motor skills were important as their diagrams often had to be re-worked. Students’ mental modelling was challenged as they had to deconstruct and re-construct concepts.

In the bridge-building activity, students had to build a bridge, to scale and specification, from paddle pop sticks and limited resources. The completed bridges were tested for scale with a model truck and for strength with a two kilogram weight. Imaginative problem-solving was indeed stimulated. Most bridges passed the test; but only one bridge resulted in an elegant, and therefore fully imaginative, solution.

Dillon’s comment provides his perception of the world of electricity and adult learning.

> When it comes to activities to help imaginative skills, I think problem-solving skills. I love problem-solving so much and I think being able to constantly problem-solve, solve problems, just means later on you can solve a problem quicker because you know how to approach a problem easier... The spatial and psycho-motor skills as well because they are applicable to everything we ever do. Those three problems are my favourites

(Dillon #27)

### 6.4.6 Definition 6

The sixth imaginative definition is the power to build and reproduce images in long term memory either pictorially or linguistically.

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Much as every tree grows differently whilst remaining a tree, people, of necessity, grow and develop their own representations thus creating different mental models. Internal consistency is provided through the imaginations skills of mental image development, standard relationships, repetition/automation, patterns, Illustration and reflection.
Images in memory form the connections in standard relationships – that is, relationships that are apparent through our physical senses. Using the tree analogy, we grow our different images of a tree from sights, aromas, textures, sounds, touch and flavours. These images are not exclusively pictorial. The connections of these relationships occur over time and usage. The strength of the connections depends on the potency and frequency of encoding. The imaginative skills are used to find distinctive ways to encode relationships and to use repetition to develop automaticity.

Many patterned phenomena are encountered in the creation. For example, we recognise the pattern of a tree, not a tree per se. The imagination skill of pattern recognition is developed from birth and needs continual development as we move into the abstract world of electrical physics. The imagination skill of illustration encourages going beyond photo-realistic representation and takes many forms.

In this study, students illustrated electrical current using, drama, animation, diagrams, algebra, geometry and measurement instruments. The skill involves using appropriate combinations of illustrations to grow mental images. Reflection has an integral role in this organic development of images in long-term memory, being used to continually adjust and re-form these mental representations. Imagination is used to recognise the role of reflection and proactively supports metacognition.

Examples of activities students undertook to improve their skills in memory image production were ‘blind Lego’ and ‘instruction-less model plane kits’. The Lego activity required two students to sit back to back. One student received a small Lego model completely separated into its component parts. The other student received the Lego instructions for the model. The student with the instructions explained to the other how to construct the model. The instructor could not see the model; neither could the builder see the instructions. The activity was repeated with a different model after class discussion which included mental image representation and use of agreed jargon. The second attempt was faster and more accurate. The
students developed the skill of setting up a language of pictures and being able to clearly describe and implement these. An additional skill is the development of language/jargon to enhance communication.

In the second activity, students constructed small plastic model aeroplanes without instructions in a celebrative group environment. Because some were experienced in this task and other totally inexperienced, they shared image language as they used each other’s skills and memory images to complete the task. Dan was particularly impacted by this activity.

So we set the goals and we want to have a finished product, like building that model, building that kit. The thing is, by working with someone else, maybe we can get it done more efficiently [...] or get a better product. So I think that’s what was coming out, we combined our mental modelling, our imagination in that respect, that was another thing. Thinking about it, those exercises were the most rewarding. I think the activities forced that mental modelling and transcendence you could not be isolated because you would not get it done. One of those activities was building those series and parallel circuits with a blindfold. I also work with that colleague and I really got an insight into how he thinks. Quite different to the way I think; so that was really good.

(Dan)

The use of the imagination exercise had a strong impact on Dan and helped him to actively develop a strong engagement with electrical physics.

6.4.7 Definition 7
This definition is the capability to create new images from former experiences, pictorially and or linguistically. This facet relates to the way we construct mental images and/or schema to represent concepts and our ability to construct, adjust and reconstruct these constructs.

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The skills that support the production of new images or ideas in memory are underpinning knowledge, finding relational links, risk, novelty, innovation and abstraction.

Consciously or subconsciously, new images and ideas are developed from the substrate of previous learning or underpinning knowledge, as was mentioned earlier by Piaget (1993, p. 5). Imagination is used to recognise this basis and to use it to learn widely. Since the imaginative connections are not obvious, a broad general knowledge and positive attitude to lifelong learning will provide the nutrients for new images and ideas. Learning requires the imaginative skills of risk-taking in areas whose value may not become apparent to others until much later. Mediating the risk is the imaginative skill of novelty: making initial superficial links in anticipation of exploring them later. In subsequent exploration, new links are found and explored. As new images and ideas arise, they are often abstract. Abstraction skills allow the memory to make links using experimentation and elaboration. This occurs as abstraction is taken to the concrete, back to the abstract again and into the concrete in a continuous cycle. To have use and meaning, abstraction must have an outworking.

Because of its non-sensory nature most concepts in electrical physics are abstract and the connections between them are therefore neither obvious nor simple. This can result in the construction of strong anecdotal misconceptions. Imaginative skills, by producing new images and ideas in memory, allow students to discover new ways electrical concepts will operate together. Any domain with a highly abstract aspect will benefit from these imaginative skills. ‘Road Runner Rules’ and the ‘Scotland Yard box game’ were use to help students gain imaginative skills involved in producing new images or ideas in memory.

In ‘Road Runner Rules’, students view several episodes of the well-known cartoon series. After a few episodes, students describe or define some of the cartoons’ nine basic ‘rules’ – for example, the coyote never wins or the Road Runner can transcend the laws of physics. Then the students view
further episodes until all nine ‘rules’ are defined. In a very engaging way, the activity requires viewers to make the same imaginative links that the cartoonists have made. Imagination has been used to transcend the physical world into a metaphysical world of humour.

‘Scotland Yard’ requires that one player be a secret agent the police are pursuing. The spy and police can only use specified types of transport and the spy only reveals his position on the game board at three specific junctures. The object is for the police (all other players) to land on the same location as the spy and at the same time as the spy. The game requires high levels of abstraction, imagination and reflection skill as the police try to estimate where the spy may be and how to get there and outwit the spy. Players must use new images and ideas in memory as they try to think like the spy, spatially, on the game board. Also required is the imagining of new ideas that relate to transport combinations, locations and what other players are thinking.

Josh enjoyed the game and understood its strategic nature but did not have the level of imaginative skills required. Further use of this tool would have probably remedied this.

The board games we played this time were completely new ones. We played the one where you had to chase the guy around the city [Scotland Yard]. That was an entirely different skill set to what I am used to, to play a game. The strategies we were using to try and track him down were not working at all. They seemed that you should-but not a chance. He was always two or three steps ahead.

(Josh #43)

6.4.8 Definition 8
The final definition of imagination is the means to synthesise sensory data into ideas with metaphysical meaning. In this concept the whole is greater than the sum of its parts.

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Whilst the metaphysical has no material or physical reality, it yet is still equally as real as anything physical. The imaginative skills of metaphysics are transcendence, creating/finding meaning, historicity, reason/logic, knowing, emotion and reflection.

The ability to understand and use this to improve learning uses the skills in historicity and mental modelling. Historicity involves transcendence to enable the examination and perception of themes and contexts of the historical narrative. We need transcendence to work in the abstract world of mental modelling. Mental modelling in metaphysics has no material outworking – that is, the model attempts not to represent a physical phenomenon, but emotional or spiritual out-workings. Whilst not materially based, these are still reality, though they are difficult to observe and measure in a quantitative sense.

The metaphorical skills deployed in creating or finding meaning are selected according to perspective. If your perspective is mechanistic, considering humans as complex biological machines, meaning is created through the complexity of social interactions of the human machine and the imagination skill selected is the understanding of the machines. If your perspective is not mechanistic but based in a creator God or mystic existence, meaning is more about discovery than creating. Yet creating meaning retains a place in relationship to the ultimate creator. The imagination skill selected then is to pursue what it is to be human in engaging and improving imagination.

Historicity is enriched by the use of imaginative skills to engage narrative at all levels, from personal stories and their contexts, through community narrative, through national narrative, to metanarrative and all the variation in between.

Reason and or logic as imaginative skills are closely related to ways of knowing. Reason is only one way of knowing or only one epistemology. For example, ethics is a particular way of knowing and creating. Using appropriate imaginative skill allows the understanding that there are many
ways of ‘knowing’ and enables the ability to compare or contrast, where possible to integrate different epistemologies in order to gain learning perspectives and creating and discovering rich models.

The metaphysics of emotion relates to imagination because emotion is a distinctive part of what it is to be human. The use of imagination enables the recognition that learning has an emotional dimension (Illeris, 2003, p. 5) and this needs to be considered with regard to improving learning. An example of this is the consideration of different learning approaches. Our approach to learning is dependent on internal and external factors, such as the nature of what is being learnt, the context in which it is learnt and the existing knowledge and understanding of the learner and teacher. Learning approaches are often referred to as learning styles (Smith & Dalton, 2005, p. 7) but is more appropriately termed learning preferences and it is these that may well change with learning contexts of place and content for the individual.

Even though electrical physics is non-sensory, it concerns a matter-based reality. Apart from learning being strongly metaphysical, electrical physics has other metaphysical aspects, most obviously the particle wave duality of electrons. The co-existence of two realities has metaphysical implications. The use of electricity has ethical, and thus metaphysical, implications as electricity can be used for great good and also despicable harm. Areas of learning that require an understanding of what it is to be human will benefit from an understanding of metaphysics.

Two of the activities that encouraged students to investigate metaphysics were the ‘Myers-Briggs personality type indicator’ (McCrae & Costs, 1989, p. 18) and completing a ‘worldview survey’. The ‘Myers-Briggs personality instrument helped the students examine their own personalities. Once completed and confirmed by the students, most were very surprised by the instrument’s accuracy. They were surprised because their scientific worldview did not acknowledge that personality was quantifiable. Following the determination of their and others’ personality types, class
discussion of the *Personality and Learning at College Guide* (Ditiberio & Hammer, 1991, p. 16) were used to connect the implications of different personality types in developing their understanding of metacognition in their learning.

In the second activity, a worldview survey, they answered questions about their belief systems. The results of the activity were confidential and students were not required to reveal their worldviews to each other or the researcher. The purpose of the exercise was to enable students to recognise that they each have a worldview and it impacts on how they learn. Following this determination, class discussions were held on how particular worldviews treat learning and imagination.

After one of those worldview discussions, Greg opined:

> I think the learning culture at TAFE apart from your class discourages imagination because they give out the booklets and it’s all set and structured. I don’t see how you could change it really if people are going to use imagination or not, they may not be able to. I don’t think it’s encouraged very much apart from the things we are doing. The cultural part and social part have definitely been encouraging imagination because we are all together and playing games and things like that. Plus we all get along pretty well; there is not anyone in the class that does not get along. It’s easy to use your imagination; you don’t feel like if you say something, people will think you are an idiot or something for it. You can use your imagination a bit.

(Greg #41)

6.4.9 Tapestry of connections

Whilst I have used discrete imagination definitions and categories for clarity, there is much crossover and interrelatedness. The following map (Figure 6.3) further indicates the interrelated diversity the tapestry of categories identified within the research data.

The connection between spatial and psycho-motor categories is so strong that the categories can almost be treated as one. The thick coloured lines represent primary relationships designated with a numerical weighting. Similarly, the secondary relationships are shown by dashed colour lines. The visual connections give a sense of the strength and inter-
There is a sense that all the imagination categories at some level relate to the imagination definitions. Whilst all the imagination categories, at some level, relate to the definition categories for purpose of clarity I have only used the primary and secondary connections indicated by the data.

The students rated imaginative problem-solving and narrative production most strongly. This was expected as narrative and problem-solving are typical aspects of adult learning. Adults learn to solve problems and narrative is their primary way of making meaning and communicating.

Figure 6.3 Relational tapestries between imagination definitions and categories.
6.5 Implications for abstract learning

The implications for abstract learning arising from the research are the need for change in attitudes to the use of imagination in learning; strategic learning activities involving imagination; the role of imagination in reconceptualising poorly understood aspects; and enhancing reflection on learning using imagination.

Need for change in attitudes to using imagination in learning

At the start of the study the attitude of most students to using imagination in learning, particularly learning electrical physics, was negative. Most of the students agreed to participate in the study despite their cultural preconceptions about using imagination in ‘real’ learning.

The proceedings of the research indicated that the cultural negativity to learning using imagination was pervasive in all students’ attitudes to learning. As the research continued, the attitudes of all the students moved toward acceptance. The research demonstrated that changing attitudes with regard to using imagination improves learning outcomes.

The achievement of the change in student attitudes required teacher commitment, development of metacognition skills by the students and strategic learning strategies to build imaginative learning skills. Arguably, unless teachers are convinced and committed to changing the student attitude with regard to imagination the response from students will be poor. In this research process, the commitment of the teacher to working with students was recognised and respected by the students as worthy of emulation. The students responded similarly to the teacher’s conviction and commitment to understanding metacognition as a tool for learning more effectively. It was through deliberate maintenance and development of metacognition that students were enabled to become more actively aware of how imagination contributed to their learning. Strategic learning activities to develop imaginative skills are an essential part of achieving attitudinal change. As has been documented the students were introduced to many imaginative skill building activities. As their range of skills
developed their attitude toward the use of imagination in learning became more positive as was their learning efficacy.

**Strategic learning activities involving imagination**

The action research nature of the research meant that a series of learning activities were introduced to test the hypothesis of the research question; that is, would improving the student’s imaginative skills result in an improvement in their learning?

The research found that the students responded positively to the imagination activities. Developing strategic learning activities using imaginative skills does impact on the efficacy of problem-solving, narrative and metacognition. All three of these require a commitment to life-long learning and appropriate risk-taking in learning.

Problem-solving is assisted through imaginative skills by recognising the learning options and possibilities that are not obviously apparent. The most common problem-solving assumption challenged by imagination was the tendency to try and find a mathematical solution. Imaginative skill building provided students with increased mental modelling, conceptualisation and schema construction which provided alternate ways to problem-solve.

Narrative, and therefore meaning making, is enhanced using imaginative skills, as these skills improved students’ ability to reflect in multiple ways. Imaginative skills assist in memory reflection of the past, concept reflection in the present and future possibilities that could produce meaning. Narrative also provides connection between experience, knowledge and possibility to further ask the question ‘what if...?’ and ‘may be we could...?’.

The research findings have also identified the importance of strategic learning activities aimed to develop understanding and application of metacognitive skills. This will enhance learning by deliberate consideration of both the process and outcomes of learning. Students are then empowered to be self-directed learners. One aspect of this is self-
monitoring and reflection on learning. The ability to know yourself and learn requires imagination to postulate possible consequences and make informed choices on learning directions. As part of the research process students were continually encouraged to apply the concept of triple loop learning (Argyris, 1991, p. 4).

**Role of imagination in reconceptualising poorly understood aspects**

The non-sensory nature of the phenomenon of electricity often results in simplistic anecdotal misconceptions. These misconceptions develop early in childhood and over time become well embedded, and so are very difficult to change.

The study repeatedly demonstrates through the student narratives that misconceptions are difficult to change. For example, this particularly is the case as students move from the relatively simplistic concepts of DC into AC and then to the combination of both DC and AC.

So an example of the DC verses AC one of the practicals we did we are using, plugging in DC and running AC signal through it I thought this must be impossible. But there two entirely different things now, it’s not like their electricity to me now. It’s AC and its DC. I thought before its just electricity, but now it’s completely different. It’s just the idea that a signal, instead of being electrical power it’s a signal, I don’t know? Working on power supplies and amplifiers just plugging DC to get them to run, then changing the DC and AC conditions and watching how it all integrates together is that, that has shifted my perceptions of electricity.

(Dillon #14).

The imaginative skill building and its application to learning produces a dissonance ‘space’ to consider and create a variety of mental models and so allows the student to re-create a concept. This imaginative re-creating involves alternative concepts or ideas that they can compare and contrast. It is important that students recognise the non-permanency of explanations. Our explanations are constructed on our experience, knowledge and perception at the time of their construction. Conceptions are built over time and experience and it is imagination that provides a safe
space for the learner to play with ideas, adjust them accordingly and so learn.

**Enhancing reflection on learning using imagination**

At the beginning of this research process most of the students’ demonstrated limited reflective skills. This is probably associated with their prevailing cultural paradigms, in which the primary purpose of reflection is bound to look back on facts and lived experience. Reflecting forward is often considered fanciful and as such not valued.

Many of the students experienced difficulty in reflecting forward, particularly with regard to areas of opinion rather than fact. A common comment was, ‘We are techies we just deal with the facts’. Imaginative skills enable the students to think through and address this false fact/fiction dichotomy and allow the students to discover covert possibilities. As Max explains;

> Re-reading and doing even more practicals re-enforced it [learning]. The imagination has helped like imagining the concepts like phaser diagrams. Imagining how they should look and how to draw them has improved.

(Max #9)

Imaginative skill building addressed the issues of general and self-reflection through activities which demonstrated that learning was not only factual but also relational. This relationality involves the establishment of both internal and external links in response to the recognition of connections between the learner and existing learning, the role context plays on the nature of learning and the essentially collaborative nature of learning. Students were empowered to understand their own approaches to learning. They also used these reflective skills to improve and enhance interpersonal relationships, which in turn improved the process of learning from and with each other. Effective learning is both collaborative and reflective.
Overall the research has successfully demonstrated that developing and using imaginative skills improves the effectiveness of learning, and especially abstract learning. Shifts in attitudes to using imagination requires committed teachers. The development of a strong understanding of metacognition by the students also is required if this is to occur. The research has shown this can be achieved by using strategic activities particularly in the areas of problem-solving, narrative and self monitoring of learning. The study also indicated strongly that imagination assisted with student mental modelling skills by producing space for options and possibilities that would challenge strongly held simplistic conceptions. Linked to this is the skill of reflection, that has been enhanced by the development of imaginative skills, thus making room for learning that is beyond just the facts.

6.6 Achievement of research objectives
My intent with this imagination project was to explore what I had perceived as an anecdotal relationship between learning electrical physics and students who appeared to be imaginative; that is, students who seemed to do well and displayed overt imaginative skills often through creativity. The object was to investigate whether a relationship existed between imagination and learning electrical physics and the nature of that relationship.

The objective of the research was to improve electrical students’ learning through the use of imaginative skills and developing their sense of metacognition by integrating imaginative skills within learning strategies. By so doing, it was theorised that learners would engage with abstract concepts and process more effectively.

The stories of the participants confirm this prediction. The student cohort may be roughly divided into thirds with regard to their experience over the duration of the research project. The first third came to the project with a positive attitude to the possibilities and usefulness of combining
imagination and learning. The second third was ambivalent or slightly sceptical, but prepared to take the risk. The final third was strongly and openly sceptical, but agreed to be involved for the researcher’s and class’s sake. Many of these believed that they would soon opt out of the imagination tutorial but continued on to become some of the strongest supporters of learning through imagination.

On completion of the imagination project, all except one student valued their increased imaginative skill base as it related to learning electrical physics. The exception remained ambivalent: sometimes valuing new insight and learning strategies and rejecting these at other times.

The success of the imagination project in improving student learning has been validated through the stories of the students and those who teach them. The improvement in learning has pervaded all areas of the students’ learning lives. This is evident through the analysis framework that accounted for imagination and learning in all thirty-six parts of the matrix. Clearly, imagination and imaginative skills need to be an integral part of the learning of electrical physics.

6.7 Conclusion

This chapter has summarised the research methodological approach through a blending of activity theory and tension field of learning theory in a new analytical framework. This framework was developed within this project and described clearly in the methods chapter. The project design was explained as a blending of PAR and narrative research. This ethnographic approach engaged and brought positive change to the learning of the students as partners investigating the research question.

New areas of knowledge resulting from the project validated the proposed relationship between imagination and learning electrical physics. The project has clearly demonstrated the benefits among the participant cohort of using a combination of greater awareness of metacognition; the
use of imaginative skills to enhance abstract learning; and the development of learning strategies which encourage students to take risks and to use multiple methods to make sense of their learning.

The new paradigm of dealing with abstraction using imagination enabled student to improve their learning approaches to electrical physics. In this context, the discussion examined each of the eight definitions of imagination, developed by this project. This thesis has pointed the way in relation to imaginative skills, application by example, implications into other paradigms and concluded with the voices of the students ringing in the projects conclusions.

The chapter closes with a discussion of future implications for research, students learning and how the objectives of the study have been achieved.

6.8 Personal reflection
It is not only the participants’ learning that has been improved by this research. Over the past five years I have learnt much and at the same time appreciated the extent of my ignorance. The challenge of not knowing what you do not know has at times been frustrating and, ironically, invigorating, as I have climbed many mountains and been supported by many guides. The process of this study has taken me many places I expected (For example the psychology of learning.) and even more that I did not expect. I was not expecting to research dream formation, artificial inelegance or children’s literature. As in Pilgrim’s Progress (Bunyan, 1678) the destination was not in doubt, but the journey has been a learning adventure. It has strengthened my conviction that our culture dose not perceive or value the strong role imagination plays in all learning, particularly adult learning. In fact, our culture continues to marginalise and devalue imagination, reducing it to the realm of childhood and entertainment. Through this journey I have been given access to the very real struggles and wisdom of my students. This has been particularly insightful part of the journey.
It is my hope that understanding and insight from this study will enhance the learning and teaching of electrical physics into the future. The critical place of imagination must to be considered in the teaching and learning of this and other highly abstractive domains.


Illeris, K. (2002). The three dimensions of learning: Contemporary learning theory in the field between the cognitive, the emotional and the social (D. Reader & M. Malone, Trans.). Frederiksborg, Denmark: Roskilde University Press.


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