Are Tablets the Smart Medicine for Physics Education?

A report into the design and evaluation of the Tablet/Workbook Pedagogy which is informed by Cognitive Load Theory and exploits Tablet Personal Computer affordances to improve learning outcomes for high school physics students.

by

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August, 2009
Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published work of others has been acknowledged in the text and a list of references is given.

Signature: .................................................................

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Acknowledgements

I wish to thank my supervisor and mentor, Associate Professor Juhani Tuovinen, for his guidance, patience and support throughout this research. Despite his very busy schedule, Juhani has happily spent time with me discussing ideas, guiding me and encouraging me. I have very much appreciated his advice, oversight and friendship. I would also like to thank Professor Tania Aspland who willingly stepped in as my supervisor to see this thesis through to its completion after Juhani took up a new position at another university just prior to submission.

I am very grateful to my colleague, Mr Frank Muller, for his assistance and encouragement throughout this research project. The time we spent discussing a wide variety of educational and technological issues was invaluable.

Mr David Bliss and Mrs Claire Lai recognized the potential benefits to our school’s students in my research proposal and provided the necessary computer hardware and permissions to conduct this research. Mrs Jenny Muller carefully transcribed the interview voice records into text. Mrs Jenny Veigel provided valuable secretarial support for this thesis and a cheery smile when I needed it. I am very grateful to each of these people.

Finally, I would like to thank my family. My husband, David, has supported me patiently and lovingly and has willingly undertaken a great many domestic duties while I have been engaged in this research. My children, Naomi and Christopher, have also been understanding and supportive.
I dedicate this thesis to my mother, Lillian Reeves and to my husband, David Fillmore. They have always had faith in me and encouraged me to take on new challenges. I am truly blessed to have two such people in my life.
Abstract

With physics education in crisis in Australia and elsewhere as student numbers continue to trend downwards (Smithers & Robinson, 2006), this research is timely as it investigated a ‘smarter’ way to teach physics. Theory and practice were blended to develop the Tablet/Workbook Pedagogy (TWP). Its use in teaching high school physics classes produced clear evidence of improved scores in, understanding of, and engagement with physics. It is anticipated that use of the TWP will ultimately attract and retain more students in physics classes.

Cognitive Load Theory, (CLT) (Sweller, 1994) provides a basis for understanding why physics is so difficult for many students to learn (Osborne, 2005), particularly when traditional methods are used (Paas, 1992). CLT views learning as the generation, elaboration and automation of mental schemas for storage in long term memory. The process of schema construction occurs in working memory which can cope with the simultaneous processing of only a very limited numbers (two to four) of chunks of complex information (Cowan, 2001). In an inherently complex subject like physics (van Merriënboer & Sweller, 2005), learning can occur only after multiple interacting elements have been simultaneously processed in working memory. For many students, particularly novices, learning is severely restricted when their limited working memory resources are overwhelmed by the required processing task and cognitive overload results.

With this understanding of why many physics students ‘just don’t get it’, the Tablet Personal Computer (Tablet PC) was selected as an optimal technology to support the embedding of CLT principles into a new instructional design. The resulting TWP is an improved way to teach physics which features dynamic interactions between teacher and students. It efficiently manages cognitive load by reducing cognitive loads which are harmful to learning (e.g. reducing split-attention, search, and redundant information, providing simultaneous complementary audio and visual information, providing worked examples and increasing spatial and temporal contiguity) and increasing beneficial cognitive loads by directing students’ attention in ways that assist their cognitive processing (e.g. providing scaffolding and colour coding, using completion problems with guidance fading) (R. C. Clark, Nguyen, & Sweller, 2006).
The teacher uses a Tablet PC connected to a data projector to display annotations in digital ink on a prepared electronic workbook. The workbook contains guided notes which are a structured skeleton of the essential information, diagrams, and sample problems for the course (Heward, 2003) and hyperlinks to digital resources such as Flash animations. The class interacts dynamically with the teacher and the learning materials to contribute to the lesson’s development as they annotate their own hard copy of the workbook.

The TWP was trialled in the researcher’s high school physics classes. Quantitative and qualitative data was collected and a mixed methods approach using causal-comparative methods was used to assess the effect of the pedagogy on students’ learning outcomes and students’ perceptions of the learning experience.

There is clear evidence that students learned physics better when the teacher taught using the TWP in comparison to teaching with traditional pedagogy. Students’ scores improved significantly (at the 5% level) in global scores, far transfer scores and in some near transfer tasks after instruction with the TWP. No such significant improvements (at the 5% level) were evident for traditional pedagogy.

The success of the TWP in improving far transfer scores contrasts with the failure of traditional pedagogy to produce any significant improvement (at the 5% level). This result is of critical importance to physics education since attaining far transfer is the major objective of physics courses (Mayer, 2004b). It appears that students developed a deeper, more meaningful understanding of physics concepts when the TWP was used. Students’ comments linked learning improvement to the TWP’s more efficient management of cognitive loads.

Students were very positive about the experience of learning with the TWP and the reasons they gave for their improved understanding and better engagement reflected the better management of cognitive load achieved by the TWP.

This research provides evidence that wherever cognitively complex subjects such as physics, chemistry, mathematics, engineering and computer science are to be learned at high school or lower university level, the TWP should be investigated as a potentially useful instructional approach to make students’ learning more effective.
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<td>British Educational Communications and Technology Agency</td>
</tr>
<tr>
<td>BOSSS</td>
<td>Board of Senior Secondary School Studies, Queensland</td>
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<tr>
<td>CLT</td>
<td>Cognitive Load Theory</td>
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<tr>
<td>CRP</td>
<td>Complex Reasoning Processes</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>K</td>
<td>Knowledge</td>
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<td>QSA</td>
<td>Queensland Studies Authority</td>
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<tr>
<td>SP</td>
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Chapter 1: 
Nature and purpose of the research

Thorndike (1910, p12) described school room life as

“a vast laboratory in which there are made thousands of experiments of the utmost interest.”

This research will investigate one such experiment.

1.1 Introduction

As a practicing teacher with twenty-five years of classroom experience, the researcher has long been committed to iterative processes of innovation and self-reflection with the aim of improving learning outcomes for students in her high school physics classes. This research is the result of a confluence of theory and opportunity to capitalise on the potential of technology to make possible what had previously been impossible (Hoadley, 2004). The focus of this research, as recommended by Fishman, Marx, Blumenfeld, Krajcik and Soloway (2004) is on a cognitively oriented technology innovation which is embedded in the regular curriculum and tightly integrated with everyday teaching and learning practices.

1.2 The purpose of the research

Substantial evidence exists that traditional pedagogy is not effective in teaching physics (Paas, 1992). The purpose of this research, therefore, is to use Cognitive Load Theory (CLT) to develop an improved way to teach physics, to trial the new pedagogy with high school physics classes, to collect and evaluate data to assess its success and finally to determine if the findings reflect or extend CLT. The Tablet Personal Computer (Tablet PC) (see Sections 1.7.1 and 2.3.2) was selected as the most promising technological aid for this endeavour. The hypothesised improved (or ‘smarter’) way to teach physics has been named the Tablet/Workbook Pedagogy (TWP).
The central research question which this research will address is “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy? If so, what is the basis for the improvement in learning theory?”

1.3 The research context

This research was conducted at an independent co-educational school in Queensland, Australia. The school has an approximate enrolment of 900 students from Kindergarten to Year 12, located on a single campus. It is affiliated with a traditional Christian church and predominantly attracts middle-class Anglo-Saxon families.

The researcher is physics teacher and Head of the Science Faculty at the research site. She is also the Chair of the Queensland Studies Authority (QSA) District Review Panel for Senior Physics.

The research participants were the members of the Year 11 and Year 12 Physics classes at the research site in 2007. All students were invited to participate with 37 students accepting including 28 boys and 9 girls. This represents 93% of the cohort.

1.4 The timeliness of the research

This research is timely in terms of two government priorities: the official concern about the decline in the number of physics students and the decision to invest heavily in computer technology for schools.

1.4.1 Crisis in physics education

Physics education is in crisis in Australia, in the United Kingdom (UK) and in the United States of America (USA) as the number of students studying physics at all levels has persistently declined for more than a decade. In the UK, the proportion of the age group taking A-level Physics dropped from 5.9% in 1990 to 3.9% in 2005 (Smithers & Robinson, 2006). A similar trend is also evident for related cognitively complex subjects such as mathematics, engineering and computer science. There are dire predictions of the consequences of this decline for industrialized societies as fewer and fewer technical innovators emerge from the western education systems (Smithers & Robinson, 2006).
Figure 1.1 illustrates this trend with data from the UK but the trend is also reflected in Australian physics student numbers at both high school and university levels. For example, the Australian Nuclear Science and Technology Organisation (ANSTO) (2005) reports that Australian school students who choose to study physics at Year 11 and 12 level has been declining since 1976 and has virtually halved since 1980. Critically, the number of qualified physics teachers available to teach high school physics has plummeted to the point where many schools do not have a qualified physics teacher on staff and those that do will find it increasingly difficult to replace them as they rapidly approach retirement age (Smithers & Robinson, 2006).

**Figure 1.1: Evidence of the declining number of physics students in the United Kingdom**
*(reproduced from Smithers and Robinson (2006), Chart 2.1)*

One reason why the number of students studying physics is declining is that physics is perceived to be an inherently difficult subject to study where maximum effort is required and the resulting grades may not always reflect the effort students have expended (Evans & Tuovinen, 2008; Prow, 2003). Many students view physics as just too hard (Osborne, 2005; Smithers & Robinson, 2006). Research currently in progress seeks to identify the factors that affect high school students’ perceptions of physics as a subject and as a possible career path (Evans & Tuovinen, 2008)
The goal of developing a better way to teach high school physics is to improve students’ academic success with physics and to improve their perceptions of physics as they become more engaged and motivated in physics classes. By assisting students to cope with the innate complexity of physics as a subject, the TWP may help to arrest the decline in numbers of students studying physics.

1.4.2 The ‘Education Revolution’

This research is also timely as government policy directs increased resources towards technology in schools. The current Australian government’s billion dollar ‘Education Revolution’ seeks to allow every Australian school student in Years 9 to 12 one-to-one access to a school computer (Australian Government, 2008). Is a one-one computer model the best model for technology delivery at schools or are there alternatives that better promote learning in specific contexts?

Many schools are investing heavily in interactive whiteboards (BECTA, 2003b) but is this the best way to deliver interactive digital pen technology?

Policymakers and educators need to know how technology can be most effectively used to improve student learning (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). If the TWP proves to be successful, then this research will suggest that the provision of a Tablet PC with a data projector provides a lower cost and more effective means of teaching physics than an interactive whiteboard and a much more effective tool than a laptop computer. It would also indicate that the ‘one laptop per child’ model may not be the most cost effective nor the most educationally sound model to assist students to learn physics.

Thus this research can inform government policy as it seeks to invest tax payers’ dollars wisely.

1.5 The significance and innovation of the research

This research is new and different from previous research in this field. The literature shows a clear gap in published research studies about the impact of digital pen technology generally and Tablet PCs specifically, on learning outcomes in education. Although there have been many pilot projects involving the use of Tablet PCs in all sectors of education, most report on the ways in which the Tablet PCs have been used
(Mathews & Khoie, 2007) and that students and staff like to learn and teach with Tablet PCs (e.g. Neal & Davidson (2008) in Australian schools, Sheehy et al. (2005) in British schools, and Amare (2006) in American schools).

Improved motivation levels may translate into improved learning outcomes (Pugh & Bergin, 2006) but only a few studies of limited sample size and in specific contexts have proven this rigorously with controlled experiments and statistical analyses of significance (Mathews & Khoie, 2007). Examples include Mathews & Khoie (2007) in university engineering, Mitchell (2007) in university mathematics, and Hojjatie, Hooshmand, Leader & Groszos (2008) in university geology and biology courses. No studies have clearly related theory-based reasons for using Tablet PCs in a specific learning context to evidence of improved learning outcomes. This study aims to provide one such instance that may be cautiously generalised at least to other similar technical subjects and similar age group students.

1.6 The outcomes that are expected from this research

This research will quantify the effect on learning outcomes of the use of digital ink enhanced pedagogy in Australian high school physics classes. It will assess whether this pedagogy provides an affordable way for teachers to effectively embed Tablet PC technology into the physics curriculum allowing students to develop a deeper, more meaningful understanding of physics concepts than has been possible with traditional pedagogy.

CLT principles will be embedded into the design of the new pedagogy so that the potential educational affordances of tablet technology can best be exploited. The research will determine whether links exist between improvements in physics students’ understanding and/or engagement when the new pedagogy is employed and CLT principles. If such links exist, CLT will be reinforced. If not, the research may suggest revisions or extensions to theory which may require further study.

1.7 The Tablet/Workbook Pedagogy

The TWP refers to a teacher-centred model of Tablet PC use in education. A single Tablet PC is used by the teacher to present lessons and its screen is visible to students via a data projector. Students do not have access to their own Tablet PCs. Apart from
the Tablet PC, the other essential element of the TWP is the workbook which contains a set of guided notes (a highly structured but incomplete skeleton of the lesson notes) (Heward, 2003) along with hyperlinks to other digital resources. Briefly, the teacher interacts dynamically with the class to develop the lesson as students view the digital resources. As the teacher digitally annotates the guided notes, students annotate their individual printed copy of the workbook (see Section 1.7.3 for more detail).

1.7.1 The Tablet PC

The Tablet PC is a mobile personal computer which features a digitizer screen and allows the user to interact with software using a digitizer pen (see Figure 1.2). The teacher can use the digital pen to annotate electronic documents by ‘writing’ directly onto the screen. The Tablet PC offers the teacher both the power of a traditional laptop computer and the flexibility of an interactive whiteboard but with the distinctive advantage of always being able to face the class or even to move around the class while teaching.

Figure 1.2: Tablet PC and digitizer pen
(Image reproduced from http://onlyvmo.com/VMOHom1.jpg)

1.7.2 The workbook

The teacher prepares a digital copy of a workbook containing the guided notes. This serves as the backbone for course delivery. The guided notes contain background text and diagrams for later highlighting or annotation. What is not written in the skeleton
notes is just as important as what is written. The ‘gaps’ must be strategically placed and sized to allow the annotation of key terms, concepts, diagrams and worked examples during class to promote students’ understanding. Figure 1.3 shows an example of the guided notes on a workbook page before and after annotation.
5. Electromagnetic Forces
5.1 The Magnetic Force on a Current Carrying Wire

Demo and animation: [http://www.walter-fendt.de/ph14e/lorentzforce.htm](http://www.walter-fendt.de/ph14e/lorentzforce.htm)

5.1.1 Direction of Magnetic Force

Examples: What is the direction of the magnetic force in the current carrying wires?

![Diagram of magnetic force orientation](image)

View from above:

- Right Hand Rule
- Thumb points into the page
- Fingers point along the current
- Palm faces the magnetic field

3D Codes:
- Out of Page
- Into Page
- Like an arrow

Examples: What is the direction of the magnetic force in the current carrying wires?
1.7.3 The pedagogy

The teacher displays a digital copy of the workbook through a Tablet PC connected to a data projector while the students have a printed copy of the workbook. The teacher teaches dynamically, interacting with students and annotating the guided notes in the electronic workbook. The students mirror the teacher’s annotations in their printed workbooks. Students must engage in the lesson to interact with the teacher as the lesson notes are developed. They must also attend to the lesson to annotate their workbooks. The teacher provides a complementary simultaneous audio commentary to the visuals displayed through the Tablet PC.

Using the Tablet PC offers the advantage of access to a large range of digital resources including: a full palette of colours, markers and highlighters; Internet access (e.g. to images, videos and information and to Flash and Java animations of physics concepts); and access to subject specific software (e.g. TI Interactive graphics calculator software, (Texas Instruments, 2008); LoggerPro data and video analysis software, (Vernier Software and Technology, 2009); and ClickView Digital Library, (ClickView Pty. Ltd., 2009)).

The solutions to example problems are annotated by the teacher with dynamic input from the students during lessons. This is done in much the same way as may have been done traditionally on a whiteboard except that the teacher can easily display the question (including complex diagrams) to the class and the teacher is facing the students as he/she annotates the workbook example on the Tablet PC. This has three major advantages. The first is that the teacher and students have a shared representation of the question information. Secondly, the teacher does not obscure the students’ view of the steps in the solution process so students can see and process the information in real time. Finally, much more direct eye contact is possible between the teacher (who is always facing the class) and the students reducing the incidence of off-task behaviour or disengagement. The teacher determines the level of scaffolding and prompting required for each example on the basis of feedback from the students.

The workbook includes hyperlinks to digital resources and frequent access to digital resources is a feature of this pedagogy. Static images from strategic points in dynamic
animations are included in the workbook. These provide a valuable reminder to students of the moving images viewed in class. They can also provide a diagram over which explanatory notes can be annotated during class. The hyperlinks to the digital resources accessed during class are also included on the e-learning portal (the school’s online content management system) to allow students to easily review the dynamic content of the lesson at a later date.

A course outline, a course concept map and a course summary are included in the workbook along with sets of conventional practice problems for homework and revision. Fully worked solutions to all homework and revision problems are available online for students. Students are free to elect to study with the worked examples or to attempt the conventional problems unassisted. Novices are encouraged to select to study from the worked examples initially but to progress to conventional problem solving as their expertise increases.

The teacher can save the annotated version of the electronic workbook after the lesson and make it available to students in electronic or print form. This is a valuable resource because students who miss a lesson can readily access this content or it can be displayed for review in class. Students with disabilities that preclude them from writing rapidly can also benefit from this resource.

1.8 Research limitations

This research was conducted in the context of high school physics classes at a coeducational school in Queensland. The number of research participants was relatively small (N=37) and very small for some sub-groups, particularly the three female subgroups (N=3, 5, 9). This will make it very difficult to detect statistically significant trends in the girls’ data. Only statistically significant results (at the 5% level) will be reported and it is recommended that further research be done using larger groups.

The research reports specifically about learning in high school physics but, because the research is based in generally applicable theory, that theory can be used to suggest that the findings should be applicable to other contexts where cognitively complex subjects must be learned by relative novices. These include, for example, chemistry, mathematics, engineering and computer science at high school and university levels.
1.9 Statement of hypotheses

1.9.1 The research questions

The central research question to be addressed by this research is:

“Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy? If so, what is the basis for the improvement in learning theory?”

Secondary research questions include:

“Are there any differences in learning outcomes on the basis of the type of assessment (i.e. near transfer tasks\(^1\) or far transfer tasks\(^2\))? If so, what is the basis in theory?”

“Are there any gender-based differences in learning outcomes? If so, what is the basis in theory?”

“Do participants’ comments about learning with the TWP suggest links back to learning theory?”

“Can these findings be generalised to other educational settings?”

1.9.2 The research hypotheses

The research questions have been formulated into hypotheses to be tested:

**Hypothesis 1:** Learning with the TWP will lead to an improvement in all students’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) relative to their scores when they learned with traditional pedagogy.

**Hypothesis 2:** Boys’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) will show greater improvements after first learning with traditional pedagogy and then with the TWP than the girls’ physics assessment scores do.

**Hypothesis 3:** The students’ experiences of learning with the TWP, as expressed in their qualitative comments, will exhibit improved cognitive conditions of learning.

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\(^1\) Near transfer tasks (also known as recurrent tasks) require learners to demonstrate their new skills in a similar context that they were presented in the instruction (R. C. Clark, et al., p 348)

\(^2\) Far transfer tasks (also known as nonrecurrent tasks) require learners to apply the principles they have learned in diverse contexts (R. C. Clark, et al., p 346)
1.10 Summary

This research is timely as governments seek to reverse the downward trend in the numbers of students studying physics (Australian Nuclear Science and Technology Organisation (ANSTO), 2005) and also to invest heavily in educational technology as part of an ‘Education Revolution’ (Australian Government, 2008). It can inform government policy makers, educational leaders and teachers about improved educational practice in the use of technology to improve learning in high school physics classes.

Unlike many studies involving similar educational applications of Tablet PC technology, this research seeks to develop a firm theoretical foundation for the pedagogy in terms of CLT, to measure statistically significant changes in learning outcomes and to explain the pattern of changes observed in terms of CLT.

Although the research was conducted in a high school physics context, its basis in generally applicable theory should allow its findings to be generalized to other similar subjects such as chemistry, mathematics, engineering and computer science at both high school and university levels.
Chapter 2:
Literature Review

2.1 Introduction

Paas & van Merriënboer (1994a) describe physics as a complex cognitive domain which, for most students, is a difficult subject to learn; but what makes physics so difficult and what instructional techniques can assist students to cope with the complexity of physics? How can the use of technology enhance these instructional techniques and which are the best technologies for this purpose?

This literature review will seek to uncover existing answers to these questions and to identify gaps in understanding in this field which may then guide this research.

CLT has been identified as an appropriate framework for understanding the process of learning in physics because it offers clear instructional design principles that have been shown empirically to provide strong benefits for learners (Cooper, 1998). Cooper suggests that the learning benefits include reduced study times and better performance (defined as reduced completion times and fewer errors) on both near and far transfer tasks. Achieving transfer is the essence of the science of instruction and the major goal of education (Mayer, 2004b). This is certainly true in high school physics classes where success, particularly in far transfer tasks, indicates that meaningful learning has occurred.

The Tablet PC has been identified as a very promising technological aid currently available to support the instructional design techniques suggested by CLT for learning physics. Other research projects have used Tablet PCs for high school and university physics classes and for similarly cognitively complex subjects such as mathematics, engineering and computer science. This literature review will provide an overview of these studies and will determine where gaps exist in the knowledge bank which this research may address. In particular, literature relating the use of Tablet PCs in high
school physics education to a theoretical framework with empirical evaluation of the effect on learning outcomes will be sought.

2.2  Cognitive Load Theory

2.2.1  Introduction

CLT provides a set of instructional principles based on the instructional implications of the interaction between information structures and cognitive architecture (Paas, Renkl, & Sweller, 2004; Rikers, van Gerven, & Schmidt, 2004). It is based on experimental research by instructional scientists extending over several decades (R. C. Clark, et al., 2006).

Wittrock (1977) describes learning as a process of changing from experience which results in the relatively permanent changes in understanding, attitudes, knowledge, information, abilities and skills. Sweller (1988) suggested that learning occurs most efficiently when learning conditions are aligned with human cognitive architecture.

Before the detailed principles of CLT can be discussed, a basic understanding of human cognitive architecture and the learning process as envisaged in CLT must be gained. What structures and processes exist in the human brain to allow this information processing to occur largely subconsciously for most people? What are the capabilities and limitations of human cognitive architecture that both facilitate and limit learning?

2.2.2  Human Cognitive Architecture

Learning from experience involves the processing, storage and retrieval of knowledge. The concept of ‘memory’ is the key to the whole learning process, but what is memory, how does it work, what are its limitations and how does it fit within human cognitive architecture?

Figure 2.1 summarises the essential features of human cognitive architecture. It shows a dual channel (phonetic and visual) short term working memory and a long-term memory which uses mental models (schemas) to store, link and catalogue information.
2.2.2.1 Short-term memory

The concept of limited capacity in short-term memory stemmed from Miller who, in 1956, proposed that there were limitations in the human ability to receive, process and remember information. Most people can retain between five and nine pieces of simple information (seven plus or minus two) in immediate or short-term memory (G. Miller, 1956). Peterson and Peterson (1959) also suggested a temporal limitation in that memories in the short-term store fade within a few seconds.

Miller (1956) suggested that this limitation could be managed by chunking or successively sequencing information. Chunks may contain several bits of information in a meaningful unit but each chunk counts as only one of the allowed pieces of information in short-term memory, vastly extending the information processing ability of the short-term memory (Gobet, et al., 2001; G. Miller, 1956). For example, seeing the single word ‘chunk’ rather than the five separate letters ‘c’, ‘h’, ‘u’, ‘n’, ‘k’ vastly reduces the processing load on short-term memory when reading this paragraph (R. C. Clark, et al., 2006).
Further research indicated that for complex information with interacting elements, only two to four (three plus or minus one) chunks can be simultaneously handled by the short-term memory (Cowan, 2001) as the interactions themselves occupy working memory resources.

### 2.2.2.2 Working Memory

After further research, Baddeley and Hitch (1974) developed their three-component model for short-term memory which they termed *working memory* to indicate that it is a system which concurrently stores and actively manipulates information. This model included Paivio’s (2006) concept of dual coding in which the human mind processes visual and verbal information separately in two distinct channels. Working memory is vitally important as it enables humans to accomplish complex cognitive activities like reasoning, learning and comprehending language (Baddeley, 1992).

The three components of working memory are thought to include: the central executive control system which is related to our sense of conscious awareness (Baddeley, 1992); the phonological loop (which processes sound and language information); and the visuospatial sketchpad (which processes visual and spatial information) (Baddeley, 2003). The latter two components are storage systems under the control of the central executive and all three components are limited in capacity (see Figure 2.2).

**Figure 2.2: The three-component model of working memory**

(Reproduced from Baddeley, 2003 Figure 1, p 830)

![Three-component model of working memory](image)

### 2.2.2.3 Long-term Memory

Unlike working memory which is limited in capacity, long-term memory seems to have essentially unlimited capacity (Landauer, 1986). To be useful, this mass of stored
information must be indexed and readily retrievable for later use in the active processing of a new task in working memory.

How is such a vast quantity of information archived and tagged in long-term memory in order to be instantly accessible in a wide variety of different processing contexts? The answer lies in the way information is linked into ‘mental webs’ called schemas.

### 2.2.2.4 Schemas

Long-term memory is not a multi-sensory recording device that accurately records an event in all its original detail nor is it just a passive receptacle for the storage of all the random facts collected over a lifetime. Rather, information is actively restructured into representations and archived in long-term memory in the form of schemas (Sweller & Chandler, 1991). Anderson, Spiro, & Anderson (1978) provided experimental evidence for the existence of schemas but noted that the concept was not new as a similar concept had been suggested two centuries earlier by Kant in his *Critique of Pure Reason* (*Kritik der reinen Vernunft*) first published in 1781 and later reprinted in English (Kant, 1963). Other authors have also suggested similar concepts with various labels such as Bartlett’s ‘schemata’ (1932), Ausubel’s ‘ideational scaffolding’ (1968), Minsky’s ‘frames’ (1975) and Schank and Abelson’s ‘scripts’ (1977).

A schema binds multiple elements of information into a single element (Pawley, Ayres, Cooper, & Sweller, 2005). It summarises the common elements of many related things or situations and gives a generic characterisation of the knowledge (R. C. Anderson, et al., 1978). Thus, schemas provide scaffolds or templates within which new information can be recognised as meaningful in the light of previous experience, and catalogued for efficient recall at a later time (Valcke, 2002). Paas and Kalyuga (2005) likened schemas to multi-dimensional webs of interconnected nodes of information.

Schema formation and retrieval can occur consciously but it is often unconscious and automatic. As new information is processed through working memory, a new schema can be established or existing schemas can be embellished or linked to accommodate the new information (van Merriënboer, Kirschner, & Kester, 2003).

Because schemas are organised meaningfully, categorising information on the basis of how it will be used (Chi, Glaser, & Rees, 1982), and because each schema is cross-linked to many other schemas in a hierarchical network, vast banks of information can
be readily retrieved (R. C. Anderson, et al., 1978; Pawley, et al., 2005). This concept is consistent with Ausubel’s suggestion that new information is best learned and retained when it can be anchored by existing knowledge (Ausubel, 1968).

In summary then, schema construction serves the dual purposes of storing and organizing information in long-term memory and reducing working memory load (Sweller, van Merriënboer, & Paas, 1998). Successful schema development and automation through practice is the goal of instruction, the characteristic of successful learning and the distinguishing feature that sets experts apart from novices (Ericsson, 2006b).

2.2.2.5 Interactions between long-term memory and working memory

The concept of schemas as information storage networks provides a link between the information processing limitations of working memory and the almost limitless expanse of information in long-term memory. It also explains the mechanism by which the apparently low-power processing capability of working memory can be used efficiently by experts to achieve amazing feats of complex processing (Sweller & Chandler, 1994; Sweller, et al., 1998).

The basic interactions between attention, working memory and long-term memory are represented in Figure 2.1. As attention is paid to audio and visual sensory information, each is processed separately through the working memory via the dual phonetic and visual channels for ultimate storage in schemas in long-term memory. Rehearsal facilitates the coding of information into long-term memory schemas where it is available for later retrieval (R. C. Clark, et al., 2006).

2.2.2.5.1 Automaticity

Repeated rehearsal or repetitive practice of a skill or process can result in automation of the associated schema in long-term memory through the processes of knowledge compilation and strengthening (J. R. Anderson, 1993; van Merriënboer & Kester, 2005). Automation occurs when the task can be performed with little or no conscious awareness or involvement of the working memory (Schneider & Shiffrin, 1977).

Quite complex tasks can be automated when practiced sufficiently (Kotovsky, Hayes, & Simon, 1985). For example, most experienced drivers can easily combine two complex
activities like having a conversation with a passenger and driving a car because the schemas for both tasks are automated. Learner drivers, on the other hand, who have not yet practiced driving to the point of schema automation, find it mentally taxing to converse whilst driving.

Automation, then, is a means of bypassing the limitations of working memory capacity (Sweller, et al., 1998). Unfortunately the path to automaticity is a long and difficult one with hundreds of deliberate repetitions required (Ericsson, 2005, 2006a).

2.2.2.5.2 The relationship between memory and learning

The acquisition of knowledge requires the learner’s active interpretation of new information within the context of his or her prior knowledge and experience (J. R. Anderson, Reder, & Simon, 1998). The learner is an active participant in the sense that he or she must exercise the working memory’s ability to orchestrate learning. The working memory must attend to the stimulus material, discern what is useful and rehearse it to avoid it fading. Next it must integrate visuospatial and audio stimuli with prior schemas retrieved from long-term memory and finally store the elaborated schemas away in long-term memory whilst embedding links to other relevant schemas (Sweller, et al., 1998).

2.2.2.5.3 Meaningful learning and transfer

Effective learning is evidenced by a student’s ability to understand and apply knowledge rather than by an ability to regurgitate isolated fragments of information (facts) (Bransford, Brown, & Cocking, 1999). Such meaningful learning (as opposed to rote learning) is facilitated by complex, linked schema acquisition.

The ability to transfer knowledge is an essential element of meaningful learning. The manner in which new schemas are formed will affect the transferability of the learned knowledge. To transfer knowledge (i.e. to activate appropriate prior knowledge in a new context) the relevant schema must be readily identified from a vast number of other archived schemas. Meaningful learning embeds cues in schemas and creates links between related schemas. Schemas incorporating relevant cues and supporting links have a greater chance of achieving transferability (R. C. Clark, et al., 2006).
Sensory cues, for instance, may be incorporated into a schema as it is learned and a similar sensory stimulus in another situation may trigger retrieval of that schema (R. C. Clark, et al., 2006). A particular song, for example, may trigger memories of a happy occasion... “They’re playing our song!”

2.2.2.6 Capabilities and limitations of human cognitive architecture

Human cognitive architecture has at its core a very low power, limited processor but with its peripheral storage mechanisms in place is capable of quite astounding feats of complex cognition. A limited working memory deals with all conscious activities and operates in conjunction with an effectively unlimited long-term memory which stores schemas of varying degrees of complexity and automaticity. Schemas incorporate multiple elements of complex information into a single chunk which uses only one unit of working memory’s limited resources. Automated schemas allow familiar tasks to be performed readily without conscious reference to working memory. By freeing working memory capacity, schemas permit higher levels of performance on both familiar and unfamiliar tasks that otherwise might overload working memory. Intellectual skill and expert performance is the result of the construction and storage in long-term memory of large numbers of increasingly sophisticated schemas with high degrees of automaticity (Sweller, et al., 1998).

An understanding of the structure and operation of human cognitive architecture provides insights into the mechanisms by which Wittrock’s simple definition of learning as a change resulting from experience may be effected. Learning may now be seen as an active and intentional cognitive process resulting in schema acquisition, elaboration, linkage, and automation which enables efficient schema retrieval for use in future processing requirements (R. C. Clark, et al., 2006; Sweller & Chandler, 1994).

2.2.3 Cognitive load

2.2.3.1 Introduction

The intrinsic limitation in working memory capacity means that no more than the allowed seven plus or minus two chunks of information can be held in working memory at any instant. This limitation is even more severe when the working memory is actively processing information during a learning episode. Then, only two to four
chunks can be simultaneously organised, contrasted or compared (Cowan, 2001). This is because the actual interactions between the chunks or elements also require working memory resources (Sweller, et al., 1998).

Cognitive load is a measure of the demands placed on working memory resources. Cognitive overload results when these demands exceed the working memory’s limited capacity, thus impairing learning. Cognitive load arises from multiple sources and the total cognitive load experienced is the sum of the effects from the individual sources (Paas & Kester, 2006; Sweller, et al., 1998). Some forms of cognitive load promote learning while others simply waste precious working memory resources on unproductive activities. The various forms of cognitive load must be balanced carefully to avoid cognitive overload and to provide optimal conditions for schema construction and hence learning to occur (R. C. Clark, et al., 2006).

Three main types of cognitive load have been identified. These are: intrinsic cognitive load which is determined by the nature of the instructional material; extraneous cognitive load which is related to the manner of instruction, particularly poorly designed instruction (Sweller, 1994); and germane cognitive load which is related to the intentional mental effort required to construct schemas and lock in the learning (Sweller, et al., 1998). These will now be discussed along with methods for managing each type of cognitive load.

### 2.2.3.2 Intrinsic cognitive load and element interactivity

The intrinsic nature of the learning material studied will always produce a load on working memory resources. This is known as *intrinsic cognitive load* and varies widely according to the innate complexity of the instructional content. Complexity is determined by the extent to which various elements interact (Sweller, 2004). An element, in this context, refers to any chunk of information (often a schema) that a learner is able to process as a single unit in working memory (Pollock, Chandler, & Sweller, 2002).

Complex curriculum materials have high element interactivity and require numerous elements to be processed or coordinated simultaneously in working memory for meaningful learning to occur. For such materials, the demand on working memory resources is high and cognitive overload is a real danger (Sweller, 1994). This is
typically the case for physics materials as well as for mathematics, chemistry, engineering and computer science (Sweller, et al., 1998).

For less complex materials, the elements do not interact to such an extent, so each element can be understood in isolation without reference to the others. Consequently, the individual elements can be processed serially through working memory, keeping cognitive load at a manageable level (Pollock, et al., 2002).

For example, when studying electrical circuits in physics, learning the symbols for the electric circuit components is a simple, low element interactivity task. Each symbol can be learned and its meaning understood in isolation from all the other symbols which must be learned. Demand on working memory is low and cognitive overload is unlikely.

However, understanding how these circuit components behave when connected into an electrical circuit is a much more complex task requiring the simultaneous coordination of many interacting elements which must be processed together in working memory. Altering any single circuit element will affect the behaviour of all the other circuit elements. If calculations must also be performed to quantify the circuit’s behaviour, even more elements must be processed simultaneously and cognitive overload is a real danger.

Intrinsic cognitive load, while primarily a property of the instructional material, must also be considered in relation to the expertise level of the learner (Sweller & Chandler, 1994; Sweller, et al., 1998). For a novice, the multiple elements in a complex task may have to be processed in working memory as a large number of interacting elements, resulting in heavy intrinsic cognitive load. For an expert with many domain-relevant schemas stored in long-term memory, the complex task and its multiple interacting elements may already be incorporated into one schema or a small number of linked schemas that either act as a single element or a small number of elements in working memory. Consequently, a task with low intrinsic cognitive load for an expert may cause a novice excessive intrinsic cognitive load (Paas & Kester, 2006; Pollock, et al., 2002; Rikers, et al., 2004).
2.2.3.3 Extrinsic cognitive load

Additional to the intrinsic cognitive load inherent in learning materials, are the extrinsic cognitive loads which result from the mode of presentation of the learning materials and the learning activities (Paas & Kester, 2006). These can be detrimental to schema acquisition (extraneous cognitive load) or beneficial to schema acquisition (germane cognitive load) (Sweller, et al., 1998).

2.2.3.3.1 Extraneous cognitive load

Where the extrinsic cognitive load imposed is ineffective in fostering learning, i.e. it interferes with schema construction or automation (Sweller, et al., 1998), it is termed extraneous cognitive load (Sweller, 1994). This arises primarily from poorly designed instructional materials and wastes limited working memory capacity unnecessarily (R. C. Clark, et al., 2006). It is, however, a cognitive load that instructors can reduce through careful design.

For example, in a textbook, if a diagram is located on one page and the associated text explaining the diagram is placed on a separate page, extraneous cognitive load results. Both the diagrammatic and the textual information are necessary for understanding, so students must hold the visual information in working memory while locating and processing the written information. These additional demands on working memory do not improve learning and may hinder it if cognitive overload occurs before meaningful learning has been achieved.

2.2.3.3.2 Germane cognitive load

If the cognitive load imposed by instructional techniques is effective in fostering learning, i.e. if it is directly relevant to schema construction or automation, it is termed germane cognitive load (Paas & van Merriënboer, 1994b). This concept arose through studies on variability of practice that found, paradoxically, that increasing cognitive load in some circumstances enhanced rather than hindered understanding (or transfer). This effect came to be known as the Transfer Paradox (Sweller, et al., 1998).

2.2.3.4 Cognitive overload

The three types of cognitive load, Intrinsic, extraneous and germane, must be added together to find the total cognitive load imposed by a learning task (Sweller, et al.,
1998). Each of these sources of cognitive load impacts on the scarce working memory resources available and together, they may approach the maximum cognitive load capacity of working memory for a learner of a given expertise level. This concept is illustrated in Figure 2.3.

**Figure 2.3: Total cognitive load is the sum of the intrinsic, extraneous and germane cognitive loads**  
(adapted from Paas & Kalyuga (2005, p6)

Cognitive overload occurs when working memory is overwhelmed by the processing demands placed on it and effective learning cannot result. Consequently, smaller amounts of processed/coded information or poorly structured information will be stored as schemas in long-term memory (Sweller, 1994).

Wegner (1997) suggested that a cognitive default in working memory occurs under conditions of cognitive overload. This can be manifested as lapses in attention (experienced as ‘wandering minds’ or ‘day dreaming’) or inappropriate behaviours. Wegner’s evidence suggested that such overload defaults are unconscious, automated and uninterruptible (R. E. Clark & Elen, 2006; Wegner, 1997).

### 2.2.4 Evidence for Cognitive Load Theory

It is important to note that CLT is evidence-based in that it is grounded in controlled experimental research studies (Sweller & Chandler, 1991). Each of the instructional principles generated by CLT has been tested using a wide range of technical materials...
in a range of curriculum areas such as mathematics (algebra, geometry and trigonometry), physics (optics and kinematics), biology, electrical engineering and computer programming in both laboratory and real-world settings (Sweller & Chandler, 1991). Such rigorous empirical demonstration is a requirement for the acceptance of new elements to CLT and Sweller argues that no claims should be accepted on the basis of simple assertion alone (Sweller, 2006b; Sweller & Chandler, 1991). Indeed, a number of the pivotal findings of CLT, for example the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003) resulted from the ‘failure’ of controlled experiments and the resulting investigations into the reasons for the unexpected results (Sweller, 2006b).

This strict insistence that all recommendations arising from CLT be empirically tested using controlled experiments represents a major difference between CLT and some more fashionable educational theories such as discovery learning (Bruner, 1963) whose recommendations are often based on process models alone without experimental testing in instructional situations (van Merriënboer & Sweller, 2005).

Some instructional techniques based on cognitive load principles are counter-intuitive and some are at odds with other educational theories (Cooper, 1998; van Merriënboer & Sweller, 2005). For example, traditional practice has students solve many conventional problems using means-end analysis on the basis that ‘practice makes perfect’. In contrast, CLT recommends that students study worked examples, then completion problems and that conventional practice problems should only be introduced gradually as support is faded (Cooper, 1998). Cooper goes on to suggest that this is a strength of CLT.

An example of contradictory recommendations between CLT and other learning theories is provided by discovery learning. Proponents of discovery learning argue that meaningful learning can only occur when students discover meaning for themselves in real world learning contexts (Bruner, 1963). CLT argues that learning will be limited and inefficient, especially for novices, in such an unstructured learning environment (Mayer, 2004a). A valid resolution of these contradictory arguments is possible with empirical testing under controlled experimental conditions. Such experiments have confirmed the predictions of CLT (e.g. Tuovinen, 1999; Tuovinen and Sweller, 1999).
A theory is strengthened if it is able to generate predictions that are subsequently empirically confirmed. CLT was used to predict that, when learning to use complex computer applications, learning may be enhanced by using just the computer training manual without access to the computer. The logic is that, given the high intrinsic cognitive load of the material to be learned, the extraneous cognitive load caused by splitting the learner’s attention between the learning materials and the computer screen will cause cognitive overload. Experiments to test this hypothesis confirmed the CLT prediction by showing significant gains in learning efficiency when the manuals but not the computers was used initially (Chandler & Sweller, 1996).

2.2.5 Cognitive Load Theory and instructional design principles

2.2.5.1 Introduction

CLT can be used to assess instructional techniques or to design instructional techniques which should be effective in achieving instructional goals (R. C. Clark, et al., 2006). In physics, the goal of instruction is meaningful learning i.e. far transfer of concepts (Mayer, 2004b). Such learning aims to integrate knowledge, skills and attitudes so that what is learned can be transferred to daily life or work settings. A number of instructional techniques have arisen which claim to achieve such far transfer of concepts.

For example, rich learning tasks (Education Queensland, 2001) and authentic learning (Herrington & Oliver, 2000) are stressed by recent instructional theories but CLT suggests that the complexity of these situated learning tasks may overwhelm the limited capacity of working memory to the detriment of learning, particularly for novices. If meaningful learning is to occur, instructional techniques designed for rich learning tasks must work within the cognitive processing limitations of working memory, yet often little support is provided for learners (Sweller & Chandler, 1994; van Merriënboer, et al., 2003).

CLT suggests that one general instructional principle is clear: when learning complex material, evidence suggests that higher levels of learner support is best for most students most of the time (R. E. Clark & Elen, 2006). What form should such support take and what implications for instructional design arise from CLT? These questions are considered in the following sections.
2.2.5.2 Efficient management of cognitive load

CLT suggests that the major goal of instructional design is to effectively manage the cognitive load experienced by a learner (R. C. Clark, et al., 2006). This involves manipulating intrinsic, extraneous and germane cognitive loads effectively to stay within working memory limitations and best promote schema acquisition and automation (Sweller, et al., 1998). Optimal levels of each type of cognitive load will vary depending on the expertise of the learner and the nature of the learning materials (Paas, et al., 2004).

The relationship between the three types of cognitive load, instructional design and learning is represented in Figure 2.4. A number of regions on the graph are identified and are described below:

**Figure 2.4: Cognitive Load and instructional design.**

The red colour indicates a danger that cognitive overload may occur. The yellow colour indicates a manageable level of cognitive load except perhaps for novices. The green colour indicates that cognitive load levels are low and should be manageable for all learners.

When less complex, low element interactivity materials are the focus of instruction, intrinsic cognitive load levels are low. In this case, the standard of the instructional materials used is not critical. Both good instructional materials with low extrinsic cognitive load (green region 1) and poorly designed instructional materials which cause
higher extraneous cognitive load (yellow region 2), can result in meaningful learning as a valuable amount of germane cognitive load can be still imposed to promote learning without reaching cognitive overload.

Meaningful learning is more difficult to promote when complex, high element interactivity materials are the focus of instruction as intrinsic cognitive load levels are high. In this case the standard of the instructional materials and techniques used becomes critical. If the instructional materials are well designed and impose a small extraneous cognitive load (yellow region 3), meaningful learning can result because a valuable amount of germane cognitive load can be still imposed to promote learning without reaching cognitive overload. However, if poorly designed instructional techniques are used, the high extraneous cognitive load imposed in this situation (red region 4) results in a real danger that cognitive overload will severely limit learning. At best this situation provides minimal opportunities to impose germane cognitive and learning will be limited.

In summary, there needs to be careful management of cognitive load (Paas, et al., 2004). A balance must be found between the intrinsic, extraneous and germane cognitive loads. The following sections will discuss methods to manage intrinsic cognitive load (see Section 2.2.5.3), extraneous cognitive load (see Section 2.2.5.4) and germane cognitive load (see Section 2.2.5.5) to allow the development of effective instructional designs.

Generally, it is desirable to decrease unproductive extraneous cognitive load (Sweller, 2006b; Sweller, et al., 1998) and to increase productive germane cognitive load (Sweller, et al., 1998; van Merriënboer, Schuurman, de Croock, & Paas, 2002) for a given level of intrinsic cognitive load. Intrinsic cognitive load should also be reduced but within limits as it adds a level of challenge to a task which may help to motivate students (Doubé, 2007).

2.2.5.3 Ways to reduce intrinsic cognitive load

Intrinsic cognitive load was considered as a property of the material to be studied and beyond the control of the instructor (Sweller & Chandler, 1994; Sweller, et al., 1998). This gave instructional designers no option but to present all of the interacting elements of the complex learning materials simultaneously despite the fact that this
frequently resulted in cognitive overload and severely limited learning (Pollock, et al., 2002).

Pollock, et al. (2002) suggested that there may be instructional methods that will effectively reduce the intrinsic cognitive load experienced by learners. By controlling the pace at which learners are required to process elements of complex materials, cognitive overload may be avoided. Several methods have been suggested which fall into two broad categories: simple to complex whole task methods; and part-task methods. Evidence suggests that simple to complex whole task methods provide better educational outcomes than part-task methods and much better outcomes than simply teaching the whole task at once (R. C. Clark, et al., 2006).

An example of a simple to complex whole task method is the four-component instructional design model (4C/ID model) (van Merriënboer, Clark, & de Croock, 2002) in which additional concepts and facts are introduced just-in-time to support the teaching of increasingly complex processes. One part-task method is the isolated interacting elements effect (Pollock, et al., 2002). In this method, intrinsic cognitive load is lowered by initially reducing the number of interacting elements at the expense of full understanding. The omitted elements can be reintroduced later when the essential elements have been learned.

The use of advance organisers (Ausubel, 1968) in text-based media or their electronic cousins, sitemaps, in multimedia environments can effectively augment learning with complex instructional materials (Mayer, 1979). Mayer suggested that they work by providing cues to existing schemas in memory in which new information may be embedded. Hence, they may be considered as a means of managing intrinsic cognitive load.

Complexity in learning materials can provide a motivating level of challenge for learners, depending on their level of expertise (Doubé, 2007). It is up to the instructional designer to determine whether the intrinsic cognitive load present is at a manageable level to motivate the learners concerned or whether it is excessive and should be reduced.
2.2.5.4 Ways to reduce extraneous cognitive load

The element interactivity effect (Sweller, 1994) suggests that reducing extraneous cognitive load will be beneficial for learning only in situations of high intrinsic cognitive load when many interacting elements must be processed simultaneously for meaningful learning to occur (Sweller, 2006b). However, numerous studies have shown that when the material to be learned has low intrinsic cognitive load, the benefits of reducing extraneous cognitive load disappear (Carlson, Chandler, & Sweller, 2003; Chandler & Sweller, 1996; Marcus, Cooper, & Sweller, 1996; Sweller & Chandler, 1994; Tindall-Ford, Chandler, & Sweller, 1997). In these situations, element interactivity is low and learning can occur with only a small proportion of working memory capacity allocated to the learning task. Surplus working memory capacity can be allocated to dealing with the extraneous cognitive loads imposed by poorly designed instructional materials without jeopardising learning (Sweller, 2006b; Sweller & Chandler, 1994).

Several ways to reduce extraneous cognitive load will be discussed in the following sections. These include the worked examples effect, the split-attention effect, the modality effect and the redundancy effect.

2.2.5.4.1 The worked examples effect

Worked examples are sample problems that include step-by-step solutions. The worked examples effect occurs when better learning is achieved if worked examples are presented to students rather than having students solve conventional practice problems (Sweller & Cooper, 1985). Having students study worked examples is also superior to directly teaching abstract principles at least for novices (Gerjets, Scheiter, & Catrambone, 2004; Zhu & Simon, 1987). This is particularly so in well-structured domains such as mathematics, physics and computer programming (Renkl, Atkinson, & Grosse, 2004).

The cognitive processes employed in conventional problem solving practice do not promote schema acquisition (Sweller, 1988). Studying worked examples focuses the learner’s attention on information that is relevant to schema construction (Sweller & Cooper, 1985) rather than on the inefficient search processes of conventional problem solving using ‘means-end analysis’ (Sweller, 1994). Consequently, the use of worked
examples reduces extraneous cognitive load and increases germane cognitive load, both of which are beneficial to schema acquisition.

While learning is enhanced by the use of worked examples, a lack of motivation can develop leading to students being unwilling to invest the mental effort necessary to impose the germane cognitive load required for understanding (Sweller, et al., 1998). One solution is to use completion problems which are partially completed worked solutions. This option is discussed in Section 2.2.5.5.1.

As expertise develops, the stereotyped solution patterns offered in the worked solutions and completion problems may stifle the generation of new, creative solutions (Renkl & Atkinson, 2003) and so the level of guidance should be gradually reduced, as suggested by the guidance-fading effect (Kalyuga, Chandler, Tuovinen, & Sweller, 2001) (see Section 2.2.5.5.1).

2.2.5.4.2 The Split-attention effect

The split-attention effect consists of reduced learning when the learner’s attention is split between two or more sources of mutually referring information that must be mentally integrated before understanding can occur (Sweller, Chandler, Tierney, & Cooper, 1990). This can often be a problem for technical instructional materials such as physics textbooks, which make frequent use of explanatory diagrams. If the diagrammatic information must be understood in conjunction with a text based explanation, the split-attention effect will occur when the diagram and the referring text are not combined in close physical proximity or ideally, integrated (Sweller, et al., 1990).

The split-attention effect was observed from anomalies in experiments investigating the worked examples effect. The benefits of worked examples were not evident in situations where worked examples incorporated separate diagrams and supporting text. Once the two sources of information were integrated, the expected improvements in learning were again attained (Tarmizi & Sweller, 1988). Since then, many studies have confirmed the split-attention effect applies across many domains provided that the instructional material has two or more mutually referring sources of information (Bobis, Sweller, & Cooper, 1993; Chandler & Sweller, 1992; Chandler &

The split-attention effect is usually referred to in connection with physically disparate sources of visual information which must be mentally integrated for understanding to occur. However, the concept can also be applied to temporally disparate sources of information whose timing should be coordinated. Mayer & Anderson (1991, 1992) found, for example, that when animations and their narrations are presented concurrently better problem solving transfer results than when animations and their narrations are presented successively. CLT suggests that this effect results from the dual-mode capabilities of working memory’s separate audio and visuospatial channels. The elaborate schemas required for problem solving success must incorporate both the visual and audio representations of the learning material and the relationships or references between them. This occurs most efficiently when both sources of information are temporally contiguous and can be processed simultaneously (Mayer & Anderson, 1992).

A consideration of both the spatial and temporal contiguity of mutually referring information sources is critical in multimedia instruction materials, particularly when teaching complex material to novices with the aim of achieving far transfer (Mayer & Anderson, 1992).

2.2.5.4.3 The modality effect

Under split-attention conditions, learning occurs best when multiple sources of mutually referring information are integrated. However, in attempting to reduce one source of cognitive load, another source of cognitive load can be inadvertently generated.

If, for example, the disparate sources of complex information to be integrated are both visual and/or spatial, combining them will reduce split-attention but may cause cognitive overload because they both have to be simultaneously processed through the visuospatial channel. However, if the two sources of information can be processed separately through working memory’s dual processing channels (audio and visual), working memory capacity can effectively be enhanced compared to the situation when only one channel is used (Penney, 1989). One way to achieve this would be to provide
a verbal explanatory narration for an animation rather than a written textual explanation.

Mayer’s multimedia principle, “Students learn better from words and pictures rather than from words alone.” (Mayer, 2001 p63) and the modality principle (Low & Sweller, 2005) recognise that under certain conditions, particularly those involving the presentation of complex material to novices, presenting information in a mixed mode (partial visual and partial audio) is more effective than presenting the same information in a single mode (either visual or audio alone). It is particularly important in the design of multimedia instructional materials and it has been demonstrated empirically by numerous studies (e.g. Mousavi, Low, & Sweller, 1995; Tindall-Ford, et al., 1997) but only in situations where element-interactivity and the resulting intrinsic cognitive load is high.

For example, if physics instructional material has a diagram and associated explanatory text, learning will be enhanced if the text is presented verbally (in audio mode) rather than in visual form (written text) because the diagram is already in visual form.

2.2.5.4.4 The redundancy effect

Redundancy occurs when the same information is presented in multiple forms or is unnecessarily elaborated (Sweller, 2005). The redundancy effect (Chandler & Sweller, 1991) occurs when the inclusion of redundant information in learning materials impacts negatively on learning in comparison with the learning achieved when the redundant materials are excluded (Sweller, et al., 1998). Redundant materials require learners to unnecessarily coordinate, relate and process materials that are surplus to the learning task creating unnecessary demands on the learner’s limited working memory (Sweller, 2005).

Early experiments with redundant materials showed that studying physics textbook summaries produced consistently superior learning than studying the full text (Reder & Anderson, 1980) and that ‘minimal manuals’ were more effective instructional tools than full computer manuals (Carroll, Smith-Kerker, Ford, & Mazur-Rimetz, 1987). The general assumption amongst researchers in the field prior to this work was that the inclusion of redundant materials would at worst have a neutral effect and may produce a positive effect (Sweller, 2005; Sweller, et al., 1998). Chandler and Sweller’s
The explanation of the effect in terms of CLT provides a theoretical basis with which to understand the mechanism by which this counter-intuitive effect occurs.

The redundancy effect has been demonstrated in many studies (Bobis, et al., 1993; Cerpa, Chandler, & Sweller, 1996; Chandler & Sweller, 1991, 1996; Sweller & Chandler, 1994), but its applicability is very dependent on the expertise of the learners. Novices require much more detailed and directed instructional materials than do experts (Sweller, et al., 1998) but the detail that is essential for a novice may be redundant for an expert.

2.2.5.4.5 Extraneous cognitive load and scientific explanations

The relationship between the format of scientific explanations and learning was tested by Mayer, Bove, Bryman, Mars, & Tapangco (1996) and demonstrates a number of the CLT principles designed to reduce extraneous cognitive load. Scientific explanations are cause-and-effect descriptions of a scientific process which aim to promote understanding and the ability to apply this understanding to far transfer problems (Mayer, et al., 1996). They concluded that there is a demonstrated need for conciseness, coherence, and coordination in presenting scientific explanations when understanding of scientific explanations is the goal.

Their intervention used multimedia summaries that combined visual and verbal information and were concise, coherent and coordinated. In this sense, ‘coordinated’ meant that each step in the explanation was presented by an illustration and a textual caption and that corresponding illustrations and words were presented simultaneously. These experiments provide evidence that multimedia summaries (containing both illustrations and captions) are more effective than summaries containing text alone or illustrations alone (modality effect); multimedia summaries are more effective when a small amount of text is used rather than a large amount of text, such as a textbook extract (redundancy effect); and multimedia summaries are more effective when the words and their associated images are presented simultaneously (split-attention effect).

2.2.5.5 Ways to increase germane cognitive load

Reducing extraneous cognitive load frees working memory capacity, but it does not guarantee that learning will improve. Attention must be directed towards the
processes which are directly relevant to schema construction and so germane cognitive load must increase if meaningful learning is to improve (Sweller, 2006a).

The completion problem effect, the guidance fading effect and the provision of signals will be discussed in the following sections as methods to increase germane cognitive load.

2.2.5.5.1 The completion problem effect

The worked examples effect (see Section 2.2.5.4.1) established that the use of well designed worked examples is more effective than the use of conventional problem solving exercises. However two problems are associated with the use of worked examples. The first concern is that, while high-ability students fully process worked solutions to show links to theory, lower-ability students do not, typically using the full worked examples as a crutch (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Secondly, maintaining motivation can be a problem when worked examples are used exclusively, particularly in courses of longer duration (Sweller, et al., 1998) as is typical in a high school physics course.

The use of completion problems which are partially worked solutions where the details of specific steps in the solution are omitted can address concerns about the exclusive use of worked examples (van Merriënboer & Krammer, 1990). In long duration studies, completion problems produced better learning in comparison to both worked examples and conventional problems (van Merriënboer, 1990; van Merriënboer & de Croock, 1992). In short duration courses, completion problems proved to be equally as effective as using worked examples (Paas, 1992).

The improvements in learning after use of completion problems are observed as better transfer performance indicating that better schema construction has occurred. CLT suggests several reasons for this. Firstly, completion problems reduce extraneous cognitive load in the same way that worked examples do. Secondly, completion problems increase germane cognitive load by forcing students to attend to the critical elements of the solution in order to complete those missing steps (Sweller, et al., 1998).
2.2.5.5.2 The guidance fading effect

While it is clear that the completion problem strategy is productive in teaching novices, the scaffolding provided can become redundant as expertise increases and it may actually begin to hinder learning (see Section 2.2.5.6 for the expertise reversal effect). Using the completion problem strategy in conjunction with guidance fading solves this problem (Kalyuga, et al., 2001).

With guidance fading, an instructor would first provide completion problems that are almost fully worked solutions with very few steps missing. Gradually instruction would progress towards completion problems where students must provide most of the solutions until students are able to solve conventional problems without support. Fading of the support mechanism produced fewer unproductive learning events and better learning outcomes. In fact, students learned most about those principles that were faded (Renkl, et al., 2004).

The design of good completion problems requires considerable skill as decisions must be made as to which elements of the solution are best omitted to allow the student to understand the partial solution but still have significant, non-trivial elements of the solution to complete. Additional decisions must also be made about how and when to reduce support as guidance is faded (Sweller, et al., 1998).

2.2.5.5.3 Provision of signals

The provision of signals and cues can direct learners’ attention by highlighting important information (Mayer & Moreno, 2003). Such attentional support can take the form of textual signals (eg a change in font size or colour coding or highlighting of important information) in printed documents or multimedia effects in electronic documents (eg flashing text). While these techniques clearly increase germane cognitive load, they may also be considered as a means of reducing extraneous cognitive load via a reduction in visual search (Foster, 1979; Jeung & Chandler, 1997).

2.2.5.5.4 Germane cognitive load and motivation

Techniques to increase germane cognitive load, are designed to focus the learner’s attention. However, the imposition of germane cognitive load alone cannot guarantee meaningful learning without the willingness of the learner to work through the difficult
mental processes represented by the germane cognitive load (Pugh & Bergin, 2006; van Merriënboer & Ayres, 2005). Learner’s motivation levels must be high and they must not find lessons ‘boring’, if learning is to improve (R. E. Clark, Howard, & Early, 2006; van Merriënboer & Sweller, 2005).

Motivation is defined as the amount and quality of the ‘mental effort’ people invest in achieving learning and performance goals (Salomon, 1984). This motivational link may not be readily evident in short laboratory experiments but becomes increasingly important in longer term studies in rich and real contexts (Paas, Tuovinen, van Merriënboer, & Darabi, 2005). Under such circumstances, motivation can affect student learning to the same extent as instructional techniques (Colquitt, LePine, & Noe, 2000; Merrill, 2002; Snow, 1996).

### 2.2.5.6 The expertise reversal effect

Expertise in a particular domain is closely related to the storage in long-term memory of increasing numbers of ever more elaborate and automated schemas (Sweller, et al., 1998).

For experts, a complex schema can be treated as a single item (or a small number of items) in working memory. This allows experts to engage in complex cognitive processing tasks which would overwhelm the working memory capacity of a novice who must process the individual elements of the expert’s elaborate schema individually in working memory (Sweller, et al., 1998).

It is therefore essential that learners’ expertise be assessed before appropriate instructional programmes can be designed. As learners’ expertise gradually increases, the benefits of some instructional techniques suggested by CLT (such as the worked examples effect, the modality effect and the split-attention effect) gradually diminish and their use may eventually become detrimental to learning. This is known as the expertise reversal effect (Kalyuga, et al., 2001).

The guidance fading effect (discussed earlier in Section 2.2.5.5.1) can be considered as an example of the expertise reversal effect. For novices, worked examples are beneficial as a means of reducing extraneous cognitive load but for students with more expertise, the detail of the worked examples becomes redundant and imposes
extraneous cognitive load. It is then more beneficial to have students solve conventional practice problems (Kalyuga, et al., 2001).

2.2.6 Practical instructional design guidelines arising from CLT

An overview of CLT and the instructional design principles that can be derived from it have been reviewed. A consideration of these principles can lead to guidelines for improving the efficiency of instructional materials. R. C. Clark et al (2006) provide a set of guidelines derived from these principles which is organised around three practical instructional design factors: the existing expertise of the target audience; the complexity of the learning materials and the goal of instruction (i.e. near transfer or far transfer); and the mix of media to be used in the training.

The existing expertise of the target audience is a crucial consideration with which to commence planning instructional materials (see Section 2.2.5.6). The guidelines suggest that steps be taken to ensure that all students in a course start with similar levels of existing expertise (e.g. run introductory and advanced courses or establish course prerequisites). Courses for novices should provide maximum support to minimise extraneous cognitive load (see Section 2.2.5.4). Courses for experienced students should avoid redundant information and allow students greater responsibility for their learning by using practice problems or guided discovery learning opportunities (R. C. Clark, et al., 2006).

A second major consideration pertains to the complexity of the material to be learned and the goals of instruction. Highly complex material has high element interactivity and so has high intrinsic cognitive load. Methods to artificially reduce intrinsic cognitive load, such as those which introduce content gradually (R. C. Clark, et al., 2006), may be employed (see Section 2.2.5.3) and methods to minimise extraneous cognitive load are critical (see Section 2.2.5.4).

The goal of the instruction is also important. Near transfer tasks require automatic performance on a specific set of familiar tasks. Drill and practice of low variability worked examples are recommended (R. C. Clark, et al., 2006). Far transfer tasks require adaptability and the ability to apply knowledge in new situations. Here variability of practice (Paas & van Merriënboer, 1994a) and the ability to generate self-explanations (Chi, et al., 1989) is crucial to understanding and the construction and
automation of elaborate schemas. If the goal of instruction is the use of new technology such as computer software, care should be taken not to split attention between the computer screen and printed instructional materials (Cerpa, et al., 1996).

Finally the mode of presentation must be considered. Whether the mode of delivery is via human or computer instructor, all sources of extraneous cognitive load must be reduced and lesson pacing is critical. Some mechanism for student control of pacing must be provided. For example, a human instructor can alter lesson pacing by responding to student feedback and a computer instructional system can include navigation panels allowing replay and skip options (R. C. Clark, et al., 2006). Also important is that materials are presented via audio and visual channels without redundancy or split-attention (R. C. Clark, et al., 2006).

These guidelines can provide valuable insights into the development of improved instructional materials for teaching high school physics.

2.2.7 Cognitive Load Theory and note taking

2.2.7.1 Traditional note taking

Traditional pedagogy requires students to record and organise their own notes during lessons. Boch and Piolat (2004) describe note-taking as a cognitively demanding, functionally complex task which students are expected to have mastered by the time they are in senior high school, yet very few students are taught even basic note taking skills. Consequently, students intuitively develop their own methods and processes for note-taking with varying degrees of success.

The major aim of note-taking is to build up a stable external information store that can be readily retrieved for later use (Kiewra, 1987), such as in revising for examinations. Students who take accurate class notes and revise from them consistently attain higher test scores than students who take inaccurate or incomplete class notes or students who only listen to the lesson or read the text (Baker & Lombardi, 1985; Carrier, 1983; Kiewra, 1987; Norton & Hartley, 1986).

Piolat, Olive and Kellogg (2005) demonstrated that taking notes from a lecture requires more cognitive effort than playing chess! They suggested that this is because note-taking requires a structure-search process that is very demanding of cognitive
resources, imposing a large extraneous cognitive load. The search process is even more demanding when students are novices, when the learning materials are complex or when the lecturer does not provide a clear organisational structure for the information (Rickards, Fajen, Sullivan, & Gillespie, 1997). The note-taking process and the process of comprehending the materials to be learned must compete for scarce working memory resources. Cognitive overload may result and schema production may be inhibited.

Success in note taking is related to gender with experimental evidence suggesting that girls are more skilful note takers than boys (Burley, 1982) and that female high school and university students perceive themselves as more competent note-takers than their male counterparts (Bonner & Holliday, 2006; Burley, 1982; Carrier, Williams & Dalgaard, 1988).

Note-taking skills are closely aligned with linguistic skills (Boch & Piolet, 2004). Linguistic skills are generally better in girls than boys even in young children (Dionne, Dale, Boivin, & Plomin, 2003) and the female advantage in verbal and written language persists through school (Lynn, 1992) and into adulthood (Parsons, Rizzo, van der Zaag, McGee, & Buckwalter, 2005). Hence, girls may be better note takers than boys because they possess better linguistic skills.

In cognitive load terms, the fact that girls are more expert note takers than boys, may indicate that girls have more elaborate or more automated schemas for note taking than boys. This would mean that the process of note taking imposes more extraneous cognitive load on boys than on girls. When learning physics with traditional pedagogy where students are required to simultaneously take notes and process complex information, boys are more likely than girls to experience cognitive overload and impaired learning.

For a skilled practitioner, the act of note-taking can actually aid internal memory storage and understanding (Kiewra, 1987). In cognitive load terms, for a student with elaborate, automated note-taking schemas, the note taking process can impose germane cognitive load rather than extraneous cognitive load because they are able to use the processes of note-taking to actively assist schema production. Hence, for girls, the process of note taking is helpful for understanding while for boys it is more likely to be a hindrance to understanding.
2.2.7.2 Guided note taking

Guided notes are handouts prepared by the lecturer that provide students with a skeleton of information and/or standard cues with specific spaces in which to write key facts, concepts, explanations, diagrams etc, during the lecture. Students must attend to the lesson, actively engage with the course content and respond appropriately to complete the guided notes (Heward, 2003).

Students of all ability levels attain higher test scores when using guided notes than when taking their own notes (Heward, 1994; Lazarus, 1993). Guided notes can act as advance organisers (Ausbubel, 1968) and students indicated that they benefited from perusing the lecture outline prior to class and they responded positively to this technique (Heward, 2003).

In cognitive load terms, guided notes reduce the extraneous cognitive load of structure search associated with traditional note taking (Narjaikaew, Emarat, & Cowie, 2009). This should enhance schema production for all students but particularly for boys who are less likely to have elaborate or automated schemas for traditional note taking.

Guided notes also impose germane cognitive load by directing students’ attention and requiring active engagement with the task (Narjaikaew, et al., 2009). This should enhance schema production for all students. Experimental evidence of improved schema production is provided by Narjaikaew et al (2009) who found that first year university physics students performed better on conceptual tests after learning with guided notes than those students who learned with traditional note taking.

The use of guided notes is recommended as a preferable instructional technique for university science courses in contrast to traditional note taking strategies (Narjaikaew, et al., 2009).

The digital pen technology offered by Tablet PCs has the potential to powerfully support guided note taking pedagogy. The next section reports on the literature relating to Tablet PCs and their use in educational contexts.
2.3 Tablet PCs in educational settings

2.3.1 Introduction

Tablet Personal Computers (Tablet PCs) are an appealing and relatively new technology, having been first announced by Microsoft in 2002 (Blickens, 2005). CLT suggests that Tablet PCs have a huge pedagogical potential for physics education (and in similar technical subjects such as mathematics, engineering and computer science).

This literature review aims to identify examples where Tablet PCs have been successfully implemented in schools and universities in ways similar to those envisaged for this research. In particular, studies will be sought which empirically assess the effectiveness of the use of Tablet PCs in terms of improved learning outcomes.

2.3.2 The Tablet PC: features and cost

Tablet PCs are lightweight mobile computers which feature digitizer screens and allow users to interact with software using digitizer pens. The digitizer pen can be used for navigation by touching the screen instead of using a mouse. Most Tablet PCs run Windows Vista or Windows XP Tablet Edition, 2005 operating systems which have in-built support for recording digital annotations made in Microsoft Office documents. Handwriting recognition in which handwritten text is recognised and converted to typed text is also supported. Tablet PC-specific software is available including Microsoft Journal and Microsoft OneNote which allow simple and convenient use of the Tablet PC as a mobile diary and organiser and a searching facility for handwritten as well as typed text. All standard Microsoft Windows based software will run on Tablet PCs. Webcam video and voice recording, and wireless connectivity in Infra-red, bluetooth and wi-fi formats also feature in most Tablet PCs to enhance their usefulness as mobile tools (Sheehy, et al., 2005).

Tablet PCs come in one of two formats: ‘slate’ and ‘convertible’. Slate Tablet PCs do not have a keyboard and the digitizer pen is used as the primary input device. Slates are designed to be lightweight and highly mobile but can be docked with other devices such as a keyboard when desired. Convertible Tablet PCs have an attached keyboard and can be used in ‘clamshell’ mode as a laptop computer. The digitizer screen, however, can be rotated for use in slate mode.
Early versions of Tablet PCs (pre 2006) sacrificed computing power and affordability to gain mobility. Tablet PCs were priced between $3000 and $4000 which was more than double a similarly featured laptop computer (BECTA, 2004). In 2009, entry level Tablet PCs contain fast dual core processors (sufficient computing power to serve as a user’s primary computer) and are priced between $1500 and $2000 which is about fifty percent more than the price of a comparable laptop computer. Tablet PCs have come of age and are now an affordable and promising option for the educational sector (Wise, Toto, & Lim, 2006) where their digital inking facility and their portability (particularly when used in slate mode) are attractive. Figure 2.5 and Figure 2.6 show images of both types of Tablet PCs.
Figure 2.5: Slate Tablet PCs

a) A slate Tablet PC is designed for mobile use (DoctorsGadgets.com, 2008)

b) Features of a slate Tablet PC (Rent-a-Computer, 2008)
Figure 2.6: Convertible Tablet PCs

A convertible Tablet PC can be used in clamshell mode or the screen will rotate to slate mode (Martins, 2008)
2.3.3 Models for Tablet PC use in educational settings

Sheehy et al (2005) conducted an extensive literature review in which two main models for the use of Tablet PCs in education were reported: the teacher-centred model and the student-centred model. In each case, a data projector is used for display purposes and may be connected to the Tablet PC via a cable or through a wireless connection using software such as Maxivista (Bartels Media GmbH, 2008). A wireless network with fast Internet access is necessary to gain maximum benefit from the Tablet PC’s potential for mobile computing (Sheehy, et al., 2005).

2.3.3.1 The teacher-centred model

In the teacher-centred model, the teacher uses a Tablet PC to teach lessons. Only one Tablet PC is used per class and so the whole group’s attention is focused on the same thing at the same time. The teacher predominantly controls the Tablet PC and uses it as a tool to direct students’ attention to pertinent information. This model is consistent with CLT principles and is suited to highly structured, complex disciplines such as physics.

The use of a Tablet PC in the teacher-centred model allows the teacher to face the class most of the time. This should allow the teacher to maintain eye contact with students and to monitor off-task activities much more effectively than is possible in a traditional classroom. It is even possible for the teacher to teach while moving around the classroom with the Tablet PC wirelessly linked to the data projector and the network.

A variation of the teacher-centred model, the shared tablet-control pedagogy, occurs when the teacher chooses to pass control of the Tablet PC to a student. The student might annotate a solution to a sample problem or analyse motion data using Logger Pro software (Vernier Software and Technology, 2009). The student’s work in progress can be displayed to the class through the data projector allowing the class to discuss the problem solution or suggest alternative data analysis paths. Muller and Tuovinen (Muller & Tuovinen, 2008) reported on this shared tablet-control pedagogy in the context of senior high school mathematics class.

Another very practical advantage of the teacher-centred model of Tablet PC use in classrooms is its cost effectiveness. Budgetary pressures on most schools are such that
one Tablet PC per classroom may be affordable but the purchase of multiple Tablet PCs per classroom is out of the question.

2.3.3.2 The student-centred model

In the student-centred model, there are multiple Tablet PCs available for the teacher and students to use. A one-to-one computer to student ratio is desirable but in some cases only one computer per group of students may be available. Students are sometimes allocated a Tablet PC for their exclusive use at school and at home. In other situations, class sets of Tablet PCs are available for occasional use by students in class or on excursions (Sheehy, et al., 2005). In a very few schools, one-to-one Tablet PC programmes operate where private ownership or leasing of the machines is encouraged (Frankston High School, 2007) or is sometimes mandatory (Trinity Grammar School, 2008). This model is reported most frequently in the context of American university physics, mathematics, engineering and computer science faculties (R. E. Anderson, Anderson, & McDowell, 2005; Theys, Lawless, & George, 2005).

This model promotes collaboration between students and allows any student to present his/her work to the group through a wireless connection to the data projector. Software such as Classroom Presenter (University of Washington Computer Science and Engineering, 2008) is designed to facilitate wireless information transfer between networked computers and also allows the teacher to wirelessly transfer his/her live digital annotations to the students’ computers in real time. Richard Anderson has reported extensively on his use of this slide-based software in university engineering classes in the USA (R. E. Anderson, et al., 2007).

Some student-centred models of Tablet PC use are based on constructivist philosophies of learning (Weitz, Wachsmuth, & Mrliss, 2006) and have students collaborating via the technology to construct their learning through real world problem solving activities or exploration learning. Such methods have been shown to be effective only when students have already gained considerable exposure to the given content area i.e. their expertise level is high (Tuovinen & Sweller, 1999). This is more likely to be the case for university students than high school students but even then, the learning materials they encounter may be complex and difficult for their level of expertise. Hence, student-centred models of Tablet PC which feature real world
problem solving or exploration learning activities in Physics are more likely to promote effective learning if the activities are highly guided (Tuovinen, 1999).

2.3.4 Reported uses of Tablet PCs in educational settings

2.3.4.1 Overview

As recently as 2005, Sheehy et al. (2005) noted that the uptake of Tablet PCs in schools was still in its infancy so available research is limited and publications tend to be project reports or news items. Consequently, the research cited here is relatively recent, mostly having occurred in the last two to three years. Much of it is published through conference proceedings or on-line rather than through peer-reviewed journals (S. D. Miller, 2008). This is indicative of the fact that this is a cutting edge use of technology. In fact, most of the reported empirical research citing evidence of improved student learning such as that by Hojjatie et al. (2008) was conducted in parallel with this research.

2.3.4.2 Use of Tablet PCs in Australian schools

Tablet PCs are not widely used in primary and secondary schools in Australia (Neal & Davidson, 2008) and there are few published studies from Australian schools research. Some early case studies were sponsored by hardware or software companies (Computelec Pty. Ltd., 2006; Hewlett-Packard, 2004; Microsoft, 2002) and did not report scholarly research findings.

A recent study (Neal & Davidson, 2008) looked at two Victorian co-educational secondary schools who equipped all teachers and some classes of Year 7 and 8 students with Tablet PCs from January 2007. They reported on both the student-centred model, as evidenced in the Year 7 and 8 classes, and on the teacher-centred model trialled when Tablet PC equipped teachers taught their Year 12 students.

Neal and Davidson conducted surveys, classroom observations and interviews which allowed comparisons to be made between the teaching methods and learning experiences enabled by the use of Tablet PCs and those enabled by use of laptop computers. It was found that teachers and students highly valued the pen-technology of the Tablet PC which enabled real-time, instantaneous modification of teaching content (e.g. annotation and highlighting of Microsoft PowerPoint slides). It also
allowed homework to be submitted electronically, marked with digital ink and returned electronically.

Neal and Davidson did not consider Tablet PC use in specific subjects and they did not attempt to quantify changes in students’ learning outcomes as a result of Tablet PC use. They simply reported on the ways in which Tablet PCs were used and on affective data showing positive attitudes of staff and students to the initiative.

2.3.4.3 Use of Tablet PCs in international schools

Of the published studies on Tablet PC usage in schools, most are from the US and the UK and most refer to the student-centred model (Dicken, 2008; Reboli, 2007).

Schools in the UK were early adopters of Tablet PC technology and the British literature refers to numerous Tablet PC projects in primary and secondary school settings. The British Educational Communications and Technology Agency (BECTA) commissioned numerous reports into Tablet PC use in schools (BECTA, 2004; Sheehy, et al., 2005; Twining, et al., 2005), and Information and Communication Technologies (ICTs) in education generally, often with references to Tablet PC usage (BECTA, 2003a, 2007; Condie, Munro, Seagraves, & Kenesson, 2007; Smith, Rudd, & Coghlan, 2008). The majority of studies refer to the student-centred model for Tablet PC use.

Sheehy et al. (2005) completed an extensive literature review of selected projects to give a snapshot of the educational use of Tablet PCs in the UK and the USA in late 2004. Most of the ninety schools or projects studied involved relatively small student-centred initiatives confined to a single group of children or staff. This is indicative of the start-up costs of any such project. About 10% involved larger and/or longer term research projects.

Teachers predominantly used the digital ink capabilities of the Tablet PCs to present lessons. Wireless data projectors were favoured because of the increased mobility afforded they afforded the Tablet PC as a presentation tool. Several schools reported that Tablet PCs provided a more versatile and cost effective option than interactive whiteboards (Sheehy, et al., 2005).

Students’ uses of Tablet PCs included annotating digital documents, using handwriting recognition software, using digital ink for drawing and artwork, preparing multimedia presentations, collecting and analysing data in science laboratories and on field work.
and for working collaboratively. Primary school students also used Tablet PCs to improve their handwriting (Sheehy, et al., 2005).

Digital ink, mobility and wireless connectivity were highly valued features of the technology. Most schools perceived Tablet PCs as highly versatile, ideal for school usage, motivational and much better than standard laptops. Most difficulties encountered were logistical in nature. For example, the availability of technical support was critical, battery life was an issue and the robustness of the machines and insurance issues emerged (Sheehy, et al., 2005).

2.3.4.4 Use of Tablet PCs in Australian universities

In the Australian tertiary education sector, Loch and Donovan from the University of Queensland used Tablet PCs to teach mathematics on campus (Loch & Donovan, 2006) and via distance education (Loch & McDonald, 2007) and reported very positive results in terms of student perceptions. On campus during 2004 and 2005, Loch and Donovan taught first year university mathematics using a Tablet PC and data projector to present and to digitally annotate Microsoft PowerPoint slides containing skeletal guided notes. Students were given a workbook with printouts of the lecturers’ unannotated slide presentations as a starting point for their note-taking. Attitudinal data collected showed that 95% of students in one class and 98% of students in the other class agreed that ‘writing (in digital ink on the Tablet PC) during lectures helps my understanding’. No quantitative analysis of actual student assessment data was performed (Loch & Donovan, 2007).

2.3.4.5 Use of Tablet PCs international universities

In the USA, the published literature about the educational use of Tablet PCs refers predominantly to tertiary educational settings (Neal & Davidson, 2008). For example, at the 2008 Workshop on the Impact of Pen-Based Technology on Education (WIPTE), 75% of papers referred to university studies (Reed, 2008).

With reference to the student-centred model in universities, many studies report on the efficacy of various software programmes enabling collaborative work by students equipped with Tablet PCs connected over a wireless network. Examples include ‘Classroom Presenter’ (R. E. Anderson, Anderson, McDowell, & Simon, 2005) and DyKnow Vision (Chambers, et al., 2006) where the lecturer and the students all have
Tablet PCs that are wirelessly networked. As the lecturer annotates his/her document, the notes are simultaneously transmitted to students’ local documents. Students can also annotate their own local document independently and transfer their annotations to others as desired. Kim, Turner and Perez-Quinones (2004) provide a comparison of numerous such note-taking platforms.

Many studies in the university context centre on Tablet PC use by lecturers and students specifically in the engineering, computer science, mathematics and science faculties (e.g. R. E. Anderson, Anderson, McDowell, et al., 2005; Mitchell, 2007). The high intrinsic cognitive load associated with these subjects may lead lecturers to look for tools such as the Tablet PC to assist students’ learning. Logistical considerations are also important.

In subjects like mathematics and science which frequently use equations and symbols, laptop use is limited because students are unable to record class notes or prepare assignments digitally without the use of complex mathematical equation editors (Cantu, Phillips, & Tholfsen, 2008). The power of pen-enabled computing in these subjects is immediately evident (van Oostveen & Muirhead, 2005).

Research regarding Tablet PC use in the physical and applied sciences provides some examples of the teacher-centred model of Tablet PC use (Theys, et al., 2005). Most have the lecturer annotating Microsoft Powerpoint slides during the lecture as well as using a range of digital resources.

2.3.4.6 Guidelines for teaching with digital ink

The pedagogical potential offered by technologies like the Tablet PC which allow teachers to dynamically add digital ink annotations to prepared content is enormous. R. E. Anderson, Anderson and McDowell (2005) provide suggestions for best practice in teaching with digital ink. They report a variety of ways in which university lecturers have employed digital ink in their teaching using slide presentations. The use by some lecturers of a guided notes strategy (Heward, 2003) (see also Section 2.2.7.2) in conjunction with digital inking was noted as an effective pedagogy.

The guidelines are provided in general terms but will be discussed here in the context of digital annotation of guided notes. They stress that good teaching is about interacting with the class to convey information, whether or not technology is used.
The guidelines aim to ensure that the use of digital ink technology enhances this information transfer and does not impede it.

The first guideline is to focus on clarity: lessons must be comprehensible; digital handwriting must be clear and legible; colours should be chosen to contrast clearly; clutter and crowding of screens should be avoided; and materials should be presented at a rate that is comprehensible for students.

Guided notes must be carefully planned: the selection of the information to be omitted is as important as the selection of the information to be included; and sufficient space must be allowed for the desired responses to be annotated.

Inking should be used to convey meaning and to focus attention. Colour coding and highlighting should be used for structure and emphasis.

The introduction of tablet technology must be carefully prepared for to avoid situations where the technology detracts from the learning: the instructor should be thoroughly familiar with the Tablet PC and digital inking; instructional use of the technology should be rehearsed to identify and correct technical and logistical problems; and technical support should be readily accessible.

The final guideline is that presenters should remember to engage the audience. They should not become so preoccupied with operating the Tablet PC that eye contact with students is lost. They should take advantage of wireless network and projector links and Tablet PC mobility to move around the classroom whilst teaching or to pass control of the Tablet PC to a student.

2.3.5 Results of research into the use of Tablet PCs in educational settings

2.3.5.1 Evidence from the affective domain

The literature on the use of Tablet PCs in education indicates that the Tablet PC is a ‘cool technology’ which often enhances student motivation, attention and engagement (S. D. Miller, 2008; Reboli, 2007; Sheehy, et al., 2005) These studies include investigations of small scale Tablet PC projects with particular classes who have completed surveys after the intervention. The focus of this overview will be on studies investigating the teacher-centred model of Tablet PC use.
Reboli’s (2007) results are typical of those obtained in such studies. She taught her second year university level Discrete Mathematics class by annotating prepared slides on a Tablet PC with a wireless connection to data projector while her students annotated their own paper copy of the slide material (a pedagogy she first saw modelled in 2006 by John Bowling of the Bolles School in Jacksonville, Florida). Students completed surveys at the completion of this course and at the completion of a previous mathematics course which did not incorporate the Tablet PC. In both cases students were asked to rate a variety of course characteristics on a five point Likert scale (1 = very effective, 5 = very ineffective). Reboli reports that the most striking changes were improvements in the response means for “understanding the content” (no Tablet PC, mean = 4.556; Tablet PC, mean = 4.778), “enjoyment of the overall course” (no Tablet PC, mean = 4.333; Tablet PC, mean = 4.667) and “enjoyment of the content” (no Tablet PC, mean = 4.000; Tablet PC, mean = 4.667). Unfortunately, no statistical analysis of the significance of these changes was reported. Anecdotal evidence that students were more engaged and attentive was also cited.

In the studies discussed so far, statistical measures of the significance of the results are rarely presented. Research by Bilén et al. (2008) provides an exception. They implemented the student-centred model to study the impact on learning resulting from students’ use of Tablet PCs in university technology and engineering courses. The study is still in its infancy, but preliminary results show that Tablet PC use enhances students’ learning experiences. The study will proceed to an analysis of students’ assessment results to determine if improvements in learning outcomes are linked to Tablet PC use by students.

Hojjatie et al. (2008) provides an example of a more rigorous controlled study with more than 1000 participants. They studied students in first year university engineering and science courses where Tablet PCs were used by lecturers and occasionally by students. Some aspects of the study attempted to tease out the effect caused by the lecturer’s use of the Tablet PC in teaching. Comparisons of student evaluations from courses taught by the same instructor both with and without the use of a Tablet PC indicated a 6% increase in student satisfaction when the Tablet PC was used. Survey results showed that more than 70% of students reported high motivation and that their learning was more effective when Tablet PCs were used as a teaching tool.
Hojjatie et al also analysed student test results and these are reported in the next section.

Satisfaction surveys such as those reported here are important first steps in assessing the effectiveness of a relatively new technology but there is a need for empirical studies to provide a direct measure of the effect of Tablet PC usage on actual student performance data (Wise, et al., 2006).

2.3.5.2 Empirical evidence of improved learning outcomes
Matthews and Khoie (2007) of the University of the Pacific in California studied a teacher-centred model of Tablet PC use with engineering students learning about electrical circuits. They reported that the use of Tablet PCs was more effective for higher ability students. Average students (C grade) showed no evidence of any significant difference in learning outcomes relative to the control group as a result of learning with a Tablet PC, but A and B level students improved their scores by about one-third of a standard deviation. It was also noted that the use of the Tablet PC led to substantial savings in class time that were then devoted to additional problem solving opportunities.

Hojjatie et al (2008) showed that the mean student grades in first year university engineering and science courses were higher when Tablet PCs were used in teaching and learning. Specifically, in the geology course, a 12% increase in A and B grades accompanied a 7% reduction in failing grades when Tablet PCs were used. Similar improvements were also shown in the biology course. They concluded that learning outcomes appear to have been enhanced but note that additional data and statistical analysis are required to confirm these findings.

Weaver (2006) reported quantitative data showing that students in a university Electronic Commerce Technology class who learned with Tablet PCs in a student-centred model achieved slightly better scores than did students who learned with laptop or traditional classroom models.

2.3.5.3 Disadvantages of Tablet PC use
Disadvantages in the use of Tablet PCs and digital pen technology include practicalities like poor battery life and fragility. Legibility can be a problem particularly if the teacher is trying to write on a small screen or if the physical arrangement of the Tablet PC
causes a poor viewing angle. Screen sizes less than 30cm are problematic (R. E. Anderson, Anderson, McDowell, et al., 2005).

Currently, the unit cost of an entry level Tablet PC ($1800) is about fifty percent more than that of a laptop PC with equivalent processing power ($1200). This may be of significant concern to schools where a student-centred model of Tablet PC use is proposed but will not be so prohibitive in the case of a teacher-centred model. The latter option is still more cost effective than the alternative interactive whiteboard option ($3000).

No literature reporting diminished learning outcomes due to the use of Tablet PCs was found. Many authors believe that the advantages of Tablet PC usage outweigh the drawbacks (Theys, et al., 2005).

2.4 Implications of the literature review for this research

This literature review has provided insights into the way in which students learn physics and the cognitive impediments to this learning. Instructional guidelines to improve learning in physics have been provided by CLT and the available evidence on the effectiveness of incorporating digital inking technologies in educational settings has been considered. The implications for this research will now be considered.

CLT provides principles to increase the efficiency of instruction by optimising the interactions between the learner’s expertise, the task complexity and the instructional design to reduce the danger of cognitive overload and increase the likelihood of schema acquisition and strengthening (R. C. Clark, et al., 2006). A pedagogical strategy using guided notes may provide improved learning outcomes in comparison with traditional teaching methods (Heward, 2003) and digital inking presentation technologies such as Tablet PCs also improve learning (R. E. Anderson, Anderson, & McDowell, 2005; Hojjatie, et al., 2008; Reboli, 2007).

Hence, it can be concluded from the review of literature that an improved way to teach high school physics may employ teacher-centred Tablet PC pedagogy based on CLT principles. The detailed development of such pedagogy will be discussed in the next chapter.
Chapter 3:
The development of the TWP

3.1 Introduction

Although the availability of computer technology is now widespread in schools, few research-sanctioned, cognitively oriented technology innovations enjoy widespread use. Instead, the primary uses of technology in schools are for drill and practice, word processing and web surfing, falling far short of the potential of technology to support rich, deep conceptual learning (Fishman, et al., 2004). Just installing technology in schools is no guarantee that it will contribute to meaningful learning (Alexander, McKenzie, & Geissinger, 1998). In fact, robust, scholarly evaluation frequently suggests that there is no evidence confirming the anticipated benefits of using educational technologies (Kearsley, 1998).

Rather than following fads with the latest glitzy new technology, educators should begin by validating the educational problem to be solved and taking time to gain a clear understanding of the problem and its causes (R. E. Clark & Estes, 1998). Educational theory may then suggest solutions and, if appropriate, characterise the educational technology that may be best suited to contributing to a solution.

For technology to be used effectively, it must be a core element of teaching and learning from curriculum design to pedagogical design to assessment (Roschelle, et al., 2000). This chapter will describe the ways in which CLT principles are embedded in the TWP and how Tablet PC use supports the pedagogy through which these materials are delivered.

3.2 Planning for success in educational reform

Many reforms, particularly those involving educational technology, have not enjoyed widespread success and have ultimately been abandoned. How can the mistakes of the past be avoided?

Dewey (1901) noted that educational reform is notoriously difficult to engineer. In his description of cycles of innovation and resistance, he suggested that the cycles
proceed in this manner: unrest concerning some aspect of the operation or performance of schools is followed by promises that a new theory or practice will solve the problem; intensive, small-scale, well resourced pilot projects demonstrate the successful use of the proposed theory or practice; subsequent widespread, poorly resourced implementation then follows with disappointing results; and the new method is ultimately abandoned.

Dewey’s typical ‘cycles’ are excellent examples of what R. E. Clark and Estes (1998) call ‘educational craft’ in action. When practicing educational craft, teachers produce experience-based solutions to local problems which prove to be at least marginally effective where they were developed but are not reliably transferable to new situations. Many of the latest educational fads have followed this pathway.

A major fault of educational craft solutions, even though they are locally successful, is that they are seldom linked to a larger body of knowledge which can suggest established theoretical reasons for the success of the initiative and guide further implementation, generalization or research (R. E. Clark & Estes, 1998). Although educational craft solutions can provide early insights into the development of new fields of knowledge, as the field matures the emphasis must shift to providing connections between the educational problem that has been identified and the educational theory that can suggest a solution.

Instead of a reliance on educational craft solutions, R. E. Clark and Estes (1998) suggest a process whereby practical problems are identified and solutions are found on the basis of sound scientific theory, principles and measurement. They emphasise that the problem should be specified clearly so that its causes and solutions can be defined and the effectiveness of the proposed solutions can be measured in a replicable way. They go on to suggest that inadequate problem specification and too hasty a choice of solution before adequate understanding of the problem exists is the root cause of the failure of many craft-based educational initiatives.

The use of Tablet PCs in education is at an early stage of its evolution and is currently in the educational craft solution stage. Numerous pilot programmes have operated over the last five years in primary, secondary and tertiary educational institutions using a range of implementation models in a variety of subject contexts (see section 2.3.4). Many of these have reported improvements in student motivation. Few have reported
rigorous studies showing improved educational outcomes and none have attempted to link the reported effects to underlying cognitive theory.

This research aims to link the educational problem and the proposed solution to theory through rigorous analysis as an improved way to teach physics is developed and assessed. CLT will be used to clearly define the problems with traditional methods of physics instruction and to inform a new instructional design. In this way it is hoped that that this educational reform will not follow one of Dewey’s typical cycles.

3.3 Model for choosing suitable educational technology

Bates (1995) suggests that it is important for educators to have an appropriate conceptual framework with which to guide their use of technology. Lambert & Williams (1999) suggests the model for choosing educational technologies shown in Figure 3.1 which considers educational issues, technology issues and management issues.

Figure 3.1: A model for choosing educational technologies
(Lambert & Williams, 1999, p 3 Figure 1)
3.3.1 Educational issues: quality teaching and learning in physics

An understanding of efficient learning processes in physics must be gained before a suitable supporting technology can be identified. CLT (Sweller, 1994) will be used as a basis for developing an understanding of why traditional pedagogy has not efficiently promoted meaningful learning in physics. It will also be used to design elements of new pedagogy and the attributes of a suitable supporting technology that should allow students to gain a deeper understanding of physics.

3.3.1.1 The nature of physics: complexity in learning

Elen & Clark (2006) suggest that the complexity of a learning task is related to the degree to which its mastery requires the learner to consciously and deliberately process numerous elements which interact in multiple ways. This is particularly so if the multiple elements or relationships are changing over time as is frequently the case in physics. The perceived complexity is increased when the learners are novices so physics is generally considered to be a very challenging subject for high school students (van Merriënboer & Sweller, 2005).

The goal of instruction in complex cognitive domains like physics is to facilitate the far transfer of acquired knowledge and skills to novel situations and that the best way to achieve this is through the creation and automation of increasingly elaborate schemas (Cooper & Sweller, 1987; Paas, 1992). CLT (Sweller, 1994) contends that the process of schema creation is constrained by the limited cognitive processing power of working memory, particularly for novices. Efficient instructional methods should, therefore, optimise the cognitive load experienced by learners. Paas (1992) suggests that this may be done in three ways: intrinsic cognitive load should be managed appropriately; extraneous cognitive load should be minimised; germane cognitive load should be increased by redirecting the learner’s attention to tasks relevant to schema acquisition and students must be motivated to invest the necessary mental effort.

3.3.1.2 Traditional instructional methods are not optimal in physics

Numerous studies have shown that traditional instructional methods are not effective in complex subject domains such as physics, mathematics, engineering and computer science (Cooper & Sweller, 1987; Larkin, McDermott, Simon, & Simon, 1980; Sweller, 1988; Sweller, et al., 1990; van Merriënboer, 1990).
The essential elements of traditional instructional methods are traditional note-taking during lessons and the extensive use of conventional practice problems (Paas, 1992). Both these activities impose large cognitive loads on novices (Boch & Piolet, 2004; Sweller, 1988) and consequently inhibit schema acquisition. Additionally, students often comment that learning in this way is ‘boring’ and so they do not invest the mental effort required for successful learning (R. E. Clark, et al., 2006; Paas, et al., 2005).

Conventional practice problems usually require means-end analysis which Sweller (1988) demonstrated to be a cognitively inefficient process which requires a large amount of working memory capacity without resulting in effective schema acquisition.

When viewed from the CLT perspective, the reasons why traditional instructional methods have restricted meaningful learning in physics have been made clear. In fact, Cooper (1998) notes that the methods of improving learning generated by CLT often directly contradict standard or ‘traditional’ practices.

3.3.2 CLT informs the design of an improved way to teach physics

CLT methods for improving learning that Cooper (1998) referred to, have been used to develop a new pedagogy for teaching physics which, it is hypothesised, will produce improved learning outcomes for high school students. This pedagogy will be referred to as the Tablet/Workbook Pedagogy (TWP) because its most obvious design elements include the use of a workbook and a Tablet PC. Detailed reasons for the choice of these key elements will be discussed in the remainder of this chapter. The three principles of CLT for optimising cognitive load (reduce intrinsic cognitive load, reduce extraneous cognitive load, increase germane cognitive load) suggested by Paas (1992) will underpin the discussion.

3.3.2.1 Description of the Tablet/Workbook pedagogy

A full description of the TWP is provided in Section 1.7. Briefly, the TWP is a teacher-centred model of Tablet PC use. A key feature of the TWP is the provision of a course workbook. Students will be given a printed workbook at the start of the term containing a course outline with all significant dates signalled, a concept map and a structured summary showing how the course elements are related, all the guided notes for the course, and sets of practice and revision problems. Full worked solutions
for all practice and revision problems will be freely available for students to download via the school’s e-learning portal (online content management system) as desired. The teacher will have an identical electronic copy of the workbook for display to the class and digital inking during lessons.

### 3.3.2.2 Reducing intrinsic cognitive load

Section 2.2.5.3 details methods of reducing intrinsic cognitive load and recommends that the instructional designer determines whether the intrinsic cognitive load present is at a manageable level to motivate the learners concerned or whether it is excessive and should be reduced. For high school students, the intrinsic cognitive load of the complex materials to be learned in physics is likely to be high and beyond a level that is motivational for most students. Consequently measures must be taken to reduce it.

The TWP will include the use of guided notes (Heward, 2003) to act as an advance organiser (Ausubel, 1968). The learning materials will be structured to incorporate simple to complex whole task strategies to introduce complex material gradually and examples involving increasingly complex real world applications will be included (van Merriënboer, et al., 2002). These methods will reduce the intrinsic cognitive load experienced by the students.

It should be noted that the use of guided notes in the TWP is distinctive from the researcher’s traditional pedagogy but the use of simple to complex whole task strategies is not.

### 3.3.2.3 Reducing extraneous cognitive load

Section 2.2.5.4 details methods of reducing extraneous cognitive load and the TWP will feature numerous design elements based on these recommendations.

The carefully structured guided notes (see Section 2.2.7.2) in the workbook will provide a skeleton of the course information with appropriate spaces for the annotation of notes. In a complex subject like physics, extensive foundational information must be delivered and complex concepts developed. Guided notes can help to effectively achieve this by reducing the extraneous cognitive load of structure search associated with traditional note taking (Narjaikaew, et al., 2009).
The workbooks will not contain redundant materials (see Section 2.2.5.4.4, the redundancy effect). Early drafts of the workbooks included ‘seductive details’ (Harp & Mayer, 1998) including text and images that it was thought would make the books more attractive to students (e.g. brief biographies and images of the scientists whose theories were being studied). These were trialled with physics classes not directly involved with this research project. Feedback from these students quite clearly indicated that they found this material distracting and so it was eliminated from the final workbooks. Harp & Mayer (1998) provide a firm basis in research for this decision.

The teacher’s electronic version of the workbook will be identical to the students’ printed workbooks and will be displayed during lessons as the teacher makes digital ink annotations. The exact congruence between the teacher’s presentation and the students’ workbooks will significantly reduce the extraneous cognitive load of split-attention (see Section 2.2.5.4.2, the split-attention effect). Split-attention is further reduced as the teacher annotates in the spaces in the guided notes and the students make annotations in the same spaces in their workbooks.

The teacher’s electronic workbook will contain functional hyperlinks to digital resources allowing immediate access to these resources without a distracting search process or a significant time lag. In this way, temporal contiguity will be enhanced. The hyperlinks will not be functional in the students’ printed workbooks but will be available on the e-learning portal for students to access as required.

Physics teachers typically make frequent use of explanatory diagrams. Multiple spatial elements must be coordinated for learning to occur with complex content (R. C. Clark, et al., 2006). Diagrams allow all the visual elements to be viewed simultaneously so that the spatial relationships between elements are explicit. In cognitive load terms, explanatory diagrams enhance spatial contiguity and reduce search (Larkin & Simon, 1987). This is true for both the TWP and for traditional pedagogy.

However, the TWP allows much more sophisticated interactive development of concepts through the use of diagrams. Simple content or high quality, prepared diagrams can be instantly displayed to students through the shared representation on the projector screen and in their workbooks. Complex concepts can be gradually and interactively developed by annotating over skeletal diagrams. This adds an element of
spatial contiguity and represents a reduced split-attention situation to that which is possible with traditional methods. Students also have the advantage of observing the teacher model the thinking process in real time (Harlow, Harrison, & Serbanescu, 2005).

As the students focus on the visual elements of an explanation, the teacher can provide a complementary verbal explanation. In this way the dual channel processing capability of working memory is harnessed to reduce extraneous cognitive load (see Section 2.2.5.4.3, the modality effect).

The use of guided notes means that the students and the teacher access the same structure so that all information will be readily accessible for reference or revision purposes. It also means that the knowledge representation of the course is shared by the teacher and all students. This should lead to a significant reduction in search compared with the situation when students take their own notes in a notebook.

The annotated guided notes in the teacher’s electronic document will provide a valuable resource for review purposes in class. Previous lessons can be instantly projected providing a shared representation for review with no split-attention. What is written in students’ workbooks will have the same structure and very similar annotations to that in the teacher’s workbook. Students who miss a lesson can have the lesson’s notes printed for them or emailed in full colour. In traditional classes, students who have missed a lesson often spend the first part of the next lesson ‘copying out’ the missed notes and missing that lesson’s content as well.

The TWP and traditional pedagogy treat conventional problem solving practice quite differently. Solving conventional problems is a key element of traditional pedagogy in physics, with the philosophy that ‘practice makes perfect’. However, the extraneous cognitive load of the solution process (means-end analysis) is detrimental to learning, particularly for novices (Sweller, 1988). CLT suggests that the provision of worked examples would be more beneficial for novices (Sweller & Cooper, 1985) (also see Section 2.2.5.4.1, the worked examples effect) but that the benefit would reduce with growing expertise and become counterproductive for experts (Kalyuga, et al., 2001) (see also Section 2.2.5.6, the expertise reversal effect).
With the TWP, the same set of conventional problems as was used with traditional pedagogy will be set for homework but the complete worked solutions to all problems will also be provided. Students will have three options: study the worked solutions to the problems; complete the problems in the conventional manner; or select some combination of these two options as their expertise increases. Students will be encouraged to begin by studying worked solutions and to gradually transition to completing conventional problems unassisted as their level of expertise increases. Thus, students will self-select the level of support they require with the TWP.

An aspect of pedagogy that is common to the TWP and to the researcher’s traditional teaching practice is the working of sample problems during class. In both cases, this is done via dynamic interactions between the teacher and the students as a solution is developed. In traditional classes, the teacher writes the solution to the problem on the whiteboard and with the TWP the teacher annotates the solution in digital ink on the Tablet PC. Differences between the pedagogies become obvious when the display of the problem statement is considered.

With traditional pedagogy, the teacher will sometimes simply identify the problem to be solved by writing a reference from the textbook on the board and the teacher and students will refer to their own textbooks. This splits attention between the textbook and the whiteboard. On other occasions the teacher will write the question in full on the board. This reduces split-attention by providing a shared view of the problem statement which can be annotated but it can be very slow and inefficient particularly if diagrammatic information must be conveyed. The teacher’s body may physically restrict the students’ view of the developing solution, adding to split attention as the student must hold the teacher’s explanatory comments in working memory until the visual information becomes visible.

With the TWP, the sample problems (including clear diagrams) will be printed in the workbook providing a shared representation of the information that the teacher and the students can annotate. Split-attention will be reduced because the students will view the teacher annotating the same material as they have in their workbook. The teacher’s body should not obstruct the students’ view of the developing solution (because the projector screen can be situated conveniently (see Figure 3.2 for a plan
view of the research classroom and for Figure 3.3 an image of the classroom with the TWP in use) further reducing split-attention.
Figure 3.2: Plan View of the teaching space where the research took place

Plan View of the Physics Laboratory at the Research Site

Legend
- Whiteboard
- Windows
- Sink
- Bench or Desk
- Chair
- Data Projector — mounted on bench
- Projector screen — mounted on ceiling
- Tablet PC

Figure 3.3: Image of the teaching space using the TWP
Many physics problems require calculations for which students often use their graphics calculator. These are quite complex devices and students, particularly novices can experience extraneous cognitive load as they operate them while working on a physics problem. Graphics calculator software can be installed on the Tablet PC and used to provide a shared representation of the calculation process to support students. Calculator screen shots can be inserted into the electronic guided notes for later reference or printed out for students to add to their notes.

### 3.3.2.4 Increasing germane cognitive load

Section 2.2.5.5 describes ways in which germane cognitive load may be increased to support and direct learners’ attention to ensure that critical information is attended to and that irrelevant information is filtered out in order to enhance schema acquisition. The TWP will incorporate several design elements based on these recommendations.

Attentional support can include signals and cues to highlight important information (Mayer & Moreno, 2003) (see also Section 2.2.5.5.3, provision of signals). Annotations of the guided notes will be made using coloured digital ink and highlighters to clearly direct the students’ attention.

Digital learning resources (e.g. simulations and animations) will be frequently accessed to dynamically link parallel representations of concepts (such as vectors and motion) as suggested by Roschelle (2000). Other software packages including TI Interactive graphics calculator software (Texas Instruments, 2008) and Logger Pro video and data analysis software (Vernier Software and Technology, 2009) will also be used to provide additional parallel representations of concepts (such as video, graphs and mathematical equations). These processes provide valuable germane cognitive load and promote the production of more elaborate schemas.

An aspect of pedagogy that is common to the TWP and to traditional teaching practice is the working of sample problems during class. This was discussed in relation to reducing extraneous cognitive load in the last section. However, this practice also includes elements of increasing germane cognitive load.

Dynamic interactions between the teacher and the students are used in both pedagogies to develop a solution to the sample problem. This imposes germane cognitive load by forcing students to take an active part in the development of the
solution. The amount of assistance offered by the teacher will vary depending on the teacher’s judgment of the students’ expertise and the feedback cues the teacher receives from the students. In this sense, there are elements of the completion problem effect (van Merriënboer & Krammer, 1990) (see also Section 2.2.5.5.1) and the guidance fading effect (Kalyuga, et al., 2001) (see also Section 2.2.5.5.2) present in both pedagogies.

However, several aspects of the Tablet PC usage in the TWP allow this pedagogy to more effectively impose germane cognitive load than the traditional pedagogy. When annotating the Tablet PC, the teacher can face the class and move around the classroom (with wireless technology). This will allow the teacher to maintain eye contact with students, more effectively directing their attention and monitoring behaviour than is possible when writing on a whiteboard (or even an interactive whiteboard). Also, with the problem statement clearly displayed in the guided notes, annotations with colour and highlighting can be used to further direct students’ attention to pertinent elements of the question.

The techniques described to increase germane cognitive load require students to invest the additional mental effort necessary for effective schema acquisition and meaningful learning. This is only likely to occur if students find the TWP motivating and they enjoy learning in this way (Paas, et al., 2005) (see also Section 2.2.5.5.4). Literature citing satisfaction surveys in educational contexts where Tablet PCs have been used suggests that students find Tablet PC pedagogies very engaging (Reboli, 2007) (see also Section 2.3.5.1).

3.3.3 Technology and Management Issues

3.3.3.1 Choice of hardware

The choice of computer hardware includes (in order of increasing expense): a desktop computer; a laptop computer; a Tablet PC; or a laptop/interactive whiteboard combination. A data projector is of course a necessary presentation tool in all cases.

The computer must be mobile, multimedia capable and have sufficient computing power to run the required software applications including: Microsoft Office applications; an Internet browser; Flash and Java scripts for scientific simulations and
animations; software to conduct video and data analyses, etc; and software allowing easy digital inking for entry of handwriting, equations and symbols.

Any relatively new computer will have sufficient processing power for these tasks. A desktop computer is ruled out through lack of mobility and a laptop computer does not allow easy digital inking. A Tablet PC and an interactive whiteboard both incorporate easy digital inking but the Tablet PC is a much more mobile device than an interactive whiteboard. This is an important consideration for a high school teacher who may teach in many different classrooms during the course of a week.

The Tablet PC has several other advantages over an interactive whiteboard: the teacher can face the class while annotating or move around the class with the computer to better interact with students whilst teaching (provided wireless links to the Internet and the data projector are available); and the teacher’s body does not obscure the students’ view of the annotations as they are made.

Use of a Tablet PC will allow the teacher to position him/herself out of the direct light beam of the projector. With an interactive whiteboard, the teacher and any students who use the board must stand in the path of the light beam. British authorities have identified this as a serious workplace health and safety issue (British Health and Safety Executive (HSE), 2007).

Use of the Tablet PC will allow the teacher to quite naturally write directly onto the Tablet PC screen to annotate the prepared electronic workbook in much the same way as writing on an A4 sheet of paper. The Tablet PC provides a finer annotation resolution to allow the teacher to write text, write equations and draw diagrams (N. Ward & Tatsukawa, 2003).

The Tablet PC has a highly developed inking capability built into its operating system (Windows XP Tablet edition or Windows Vista) which embeds inking directly into Microsoft Office documents and allows the annotations to follow the background document accurately as it is scrolled. Interactive whiteboard software is not so versatile and does not handle scrolling annotations so well.

For these reasons, the Tablet PC was selected as the most promising hardware to support learning in high school physics classes and the new pedagogy was named the Tablet/Workbook Pedagogy (TWP).
Tablet PCs are available in a range of screen sizes most frequently from 25cm to 35cm. The most popular size is 30cm because this combines good portability and battery life with a screen which is large enough for convenient digital annotation (i.e., it provides sufficient ‘screen real estate’).

3.3.3.2 Choice of software

The TWP is a teacher-centred model of Tablet PC use so the supporting software for this pedagogy will not be required to support networking between multiple Tablet PCs as would be the case for a student-centred model. Hence, software packages like Classroom Presenter and DyKnow Vision which have this capability (see Section 2.3.3.2) will not be considered.

The software chosen to display the guided notes in the TWP’s electronic workbook must support digital annotations in a way that is simple and quick for the teacher to operate. For instance, it must provide easy access to a menu of ink tools and it must allow quick and easy transitions between ink functions (e.g., pen, eraser, and highlighter). When the teacher accesses the pen tools while annotating, it is important that the process does not display distracting images to the students which may cause split-attention. Microsoft’s Office 2007’s Word, One Note, Journal and Powerpoint all have such a facility (Microsoft, 2009).

Figure 3.4 illustrates the unobtrusive ink tools menu in a Microsoft Word document. It also shows an example of an annotated page of guided notes.
As complex concepts are developed, the hardware/software combination must allow all the information required for understanding to be displayed simultaneously in a persistent manner to avoid split-attention and reduce cognitive load (R. E. Anderson, 2004). This is absolutely crucial for analytical subjects like physics and mathematics where multiple mutually referring pieces of visual information must be processed simultaneously for understanding (e.g., diagram, text, equations) but may not be such an important consideration for descriptive disciplines such as history (Harlow, et al., 2005).

In this respect, ‘display real estate’ is an important concept. The humble blackboard/whiteboard has a large display area so a considerable amount of information can be displayed simultaneously (e.g., a full derivation of a formula can be displayed at one time) and it is a very effective presentation tool from a split-attention viewpoint (Harlow, et al., 2005). The Tablet PC can also display information in an effective way by using the smooth scrolling capability of Microsoft Word, One Note or Ink tools.
Journal. Much of the previous page can still be visible while annotations are made at the top of a new page.

Slide-based software such as Microsoft PowerPoint can be used to create slides of guided notes for annotation during a lesson in a similar way to using over head projection (OHP) slides. However, slide based displays are not ideal. Single slides typically do not hold very much information so frequent transitions are necessary. Previous information is lost to the viewer when new information is displayed so split-attention occurs frequently (Harlow, et al., 2005).

Figure 3.5 shows annotated guided notes on a slide. A comparison with the annotated guided notes in Microsoft Word format (see Figure 3.4) shows that the inking tools menu is more obtrusive and less information is visible at one time. In fact, four slides are required to display the same information (see Figure 4.2).

**Figure 3.5: Screenshot of annotated guided notes in Microsoft PowerPoint (contrasts with Figure 3.4)**

A typical Microsoft PowerPoint presentation in which all the information on the prepared slides is predetermined does little to engage students’ attention, imposing little germane cognitive load. Even though ‘builds’ can allow successive points to be revealed one-by-one and ‘overlays’ can add successive layers of detail, the entire presentation must be predetermined before the lesson begins. In consequence, the
opportunity for interactivity is limited as the teacher cannot readily use this technology to respond to student input or questions. The phrase ‘death by PowerPoint’ suggests typical student responses to learning in this way (Felder & Brent, 2005).

In this research, Microsoft Word was chosen for the electronic workbook to create and display the guided notes. It is widely available and familiar to many teachers. Its digital inking tools are unobtrusive and easy to use. The use of a Tablet PC and the electronic workbook in Microsoft Word format empowers the teacher to teach interactively, smoothly scrolling through the information and gradually developing the course concepts through digital ink annotations on the basis of student responses. A digital copy of the lesson material can be stored and made available for later review or for access by students who missed the lesson.

### 3.3.4 Ethical issues

Teaching technologies should only be adopted if they have a positive (or at least a neutral) effect on student learning (Lambert & Williams, 1999). Although the effect of the TWP on student learning is not yet known, it is known that CLT suggests reasons to anticipate positive results and that literature reports evidence of high student satisfaction in instances where similar techniques have been used in similar contexts with some evidence of improved student motivation (Reboli, 2007) and improved learning outcomes (Hojjatie, et al., 2008). This research can, therefore, proceed ethically.

### 3.4 Summary

Traditional instructional methods have been less than optimal in developing the deep conceptual understanding necessary for students to successfully apply their knowledge of complex subject domains in novel situations (Sweller, et al., 1990). CLT was used to explain the reasons why traditional pedagogy has failed in this respect and to develop the TWP.

Lambert and William’s model (1999) for choosing a suitable educational technology was employed to determine that the combination of a Tablet PC with an electronic workbook stored in Microsoft Word format and used in a teacher-centred model was the best choice of technologies and pedagogies for teaching high school physics.
By clearly specifying the problems with existing educational practice in high school physics and using appropriate educational theory to develop an optimal solution, as suggested by R. E. Clark and Estes (1998), it is hypothesised that this educational reform will avoid many of the pitfalls noted by Dewey (1901) when he described typical cycles of educational reform.
Chapter 4:
Research Design

4.1 Epistemological Considerations

The need to establish a clear ontological and epistemological position at the outset of any research project is paramount as it determines the kind of knowledge the researcher believes can be attained from the research and how any conclusions made will be viewed by others.

It is critical that the researcher undergoes a metacognitive process to identify the innate assumptions about the nature of reality and of knowledge that he/she brings to the research. Each stage of the research process (design, data collection, interpretation, and reporting) is informed by assumptions. The researcher’s willingness to state these assumptions clearly in the reporting process will empower readers of the research report to make judgments about the validity of any claims made.

Michael Crotty (1998) suggests a scaffolding with which to organise the vast body of research theory in an attempt to provide a suitable structure for the research process. Crotty’s hierarchy is based on the organisers: epistemology (the theory of knowledge); theoretical perspectives (the philosophical stance providing a context for the process and grounding its logic and criteria); methodology (the strategy, action plan, process, or design underpinning the choice of methods and linking them to the desired outcomes; and methods (the techniques and procedures used to gather and analyse data).

The interplay amongst research paradigms, epistemology, methodology and research methods is summarised in Figure 4.1 as a flowchart for determining a preferred pathway through the research labyrinth. It represents the researcher’s visualisation of Crotty’s scaffolding.

Colour has been used to emphasise logically consistent links through the process although many variations are possible. The rainbow of the methods box indicates that
there is a gradient from the blue quantitative methods favoured by objectivists at the top, all the way through the spectrum to the pink qualitative methods favoured by subjectivists. It also indicates that the use of a combination of quantitative and qualitative methods (blended methods) is well established.

The pathway underpinning this research is shown by the red ellipses: an ontology of nominalism; an epistemology of constructionism; a theoretical perspective of interpretivism; causal-comparative research methodology; and a mixed methods approach with triangulation of quantitative and qualitative data from statistical analysis, a survey, interviews and focus groups.

The nature of the knowledge to be gained from this research must be considered in the context of an ongoing debate about educational research. A tension exists between the desire by teaching practitioners for pragmatic knowledge that is locally usable and the requirements of researchers for scientifically sound, generalisable knowledge that can add to the body of academic knowledge about the process of education (Sandoval & Bell, 2004).

There are long standing concerns amongst teaching practitioners regarding the real world applicability and validity of educational theory developed via experimental research (Brunswik, 1943; Lagemann, 2002). Similarly, the educational research community is uneasy about the perceived ‘credibility gap’ (Levin & O’Donnell, 1999) of much educational research because it has not been produced using accepted scientific methods.

Thorndike (1910), Snow (1974), Grinder (1989), Klausmeier (1988) and Salomon (1995) all note the need for educational research to be educationally relevant and to contribute to the improvement of education whilst also developing the theoretical underpinnings of complex learning and instruction. It is the aim of this research to produce such knowledge.

Whilst informed by nominalism, constructionism and interpretivism, the choice of methodology and methods will ultimately be highly dependent on the practicalities of what is possible given the inherent logistical and ethical constraints of the research context in which the researcher is also the teacher within a functioning high school classroom. Such issues will be considered in the next section.
Figure 4.1: Flowchart to determine a logical pathway through the research process
(researcher’s visualisation of Crotty’s (1998) scaffolding)

Start at the black diamond

Is there objective truth that we need to identify?

Yes

Ontology

REALISM

- Objective truth exists and awaits discovery
- Meaning and reality exist apart from the conscious observer

Epistemology

OBJECTIVISM

- Objective knowledge exists
- Our aim is to uncover it
- Research findings may claim objectivity or validity and generalisability.

Theoretical Perspectives

POSITIVISM

- Researchers aim to explore and exploit the construction of meaning.

Quantitative methods predominate

Methodologies

Experimental research

Survey research

Causal-comparative research

Phenomenological research

Ethnography

Grounded theory

Design experiment

Heuristic enquiry

Discourse analysis

Action research

Feminist standpoint

research

etc

No

Ontology

NOMINALISM

- There is no objective truth
- Meaning is constructed
- Objects exist but meaningful reality does not exist apart from the conscious observer
- Meaning is constructed out of the object by the subject
- Different people may construct different meanings from the same observation.

Epistemology

CONSTRUCTIONISM

- All understandings including your findings are 'constructions'.
- Be wary of any claims of objectivity, validity or generalisability.

Mixed Methods predominate

such qualitative and quantitative methods are acceptable.

No

Ontology

IDEALISM

- There is no objective truth
- Reality is subjective
- Meaning and reality do not exist apart from the conscious observer
- Meaning is imposed on the object by the subject
- Different people may construct different meanings from the same observation.

Epistemology

SUBJECTIVISM

- My 'meaning' is just as valid as anyone else's 'meaning'.
- Research findings cannot claim objectivity, validity or generalisability.

Researcher aims to explore and exploit the construction of meaning.

Researcher aims to walk in the shoes of the subject to make the same meaning.

Critical Methods predominates

Qualitative Methods

predominate

Critical inquiry

Feminism

Postmodernism

Functionalism

Indigenous perspectives

etc

How can this truth be identified?

On the subject and the object contribute to the construction of meaning?

Yes

Do the subject and the object contribute to the construction of meaning?

No
4.2 Research Methodology

4.2.1 Key requirements of a suitable methodology

The central research question which this research will address is “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy? If so, what is the basis for the improvement in learning theory?”

This study will address the question using empirical research where a systematic investigation is conducted in a sceptical and ethical manner (Cresswell, 2005). While no single method or collection of methods is universally appropriate, Guba and Lincoln (2006) argue that some methods are more suited to particular types of research than others.

As the research design is conceptualized, several key requirements will inform the selection of an appropriate methodology.

This research will be based in CLT and it is envisaged that its empirical results will inform this theory. An essential requirement of the selected methodology, therefore, will be that it is able to embed theory into the design and evaluation of the research and that it will allow the collection of data that may inform theory.

Another essential requirement is that the research can validly operate in the complex, naturalistic setting of a functioning classroom with the teacher as researcher. For the TWP to provide a credible alternative to traditional pedagogy in high school physics classes, its use must be tested in a real classroom and the research methods chosen must be able to validly assess its efficacy under these conditions.

Within this practical, educational context, the collection of both quantitative and qualitative data will be required to answer the research questions. It is envisaged that the research analysis will involve a close interplay of the quantitative and qualitative data to emerge with an integrated, holistic perspective of the use of the TWP in a high school physics classroom.

4.2.2 Selection of a suitable methodology

Tashakkori and Creswell (2007, p4) define ‘mixed methods’ as
“research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or programme of inquiry.”

The notion of ‘integration’ of methods is key to this definition. Genuine integration requires the findings of the quantitative and qualitative aspects of a study to be analysed, interpreted and reported so as to allow them to be ‘mutually illuminating’ (Bryman, 2007).

It is just such a close and ‘mutually illuminating’ integration of quantitative and qualitative methods that is envisaged for this research. Hence mixed methods will provide a suitable methodology for this research.

The collection of different types of data from different sources will also allow the process of methodological triangulation (Cohen, Manion, & Morrison, 1986) to be used to add to the validity of the results of the study as a whole.

4.3 Research Methods

Having established the key requirements of the research methodology and settled on a mixed methods approach, the specific methods to be used in this research can now be addressed. Two quantitative studies and a qualitative study will be performed using appropriate methods.

The first quantitative study will address the first part of the central research question, “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy?” An additional quantitative study and a qualitative study will address the second part of the central research question, “If so, what is the basis in learning theory?” by collecting students’ comments about their experiences and perceptions of learning with the TWP. The second quantitative study will provide data that is sufficiently structured to allow trends in students’ responses to be identified. The qualitative study will be sufficiently unstructured as to allow students to communicate responses that have not been anticipated by the researcher and may suggest new directions in theory (Gall, Gall, & Borg, 2007).
4.3.1 Study 1: Quantitative analysis of the effect of the TWP on learning outcomes

4.3.1.1 Requirements of the study

This study will address the first part of the central research question: “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy?”

The construct, ‘students’ learning outcomes’, will be operationalised as a variable quantifying students’ scores on the approved QSA physics tests that form part of the usual assessment programme for physics students at the research site (Gall, et al., 2007).

A quantitative method is required to validly link the cause (the introduction of the TWP) with the effect (changes in students’ learning outcomes) in order to test the first two research hypotheses:

**Hypothesis 1:** Learning with the TWP will lead to an improvement in all students’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) relative to their scores when they learned with traditional pedagogy.

**Hypothesis 2:** Boys’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) will show greater improvements after first learning with traditional pedagogy and then with the TWP than the girls’ physics assessment scores do.

4.3.1.2 Choice of research methods

Two methods were considered: experimental research (also known as natural scientific research) and causal-comparative research (non-experimental, ex post facto research) (Gall, et al., 2007). The former provides the most rigorous test of cause and effect for quantitative data but has very strict demands on control of variables and randomization of the intervention and control groups (Gall, et al., 2007). The latter can accommodate situations where the strict control of variables is not possible but it does so at the expense of the strong link between cause and effect. The results of such research must be viewed more tentatively (Gall, et al., 2007).
Whilst experimental research would provide stronger cause-effect links for any research findings, the rigorous requirements to establish this link cannot be met in the functioning classroom context envisaged for this research. There is no intention to change this context since Thorndike (1910), Snow (1974) and Grinder (1989) all argue for the superiority of a real classroom setting over a laboratory setting for evaluating educational initiatives. Hence, causal-comparative research methods will be used and issues of validity will be closely monitored in order to strengthen, as much as is possible, any cause-effect claims that may result from this research as the research hypotheses are tested. Even so, the safest interpretation of this type of research study is that it provides evidence suggesting that a cause-effect relationship exists (Gall, et al., 2007).

4.3.1.3 Causal-comparative research

A causal-comparative study, like an experiment, commences with the statement of a research hypothesis or question. The hypothesis will be the result of background experience, previous research findings or an analysis of theory and will relate a cause to an effect with respect to an observable phenomenon of interest. It should then continue with attempts to state and test alternative hypotheses that might explain any observed differences between the groups (Gall, et al., 2007).

The next step in a causal-comparative study is to form the comparison groups and this is the key factor that distinguishes this type of study from experimental research and usually determines which approach will be selected. In an experimental study, a randomized selection process would occur. However, in a causal-comparative study, comparison groups would be selected from pre-existing groups that had naturally occurring variations in the parameter of interest or were intact groups that have already been established administratively and randomization of the research participants is not possible (Gall, et al., 2007).

In a causal-comparative study, a wide range of measuring instruments can be used to collect data about presumed cause-and-effect relationships. Interviews, questionnaires, standardized tests, etc, are all useful tools (Gall, et al., 2007).

Many of the same data analysis tools used for experimental studies are appropriate for use in analysing causal-comparative data. Descriptive statistics for each comparison
group (e.g. group mean and standard deviation) would be computed and an appropriate significance test would be applied. The use of the paired-samples t-tests for the significance of the difference between two sample means taken at different points in time is appropriate when these three data set requirements are satisfied: scores form an interval or scale ratio; scores are normally distributed; and the variances for the two populations are equal. If these requirements are not met, then a nonparametric test (Mann-Whitney U test or the Wilcoxon signed rank test) is more appropriate (Gall, et al., 2007).

The internal validity of an experiment or causal-comparative study is dependent on the extent to which ‘extraneous’ or ‘confounding’ variables (any variable other than the treatment variable that can affect the experimental outcome) can be identified and controlled (Gall, et al., 2007). Examples of confounding variables include: ‘history’ where the observed effect may be due to an event other than the treatment which occurs between the pre-test and the post-test; ‘maturation’ where the observed effect may be due to respondents’ growing age or experience rather than the treatment; ‘testing’ where a test is administered a number of times and the respondents’ growing familiarity with a test can affect the outcome; and ‘instrumentation’ where an effect may be due to a change in the measuring instrument between pre-test and post-test (Campbell, Stanley, & Gage, 1963; Cook & Campbell, 2004).

In this study, the most likely confounding variable is ‘maturation’ as students will undoubtedly mature and gain experience in sitting physics tests over the two year period of the study. To account for this effect, a control group will be established which does not receive the intervention. Comparisons made for this group will establish a benchmark quantifying the effect of maturation alone.

Finally, the interpretation of causal-comparative findings must be considered. If alternative hypotheses have been formulated and tested, then the results of these tests will inform the claims that can be made about the central hypothesis. At best, the study will provide evidence suggesting that a cause-effect relationship exists. Such an indicative causal-comparative study could be followed up by a controlled experiment to verify the relationship (Gall, et al., 2007).
4.3.2 Study 2: Quantitative analysis of students’ perceptions of learning with the TWP

4.3.2.1 Requirements of the study

This study will address the second part of the central research question: “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy? If so, what is the basis for the improvement in learning theory?”

This study is designed to collect quantitative data about students’ experiences with learning with the TWP and their attitudes to these experiences.

4.3.2.2 Choice of research methods

A survey will be used to elicit students’ responses on Likert scales to predetermined questions (Gall, et al., 2007). Such a survey can be an effective research tool provided it is well designed and the anonymity of respondents is assured (Gall, et al., 2007).

Although the majority of questions will be in closed form where the question only allows prespecified responses, some questions will be in open form where respondents are free to make any response they wish (Gall, et al., 2007). The latter form of questions will provide qualitative data for the third study.

4.3.3 Study 3: Qualitative analysis of students’ perceptions of learning with the TWP

4.3.3.1 Requirements of the study

This study will address the second part of the central research question: “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy? If so, what is the basis for the improvement in learning theory?”

It will also test the third research hypothesis:

Hypothesis 3: The students’ experiences of learning with the TWP, as expressed in their qualitative comments, will exhibit improved cognitive conditions of learning.
This study will collect qualitative data about students’ perceptions of learning with the TWP. It is anticipated that this data will add a rich dimension to the research by linking any observed effects back to CLT or possibly suggesting new directions for theory.

### 4.3.3.2 Choice of research methods

Semi-structured interviews and focus group discussions (Gall, et al., 2007) will be used to establish a dialogue between the researcher and the students based on, but not restricted to, a set of scripted questions.

All students will self-select either an individual interview or a focus group discussion. The interactions among participants in focus groups may stimulate them to state attitudes or perceptions that they may not be comfortable expressing if they were interviewed individually (Gall, et al., 2007).

Additional qualitative data will be collected through the ‘open’ survey items in the survey from the second study (see Section 4.3.2.2).

In each case, the researcher will clearly indicate that it is students’ honest responses that are valued and that no positive or negative ramifications will result from their responses.

### 4.4 Issues of research validity

The concept of validity addresses the authenticity of the research findings and questions the likelihood that the stated interpretation of the results accurately reflects the truth of the theory and hypothesis being investigated (Hoadley, 2004). Two questions arise: is the method used valid and appropriate to the research context?; and have appropriate interpretations been drawn from the collected data? (Guba & Lincoln, 2006).

#### 4.4.1 Method validity

In Section 4.3 appropriate research methods were carefully selected: causal-comparative research for the first study; survey research for the second study; and interviews and focus groups for the third study. Provided these standard methodologies are conducted appropriately throughout the research, method validity will be assured.
Method validity issues for the causal-comparative study are discussed in Section 4.3.1.3.

Gall, Gall and Borg (2007) suggest factors to consider to ensure method validity in survey research. For this study, there will be no sampling bias as the whole population (i.e. all students in the cohort) will be surveyed. Anonymity of the respondents will be assured and the researcher will clearly indicate that it is students’ honest responses that are valued and that no positive or negative ramifications will result from their responses. Survey items will be carefully constructed and will pose questions in both the positive and negative sense. Although it will not be possible to formally pilot the survey with students, the survey will be assessed for clarity and age-appropriate literacy requirements.

Gall, Gall and Borg (2007) also suggest factors to consider to ensure method validity in interviews and focus groups. For this study, there should be no sampling bias as the whole population (i.e. all students in the cohort) will be invited to participate. However, as participation will require the commitment of some personal time, some students may choose not to participate, introducing an element of bias.

The researcher, who is also the teacher, will conduct the discussions so there will be no anonymity of participants at this level although no identifying details will appear in the research data. To minimise issues of reflexivity (see Section 4.4.5) the researcher will clearly indicate that it is students’ honest responses that are valued and that no positive or negative ramifications will result from their responses.

### 4.4.2 Interpretive validity

Interpretive rigor is much more difficult to define and assure. This is particularly so with respect to the causal-comparative study and so the following discussion will focus on interpretive validity in this context.

#### 4.4.2.1 The ‘CAREful’ criteria

Levin and O’Donnell (1999) identified four criteria which can be used to judge whether evidence of an intervention is credible: the intervention must be compared to an appropriate comparison group; the outcomes produced by the intervention must be replicable; the intervention must be directly related to the outcome i.e. the intervention
must actually produce the effect; and alternative explanations for the effect must be considered. These four criteria have been referred to as the components of ‘CAREful’ intervention research (Comparison, Again and again, Relationship and Eliminate).

Each of the four ‘CAREful’ components will now be discussed.

4.4.2.1 Comparison

In the complexity of naturalistic classroom situations, control groups are difficult to engineer due to resource limitations and moral/ethical problems (Brown, 1992). Children and schools are rarely organized for the benefit of a researcher and it would be unethical to expect this to be so. When a perfect control group cannot be engineered, it is desirable that the most ‘obvious’ variables be considered in establishing a realistic control group.

Considerable care will be taken in this study to identify and control these ‘most obvious variables’. For instance, the control group and the intervention group should learn from the same curriculum, with the same teacher at the same school and be assessed using the same testing instruments.

4.4.2.1.2 Again and again

The outcomes produced by the intervention must be replicable. The accepted validity of research results increases if the same results have been found by other researchers or in other contexts.

4.4.2.1.3 Relationship

There must be a clear link between the intervention and the outcomes i.e. the intervention must actually produce the effect. This is a weakness of causal-comparative research methods (Gall, et al., 2007). However, one way to achieve this is to use appropriate theory to predict the outcome of the proposed intervention.

4.4.2.1.4 Eliminate

It is the responsibility of the researcher to carefully consider alternative explanations for the observed results. These must be eliminated to firmly establish the link between the intervention and the effect.
4.4.3 The Bartlett Effect

Evidence cited in qualitative research often includes examples such as portions of edited transcripts selected from a vast array of potential samples to illustrate a point. The sheer volume of qualitative data collected during interviews and focus groups means that the researcher must be selective in what evidence is cited. Unfortunately, researchers have a natural tendency to be selectively attentive to data that conform to his/her expectations. This concept of selective attentiveness is known as the Bartlett Effect (Bartlett, 1932) and can threaten the credibility of qualitative research (Dede, 2004).

4.4.4 The Hawthorn Effect

Another issue of validity relates to the possibility that the Hawthorn Effect (Landsberger, 1958) may be in play i.e. that any intervention tends to have a positive effect simply because of the attention paid to the subject by the researcher(s). In educational research, the participating teacher and students are often given special attention by a visiting researcher and this provides the perfect conditions for the Hawthorn Effect to occur (Gall, et al., 2007).

4.4.5 Reflexivity

The ‘teacher as researcher’ model used in this research requires a consideration of reflexivity where the researcher must reflect critically on his/her own role in the research setting (Guba & Lincoln, 2006).

With the teacher as researcher, research can be prone to: hypothesis guessing where the subjects try to guess what ‘right answer’ the researcher really wants; researcher expectancies where the researcher consciously or unconsciously communicates the ‘right answer’ to students; and uneven treatment where the researcher does not treat each subject in exactly the same way (Trochim, 2000).

Conversely, having the researcher as the teacher can actually add validity to the research (Hoadley, 2004). It gives the researcher a valuable emic perspective (Fishman, et al., 2004) because the insights are provided by someone who is intimate with all aspects of the intervention and his/her insights are therefore extremely valuable.
4.4.6 Triangulation of results

Two aspects of methodological triangulation are described by Cohen, Manion & Morrison (1986) and will be built into this research to add to its validity. ‘Within methods’ triangulation occurs when a study is replicated to confirm its reliability. ‘Between methods’ triangulation occurs when more than one method is used to obtain results.

4.4.7 External validity

The relevance of the research findings for others who may read them is important. External validity is related to the extent to which the results of the research can be generalized to other contexts (Bracht & Glass, 1968).

4.5 Research Ethics

This research is set in the context of normally functioning Year 11 and Year 12 physics classrooms at the research site and has the teacher as researcher. This raises a number of ethical considerations which it is necessary to address (Guba & Lincoln, 2006). Paramount at all times in the mind of the researcher must be the intention that no student is disadvantaged by participation in this research project and that no student feels compelled to provide a response that they anticipate will please the teacher.

4.6 The Contrasted Pedagogies

The primary purpose of this research is to contrast the effectiveness of teaching high school physics using traditional pedagogy and using the Tablet/Workbook pedagogy. A third pedagogy, the Tablet/PPT (Tablet/PPT Pedagogy) will also be considered as an alternative tablet pedagogy.

4.6.1 Traditional pedagogy

The essential elements of traditional pedagogy in teaching high school physics are traditional note-taking during lessons and the extensive use of conventional practice problems. Classroom discussions and activities are summarised by the teacher who writes notes on a whiteboard and these are recorded as deemed appropriate by the students who take notes in their notebooks. Additional resource sheets are handed
out as required and their organisation is the responsibility of the individual student. Limited use is made of computer technology to occasionally display animations or web information or for data analysis.

4.6.2 Tablet/Workbook Pedagogy

The TWP is described in detail in Section 1.7. Briefly, the TWP is a teacher-centred model of Tablet PC use. A key feature of the TWP is the provision of a course workbook. Students will be given a printed workbook at the start of the term containing a course outline, a concept map, a summary showing how the course elements are related, all the guided notes for the course, and sets of practice and revision problems. Full worked solutions for all practice and revision problems will be freely available for students to download via the school’s e-learning portal (online content management system) as desired. The teacher will have an identical electronic copy of the workbook for display to the class and digital inking during lessons.

4.6.3 Tablet/Powerpoint Pedagogy

The (Tablet/PowerPoint Pedagogy) (Tablet/PPT Pedagogy) provides an alternate model for teaching physics with a Tablet PC. It is also a teacher-centred model like the TWP but no workbook is provided. Instead, handouts of the relevant slides (up to 6 to a page) are provided at the start of each new section of work (approximately weekly). As the teacher teaches, dynamically interacting with the students, he/she annotates the guided notes on the slides while the students do the same thing on their handouts (see Figure 4.2 and Figure 4.3). It is the students’ responsibility to organise the handouts along with any other records of the lesson that they choose to keep.

The guided notes are organised in slide format and presented in an attractive way using coloured backgrounds and sometimes including additional related images. The teacher uses Microsoft PowerPoint software which provides easy inking tools but they are accessed via a tool bar menu that intrudes onto the screen (see Figure 3.5). The nature of the slide format (in contrast to the book format of the TWP) leads to the presentation of information in ‘chunks’ and typically less information is contained on one screen. For example, contrast Figure 3.4 and Figure 4.2) which display the same amount of information in one screen for the TWP and over 4 slides for the Tablet/PPT Pedagogy. There is also less direct correspondence between the projected image and
Reading a micrometer

Animation: Introduction to Use of a Micrometer Gauge

• The rotating screw section has markings that show hundredths of a millimeter.

Figure 4.2: Series of slides showing annotated guided notes in Tablet/PowerPoint Pedagogy
(shows the same information as shown in Figure 3.4 for TWP)
Reading a micrometer

Animation: to practice reading a micrometer scale

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Reading a micrometer

**Homework:**
Use the link on the e-learning portal to access the Animation to practice reading a micrometer scale and practice until you get three measurements right in a row.
4.7 Assuring research validity

In a real classroom setting, there are many variables which may impact the outcome of the research. As it is not possible to clinically control them all, causal-comparative research methods require as many of the highly significant variables as possible to be controlled in order to strengthen the cause-effect link. The other issues of research validity raised in Section 4.4 will also be addressed.

4.7.1 Control of student attributes

Ideally, students should be randomly selected into research cohorts to ensure that differences in aptitude, work ethic, or motivation are randomized. However in a real school setting this was not possible and the research cohorts are simply ‘convenience samples’ of all those students studying physics in Year 11 (Cohort 2) and Year 12
(Cohort 1) at the research site during 2007. Therefore it is not possible to control
student attributes across research cohorts.

This limits the types of comparisons of scores that can be validly made. No
comparisons of scores will be made across cohorts. Comparisons will be made only
within a cohort at two points of time (pre-intervention and post-intervention).

4.7.2 Control of assessment standards

Since comparisons of students’ assessment scores are to be made, it is critical that the
content and standard of the assessment instruments remains uniform across the
intervention cohorts and the control group. This is also important for ethical reasons
and to satisfy parental and school expectations.

Throughout the research project, the teacher will be required to cover all aspects of
the QSA physics course to the required depth and to set examinations of a standard
acceptable to the QSA. For this reason, the usual depth and breadth of course
coverage will be maintained throughout the research project and the examinations
that students involved in the study participate in will be of a very similar standard and
content to those completed by all other groups of students whether involved in the
research or not. In other words, the fact that the students and teacher are involved
with the research project will not alter the scope, sequence, assessment or standards
of the course.

By establishing these external benchmarks, this critical variable will be controlled and
the validity of the research will not be compromised by any variability in the standards
of assessment.

4.7.3 Control of cohort’s teacher effect

It is hypothesised the cohort’s teacher will be an important variable to control.
Unfortunately, the allocation of teachers to classes in schools is seldom determined by
the requirements of the research design.

To test the hypothesis that the teacher is indeed a critical variable to control, three
cohorts which are not part of the current study but for which there is historical data
have been selected. Cohort 3 was taught by Teacher X using traditional pedagogy in
Year 11 (2002) and by Teacher Y (the researcher) using traditional pedagogy in Year 12
The same was true for Cohort 4 in 2003/2004. The third cohort, Cohort 5, had the same teacher (Teacher Z) who taught using traditional instruction techniques in both Year 11 (2000) and Year 12 (2001). This was the most recent cohort which was taught by the same teacher for the two years of the course.

Comparisons of scores before and after the changes in teacher will be for Cohorts 3, 4 and 5 to determine if teacher is a significant variable which must be controlled.

### 4.7.4 Control of the teaching space

The same teaching space will be used for all cohorts. This is the physics laboratory at the research site and its physical arrangement is shown in Figure 3.2. The diagram shows the most frequent placement of the Tablet PC, the data projector and the projector screen for the TWP. When traditional pedagogy was used, the only difference in physical arrangement was the absence of the Tablet PC, the data projector and the projector screen.

### 4.7.5 The choice of a control group

In the real school setting of this research, only one physics class is timetabled at each year level. Therefore, control groups could not be run in parallel with the intervention groups. Instead, a control group has to be selected from previous cohorts of students. Ideally the control group should have had the same teacher who teaches the intervention groups (the researcher) and it should have learned with traditional pedagogy for the two years of the physics course. However, no such group was available.

Assuming the hypothesis that the group’s teacher is an important variable to control (suggested in the previous section) proves to be correct, Cohort 5 (the 2000/2001 cohort) will be used as the control group because this is the most recent cohort which was taught by the same teacher (Teacher Z) using traditional pedagogy for the whole two years of the physics course.

The requirement that the course content and assessment standards be consistent (see Section 4.7.2) means that a cohort from previous years can validly be used as a control group, provided that all the known critical variables (e.g. class teacher) are controlled.
4.7.6 Addressing the ‘CAREful’ criteria for research validity

Section 4.4.2.1 described the ‘CAREful’ criteria for research validity. Each of these issues will be addressed in this section in the context of this research to describe how research validity will be assured.

4.7.6.1 Comparison

For validity, the intervention group must be compared to an appropriate comparison group. A suitable control group has been identified and will be used to establish benchmarks for the research.

4.7.6.2 Again and again

For validity, the outcomes observed for the intervention cohort must be replicable. This research includes two intervention cohorts in order to establish whether the results of the first intervention are replicable with a second cohort. The two interventions will occur at different stages of the course.

4.7.6.3 Relationship

For validity, it must be possible to directly relate the intervention to the outcome i.e. the intervention must actually produce the effect. Having two intervention cohorts will allow the link between the intervention and the effect to be more clearly established. The intervention is the same for the two cohorts but its timing will be different. For Cohort 2, the instructional methods change from traditional pedagogy to the TWP at the start of Year 11 Semester 2. For Cohort 1, the same instructional change will be made but not until the start of Year 12 Semester 1. If an improvement in scores occurs only at the time of the intervention for each cohort, the link between the intervention and the effect will be clearly established.

Methodological triangulation (Cohen, et al., 1986) of the results of Study 1 with evidence from Studies 2 (survey) and 3 (interviews/focus groups) may serve to strengthen the link between the intervention and the effect. If the students’ responses resonate with the aspects of CLT on which the intervention is designed, then the link between intervention and effect will be strengthened.
4.7.6.4 Eliminate

For validity, alternative explanations for the observed effect must be considered. An important alternative explanation for any improvements in students’ assessment scores observed in Study 1 is that the improvement may be due to maturation i.e. the students’ growing maturity and experience with physics may be sufficient to explain the observed improvement. This possibility will be tested by analysing the control group’s data over the same time period. The control group did not experience the intervention so any observed trends in scores for this group will provide an indication of what can be expected simply through maturation.

Students’ responses in the survey, interviews and focus groups, may also suggest alternative explanations for the observed effects.

4.7.7 Addressing the Bartlett Effect

The best way to defend against the Bartlett Effect (see Section 4.4.3) adversely affecting research validity is for the researcher to be aware that it exists and to reflect metacognitively on his/her evidence-selection process to assure that no bias occurs.

4.7.8 Addressing the Hawthorn Effect

Because all students studying physics at the research site will be involved in this research, and because it spans a two year period, it is unlikely that use of the TWP will be perceived as ‘special treatment’ and the incidence of the Hawthorn Effect (see Section 4.4.4) is unlikely.

Even so, the extent to which the Hawthorn Effect has an impact on research validity in this context can be allayed by using theory to predict the outcomes of the research interventions. If the predicted results are found, particularly if some predictions are for negative or neutral results as well as for positive results, then the Hawthorn Effect can be discounted.

In this research Interventions 1 and 2 are timed to occur at different stages of the course. CLT predicts that improvements in far transfer scores for each cohort should coincide with the timing of the intervention (i.e. the change from traditional pedagogy to TWP) for each cohort. Specifically, for Cohort 1, no improvement in far transfer scores should occur until Year 12. For Cohort 2, an improvement in far transfer scores
should occur in Year 11, Semester 2 and these elevated scores should be maintained but probably not improved in Year 12. If these effects (both positive and neutral) are observed at the predicted times but not at other times, the Hawthorn Effect can be discounted.

4.7.9 Addressing reflexivity

The effect that reflexivity may have on research validity was discussed in Section 4.4.5. In playing the dual role of researcher and teacher, the researcher must guard against these issues arising, by being aware that they are of concern and ethically monitoring her own behaviour, taking care to guard against possible hypothesis guessing and uneven treatment of participants. Students will be explicitly reassured that there are no right answers and that it is his/her opinion/perspective that is important, and that no consequences will result from any comments they make. Anonymity will be assured in responses to the survey and no identifying information will be recorded in the research records.

The Head of the Secondary School is delegated as an independent person at the research site to whom any concerns that students or parents have regarding the conduct of the research can be addressed. Additionally, an independent person at the university will also be nominated.

4.7.10 Addressing triangulation

This research will allow within methods triangulation in the causal-comparative study because the intervention will occur twice; once for each of two cohorts but at different stages of the course. Between methods triangulation will also be possible because several sets of data, both quantitative and qualitative, will be collected and analysed to determine if consistent themes are present.

4.7.11 Addressing external validity

Although the outcomes of the causal-comparative study relating use of the TWP to students’ learning outcomes will necessarily be tentative (Gall, et al., 2007), they will be strengthened if verified through triangulation with the qualitative data and predictions from CLT. CLT may also provide guidance as to what other contexts this research may reasonably be expected to inform.
4.8 Research plan

The research plan detailing the way in which each of the three research studies will be conducted in order to validly answer the research questions and test the research hypotheses will be discussed in this section.

The research will be conducted over a three year period (2006, 2007, and 2008) in the context of the researcher’s physics classes. Two cohorts of students (Cohorts 1 and 2) will experience the TWP intervention and will be the primary focus of the research. Cohorts 3, 4 and 5 will be considered to determine a valid control group.

4.8.1 Conditions for research cohorts

4.8.1.1 Conditions for Cohort 1

Cohort 1 is the physics class of 2006/2007. The researcher will teach Cohort 1 during 2006 as they complete Year 11, using traditional instructional methods. This class will continue into Year 12 in 2007 with the same teacher (the researcher), the same cohort and the same classroom. However, for that year, the group will be instructed using the TWP.

4.8.1.2 Conditions for Cohort 2

Cohort 2 is the physics class of 2007/2008. The researcher will teach Cohort 2 using a variety of methods during 2007 as they complete Year 11.

During Term 1 2007 (Year 11), Cohort 2 will learn with the Tablet/PPT Pedagogy. At the same time, the TWP will be trialled with Cohort 1 during their Term 1 2007 (Year 12). The teacher’s experience and feedback from students in Cohorts 1 and 2 at the end of Term 1, 2007 will be used to assess which Tablet PC pedagogy provides a better approach. The successful Tablet PC pedagogy will be adopted, for the remainder of the study.

It is anticipated that the successful Tablet PC pedagogy will be the TWP and so the remaining research plan will be constructed on the assumption that this is the case and changed if required as data becomes available.

During Term 2 2007 (Year 11), the researcher will teach Cohort 2 with traditional instructional methods. This will be done to provide students with an experience of
learning in a traditional classroom so that they can make comparisons to learning with the Tablet/PPT Pedagogy and the TWP.

During Terms 3 and 4 (Semester 2 Year 11) 2007, Cohort 2 will learn with the TWP, assuming it proves to be the most successful pedagogy identified by students as a result of their experiences in Term 1. This will continue throughout 2008 (Year 12) for this cohort.

4.8.1.3 Conditions for Cohort 5 (the control group)

Cohort 5 is the physics class of 2000/2001. Teacher Z taught Cohort 1 during 2000 as they completed Year 11, using traditional instructional methods. This class continued into Year 12 in 2007 with the same teacher (Teacher Z), the same cohort and the same classroom.

4.8.1.4 Conditions for Cohort 3

Cohort 3 is the physics class of 2002/2003. Teacher X taught Cohort 3 during 2002 as they completed Year 11, using traditional instructional methods. In Year 12 in 2003, Teacher Y (the researcher) taught this class using traditional instructional methods but with the same cohort in the same classroom.

4.8.1.5 Conditions for Cohort 4

Cohort 4 is the physics class of 2003/2004. Teacher X taught Cohort 4 during 2003 as they completed Year 11, using traditional instructional methods. In Year 12 in 2004, Teacher Y (the researcher) taught this class using traditional instructional methods but with the same cohort in the same classroom.

4.8.2 An overview of the research plan

Table 4.1 provides an overview of the research plan based on the assumptions that the TWP is the Tablet PC pedagogy adopted and the control group is Cohort 5 (the 2000/2001 cohort).
### Table 4.1: Overview of research plan

#### a) Intervention Plan

<table>
<thead>
<tr>
<th>Year</th>
<th>Course Stage</th>
<th>Course Stage</th>
<th>Pedagogy (Teacher)</th>
<th>Pedagogy (Researcher)</th>
<th>Comments</th>
<th>Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Year 11</td>
<td>Term 1</td>
<td>Traditional</td>
<td>Tablet/Workbook</td>
<td></td>
<td>Provides baseline data for Cohort 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 2</td>
<td>Traditional</td>
<td>Tablet/PowerPoint + handouts</td>
<td></td>
<td>Quantitative data re learning outcomes: Students' assessment data (collected as part of the normal QSA Assessment Programme)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 3</td>
<td>Tablet/Workbook</td>
<td>Traditional</td>
<td></td>
<td>Quantitative and Qualitative data re students' perceptions: At the end of Term 4, all students complete a survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 4</td>
<td>Table/Workbook</td>
<td>Tablet/Workbook</td>
<td>Best Tablet PC pedagogy applied to both cohorts.</td>
<td>Qualitative data re students' perceptions: At the end of Term 4, all students participate in either an individual interview or a focus group discussion</td>
</tr>
<tr>
<td>2007</td>
<td>Year 12</td>
<td>Term 1</td>
<td>Tablet/Workbook</td>
<td>Traditional</td>
<td></td>
<td>Quantitative data re learning outcomes: Students' assessment data (collected as part of the normal QSA Assessment Programme)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 2</td>
<td>Tablet/Workbook</td>
<td>Traditional</td>
<td></td>
<td>Quantitative data re learning outcomes: Students' assessment data (collected as part of the normal QSA Assessment Programme)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 3</td>
<td>Tablet/Workbook</td>
<td>Tablet/Workbook</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 4</td>
<td></td>
<td>(Researcher)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Year 12</td>
<td>Term 1</td>
<td>Tablet/Workbook</td>
<td>Continued application of best Tablet PC pedagogy to Cohort 2.</td>
<td></td>
<td>Quantitative data re learning outcomes: Students' assessment data (collected as part of the normal QSA Assessment Programme)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Term 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>Year 11</td>
<td>Traditional (Teacher Z)</td>
<td></td>
<td></td>
<td>Provides Control group data for comparison with intervention groups' data.</td>
<td>Quantitative data re learning outcomes: Students' assessment data collected as part of the normal QSA Assessment Programme</td>
</tr>
<tr>
<td>2000</td>
<td>Year 12</td>
<td>Traditional (Teacher Z)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>Year 12</td>
<td>Traditional (Teacher Z)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
b) Plan for selection of control group

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Year</th>
<th>Course Stage</th>
<th>Pedagogy</th>
<th>Comments</th>
<th>Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 3</td>
<td>2002</td>
<td>Year 11</td>
<td>Traditional</td>
<td></td>
<td>Provides comparison data to determine if ‘teacher’ is a variable to be controlled</td>
</tr>
<tr>
<td></td>
<td>2003</td>
<td>Year 12</td>
<td>Traditional</td>
<td></td>
<td>Provides comparison data to determine if ‘teacher’ is a variable to be controlled</td>
</tr>
<tr>
<td>Cohort 4</td>
<td>2003</td>
<td>Year 11</td>
<td>Traditional</td>
<td></td>
<td>Provides comparison data to determine if ‘teacher’ is a variable to be controlled</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>Year 12</td>
<td>Traditional</td>
<td></td>
<td>Provides comparison data to determine if ‘teacher’ is a variable to be controlled</td>
</tr>
<tr>
<td>Cohort 5</td>
<td>2000</td>
<td>Year 11</td>
<td>Traditional</td>
<td></td>
<td>Provides Control group data for comparison with intervention groups’ data.</td>
</tr>
<tr>
<td>(Control Group)</td>
<td>2001</td>
<td>Year 12</td>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.8.3 Study 1: Quantitative analysis of the effect of the TWP on learning outcomes

Study 1 is a causal-comparative study of quantitative data from students’ QSA assessment scores (see Section 4.3.1). It will test the first two research hypotheses:

**Hypothesis 1:** Learning with the TWP will lead to an improvement in all students’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) relative to their scores when they learned with traditional pedagogy.

**Hypothesis 2:** Boys’ physics assessment scores (including global scores, scores on near transfer tasks and scores on far transfer tasks) will show greater improvements after first learning with traditional pedagogy and then with the TWP than the girls’ physics assessment scores do.
4.8.3.1 Assessment criteria

Three assessment criteria or general objectives are mandated by the QSA, formerly the Board of Senior Secondary School Studies (BOSSS), in the 1995 Physics Senior Syllabus (current at the time of this research). They are Knowledge of Subject Matter (K), Scientific Processes (SP) and Complex Reasoning Processes (CRP).

The K criterion assesses the student’s ability to recall and apply content in simple rehearsed situations (BOSSS Queensland, 1995). The SP criterion assesses the student’s ability to collect, organise, process, evaluate and communicate primary and secondary data in a guided and rehearsed way (BOSSS Queensland, 1995). These criteria essentially assess a student’s ability to complete near transfer tasks (Mayer & Greeno, 1972).

The CRP criterion refers to the assessment of challenging higher order cognitive processes. In this criterion, students are required to solve challenging, multi-concept, multistep tasks which are set in novel contexts. They are also required to use creative, critical thinking to make logical judgments (BOSSS Queensland, 1995). These are essentially far transfer tasks (Mayer & Greeno, 1972).

To determine a student’s global standard at the end of the two year course, the student’s individual achievement in each of the three criteria must be combined according to the QSA’s guidelines. Where the student’s achievement is consistent across all three criteria, this is a simple process. However, where the student has achieved different standards in the three criteria, trade-off rules must be applied. A slight deficiency in one of either the K criterion or the SP criterion can be offset by a comparable excess in the other criterion or in the CRP criterion. No trade-off is allowed to compensate for a deficiency in the CRP criterion (BOSSS Queensland, 1995).

It is the researcher’s experience (in her own classroom and as QSA District Review Panel Chair with oversight of physics assessment across all schools in the QSA district) that most students find the far transfer tasks of the CRP criterion very difficult and perform at a lower standard in this criterion than in the two near transfer criteria. This means that, for most students, their final grade in physics is limited by their performance on the far transfer tasks. Many students ultimately ‘drop out’ of physics frustrated and discouraged because, despite their efforts and those of their teacher
using traditional pedagogy, they ‘just don’t get it’ and cannot succeed in far transfer tasks.

4.8.3.2 Data analyses

A causal-comparative analysis (see Section 4.3.1.3) will be performed to compare students’ learning outcome data (assessment scores) before and after the introduction of the TWP for Cohorts 1 and 2. A similar comparison will be performed with the control group’s scores. The trends observed in the control groups’ scores will provide an indication of the improvements in scores that can be expected for a cohort simply through growing experience and maturity.

For Cohort 1, traditional pedagogy will be used in Year 11 and the TWP will be used in Year 12. Comparisons will be made between Cohort 1’s Year 11 and Year 12 data. Similar comparisons will be made for the control group and also for Cohort 2.

For Cohort 2, the TWP will be introduced in Semester 2, Year 11 after students have learned with traditional pedagogy in Term 2 Year 11. Comparisons will be made between Term 2 Year 11 data and Semester 2 Year 11 data. Similar comparisons will be made for the Control Group and for Cohort 1.

During Term 1, 2007 Cohort 1 will learn with the TWP but Cohort 2 will learn with the Tablet/PPT Pedagogy. Comparisons will be made between the two tablet pedagogies at the end of this period to determine which pedagogy is more effective and its use will continue for the remainder of the study. Term 1 data for the cohort which learned with the less effective pedagogy will not be used as baseline data for that cohort.

The remaining discussion of the experimental plan will be based on the assumption that the TWP is the more effective pedagogy and that its use will be continued throughout the study.

As quantitative comparisons of each cohort’s pre-intervention and post-intervention scores are required, paired-sample t-tests will be used for all normally distributed data sets. If a data set fails the normality requirement for a paired-sample t-test (see Section 4.3.1.3), a Wilcoxon signed-rank test will be used (Manning & Munro, 2007).

The results of these analyses are shown in Section 5.2.
4.8.3.3 Data preparation

Only assessment data for students who complete the whole two year physics course will be used in these analyses. Each student’s scores will be combined to give a single score to quantify that student’s pre-intervention and post-intervention achievement. In all cases, the assessment plan and the assessment items will be those approved by the QSA. The QSA approved assessment schedule is shown in Table 4.2.

Table 4.2: Q.S.A. approved physics assessment schedule

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Assessment item</th>
<th>Knowledge</th>
<th>Scientific Processes</th>
<th>Complex Reasoning Processes</th>
<th>Global</th>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>A1</td>
<td>Mid Semester 1 Test</td>
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<td>/10*</td>
<td>/10*</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Investigation 1</td>
<td></td>
<td>/10*</td>
<td>/10*</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>End Semester 1 Test</td>
<td>/20</td>
<td>/10*</td>
<td>/10*</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>Semester 1 Report</td>
<td>/40</td>
<td>/30*</td>
<td>/20*</td>
<td>/90</td>
</tr>
<tr>
<td>S2</td>
<td>Semester Two</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>Mid Semester 2 Test</td>
<td>/20</td>
<td>10</td>
<td>/10</td>
<td></td>
</tr>
<tr>
<td>A5</td>
<td>Investigation 2</td>
<td></td>
<td>/10</td>
<td>/10</td>
<td></td>
</tr>
<tr>
<td>A6</td>
<td>End Semester 2 Test</td>
<td>/20</td>
<td>/10</td>
<td>/10</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>Semester 2 Report</td>
<td>/40</td>
<td>/30</td>
<td>/20</td>
<td>/90</td>
</tr>
<tr>
<td>R3</td>
<td>QSA Monitoring</td>
<td>/80</td>
<td>/60</td>
<td>/40</td>
<td>/180</td>
</tr>
<tr>
<td>S3</td>
<td>Semester Three</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A7</td>
<td>Mid Semester 3 Test</td>
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</tr>
<tr>
<td>A8</td>
<td>Investigation 3</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A9</td>
<td>End Semester 3 Test</td>
<td>/20</td>
<td>/15</td>
<td>/15</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>Semester 3 Report</td>
<td>/40</td>
<td>/40</td>
<td>/30</td>
<td>/110</td>
</tr>
<tr>
<td>S4</td>
<td>Semester Four</td>
<td></td>
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<td></td>
</tr>
<tr>
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<td>Mid Semester 4 Test</td>
<td>/20</td>
<td>/10</td>
<td>/10</td>
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</tr>
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<td>QSA Verification</td>
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<td>/90</td>
<td>/60</td>
<td>/290</td>
</tr>
<tr>
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<td>End Semester 4 Test</td>
<td>/20</td>
<td>/10</td>
<td>/10</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>Semester 4 Report</td>
<td>/40</td>
<td>/30</td>
<td>/20</td>
<td>/90</td>
</tr>
<tr>
<td>R6</td>
<td>QSA Certification / Exit</td>
<td>/160</td>
<td>/100</td>
<td>/70</td>
<td>/330</td>
</tr>
</tbody>
</table>

*QSA summary scores at Verification and Certification do not include these scores which are regarded as formative.
In the analysis of the intervention for Cohort 1, a student’s ‘pre-intervention’ assessment performance will be defined as the student’s Year 11 score and will include data from assessment items A1-A6 as indicated in Table 4.2. His/her ‘post-intervention’ assessment performance will be defined as his/her Year 12 scores and will include data from assessment items A7-A12 as indicated in Table 4.2.

In the analysis of the intervention for Cohort 2, a student’s ‘pre-intervention’ assessment performance will be defined as the student’s Year 11 Term 2 score (includes data from assessment item A3) and his/her ‘post-intervention’ assessment performance will be defined as his/her Year 11 Semester 2 scores (includes data from assessment items A4 and A6). Students’ Year 12 scores (includes data from assessment items A7, A9, A10, and A12) will provide further ‘post-intervention’ data for some analyses.

For Cohort 2, no assessment data from investigations will be included because the Semester 1 Investigation (assessment item A2) is related to Term 1 data which, it has already been explained (see Section 4.8.1.2), will not be used as baseline data because this is when the Tablet/PPT Pedagogy will be trialled. For consistency in the comparisons, all other investigation scores (assessment items A5, A8, A11) will also be excluded.

4.8.4 Study 2: Quantitative analysis of students’ perceptions of the TWP

4.8.4.1 Purpose and design of the survey

A survey will be administered to all students to collect information about students’ perceptions about learning with the TWP.

Specifically, the survey is designed to collect both qualitative and quantitative data from respondents regarding:

- the frequency with which they experienced various forms of usage of the Tablet PC in physics classes both personally and by the teacher
- their attitude to these experiences
- their perceptions about learning in a classroom which features the use of a Tablet PC
• the frequency with which they used computer technology in subjects other than physics
• their attitude to these experiences

Participants will respond to survey items seeking frequency data using the categorical scale shown in Table 4.3.

Table 4.3: Categorical responses for survey frequency items

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>N</td>
<td>Never</td>
</tr>
<tr>
<td>Rarely</td>
<td>R</td>
<td>Rarely used in lessons (used 1 or 2 times per term)</td>
</tr>
<tr>
<td>Weekly</td>
<td>W</td>
<td>Weekly use in lessons (used 2 or 3 times per month)</td>
</tr>
<tr>
<td>Frequently</td>
<td>F</td>
<td>Frequent use in most lessons (used 2 or 3 times per week)</td>
</tr>
<tr>
<td>Often</td>
<td>O</td>
<td>Often used several times per lesson</td>
</tr>
</tbody>
</table>

Participants will respond to survey items seeking attitudinal data using a 5 step Likert Scale (Manning & Munro 2007): Very negative (VN), Negative (N), Not Sure (NS), Positive (P), Very positive(VP).

Participants will respond to survey items seeking an opinion using a 5 step Likert Scale (Manning & Munro 2007): Strongly Disagree (SD), Disagree (D), Indifferent/Undecided (I), Agree (A), Strongly Agree (SA).

Where a respondent does not complete all items in the survey, his/her data will be included for the particular analyses where he/she had available scores (Manning & Munro 2007).

Participants will also have the opportunity to write short responses to open ended questions.

Some survey items will be posed in the negative sense to ensure that respondents have to think carefully before answering each question and so the incidence of thoughtless responses will be reduced (Coakes & Steed, 2003).
A copy of the survey is provided in Appendix A.

4.8.4.2 Participants and recruitment

All members of Cohort 1 (the 16 Year 12 Physics students at the research site in 2007) and Cohort 2 (the 25 Year 11 Physics students at the research site in 2007) will be invited to participate in the survey. In total 41 students will be invited to participate in the survey.

4.8.4.3 Survey administration

The survey will be administered during class time. Students will take approximately 30 minutes to complete the survey. The anonymity of the survey respondents will be assured and students will be encouraged to answer openly and honestly.

Respondent anonymity will be achieved in the following way. For ease of distribution, the survey document will contain a cover sheet identifying the student and stating the student’s ID number. Subsequent sections of the response booklet will contain a reference only to the student’s ID number. Students will be asked to remove the cover sheet prior to submitting their response booklet.

4.8.5 Study 3: Qualitative analysis of students’ perceptions of the TWP

4.8.5.1 Purpose and design of interview and focus group script

The scripts for the semi-structured interviews and the focus groups will be identical and are displayed in Appendices B and C. The discussion starter questions are designed to collect qualitative data from respondents about their perceptions of how the use of the Tablet PC during physics classes has affected their learning.

The interviews and focus groups will allow students the opportunity to expand on the written answers that they give in the short response questions in the survey.

4.8.5.2 Participants and recruitment

All members of Cohort 1 (16 Year 12 Physics students at the research site in 2007) and Cohort 2 (25 Year 11 Physics students at the research site in 2007) will be invited to participate in the semi-structured interviews and focus groups giving a total of 41 students. Discussions will be conducted during lunch breaks. Interviews will take
about 10 minutes and focus group discussions will take 15-30 minutes depending on
the number of students in the group.

**4.8.5.3 Interview and focus group administration**

The semi-structured interview and focus group scripts contain scripted discussion
starter questions. In each discussion forum, every scripted question will be asked of all
participants. Additional questions will sometimes be posed as a result of participant’s
responses to the discussion starter questions.

An audio recording of each semi-structured interview and focus group discussion will
be made. Students will be asked to identify themselves on the audio track by name
and by student ID Number for data tracking purposes. All identifying information will
be removed from the written transcripts.
Chapter 5: Results

5.1 Introduction

This chapter reports the results obtained in the three studies conducted in this research. Quantitative data will be documented in detail in this chapter. Qualitative data in the form of students’ comments will not be listed verbatim here. Instead, such comments will be directly quoted as relevant in the discussion (see Chapter 6). Quantitative analyses of the number of students who made comments of a given nature and the number of comments made of a given nature are also provided.

5.2 Results of Study 1: Quantitative analysis of the effect of the TWP on learning outcomes

5.2.1 Introduction

The causal-comparative studies of QSA assessment scores are shown separately for Intervention 1 and Intervention 2. Each intervention took the form of a change from learning with traditional pedagogy to learning with TWP but the change occurred at a different stage of the two year course for each of the two study cohorts, as per the research plan (see Table 4.1).

The variables to be compared were sampled at two different points in time: pre-intervention and post-intervention. Paired-sample t-tests are used to determine whether there was a statistically significant change in the variable (Manning & Munro, 2007).

Intervention 1 occurred at the start of Year 12 for Cohort 1. Comparisons were made between the Year 11 and Year 12 scores for Cohort 1. Similar comparisons were made for Cohort 2 and for the Control Group to provide a contrast for the Cohort 1 results. These comparisons are represented in Section 5.2.2.1.

Intervention 2 occurred at the start of Year 11 Semester 2 for Cohort 2. Comparisons were made between the Year 11 Term 2 and the Year 11 Semester 2 scores for Cohort 2. Similar comparisons were made for Cohort 1 and for the Control Group to provide a
contrast for the Cohort 2 results. These comparisons are also represented in Section 5.2.3.1.

Comparisons of global scores and comparisons of scores in each of the three criteria (K, SP and CRP) were made for all students and for boys and girls separately. All data sets (including subgroups based on gender and criterion) were tested for normality (Manning & Munro, 2007). The data sets that were normally distributed were compared using paired-sample t-tests. The only data set that failed the normality test was ‘Cohort 2 Term 2 SP for all students’. Comparisons involving this data set were done using a Wilcoxon signed-ranks test (Manning & Munro, 2007).

A preliminary investigation to assess whether the cohort’s teacher was a critical variable to control was also carried out as suggested in Section 4.7.3 and outlined in the experimental plan (see Table 4.1). The comparisons were made using paired-sample t-tests and are reported in the same way as the comparisons for Interventions 1 and 2. The results are shown in Section 5.2.4.1.

Comparisons for which statistically significant differences (with $p \leq 5\%$) were evident have been highlighted in the tables and graphs according to the level of significance code shown in Table 5.1.

**Table 5.1: Level of Significance Code**

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>***</td>
<td>Significant improvement at the 0.1% level</td>
</tr>
<tr>
<td>**</td>
<td>Significant improvement at the 1% level</td>
</tr>
<tr>
<td>*</td>
<td>Significant improvement at the 5% level</td>
</tr>
<tr>
<td>-</td>
<td>No significant change</td>
</tr>
<tr>
<td>*</td>
<td>Significant decline at the 5% level</td>
</tr>
<tr>
<td>**</td>
<td>Significant decline at the 1% level</td>
</tr>
<tr>
<td>**</td>
<td>Significant decline at the 0.1% level</td>
</tr>
</tbody>
</table>
5.2.2 Results for Intervention 1: Comparison of Year 11 scores with Year 12 scores

5.2.2.1 Data tables for Intervention 1

Table 5.2: Results for Cohort 1, Intervention 1

Comparison of:

Cohort 1 Year 11 (2006) Researcher as Teacher, traditional pedagogy (Pre-intervention)

Cohort 1 Year 12 (2007) Researcher as Teacher, TWP (Post-intervention)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Grouping</th>
<th>N</th>
<th>Mean (%)</th>
<th>SD</th>
<th>Mean (%)</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>p</th>
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<tbody>
<tr>
<td></td>
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<td>PRE-</td>
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<td>Cohort 1 Year 11</td>
<td>Cohort 1 Year 12</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (%)</td>
<td>SD</td>
<td>Mean (%)</td>
<td>SD</td>
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<tr>
<td>Global</td>
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<td>14.459</td>
<td>72.08</td>
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### Table 5.3: Results for Cohort 2, Intervention 1

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| Cohort 2 Year 12 (2008): | Researcher as Teacher, TWP |

#### Comparison of QSA Raw Scores (based on Paired-samples t-tests)

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Table 5.4: Results for Control Group, Intervention 1
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### 5.2.3 Results for Intervention 2: Comparison of Year 11 Term 2 scores with Year 11 Semester 2 scores

#### 5.2.3.1 Data tables for Intervention 2

**Table 5.5: Results for Cohort 2, Intervention 2**

Cohort 2 Year 11 Term 2 (2007): Researcher as Teacher, Traditional Pedagogy  
(Pre-intervention)

Cohort 2 Year 11 Semester 2 (2007): Researcher as Teacher, Workbooks, Workbook/Tablet pedagogy (Post-intervention)

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# A Wilcoxon Signed-Ranks test was performed as the data set failed the normality
### Table 5.6: Results for Cohort 1, Intervention 2

**Comparison of:**

**Cohort 1 Year 11 Term 2 (2006): Researcher as Teacher, Traditional Pedagogy**

**Cohort 1 Year 11 Semester 2 (2006): Researcher as Teacher, Traditional Pedagogy**

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Table 5.7: Results for Control Group, Intervention 2

Comparison of:

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Control Group Year 11 Semester 2 (2000): Teacher Y, Traditional Pedagogy

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<td>72.73</td>
<td>13.297</td>
<td>70.09</td>
<td>14.896</td>
<td>-0.970</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>22</td>
<td>64.77</td>
<td>11.698</td>
<td>60.86</td>
<td>15.223</td>
<td>-1.193</td>
<td>21</td>
</tr>
<tr>
<td>Complex reasoning processes</td>
<td>All</td>
<td>33</td>
<td>43.03</td>
<td>27.696</td>
<td>48.64</td>
<td>18.803</td>
<td>1.566</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11</td>
<td>47.27</td>
<td>26.016</td>
<td>51.91</td>
<td>18.528</td>
<td>0.659</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>22</td>
<td>40.91</td>
<td>28.853</td>
<td>47.00</td>
<td>19.154</td>
<td>1.458</td>
<td>21</td>
</tr>
</tbody>
</table>
5.2.4 Assessment of 'Teacher' as a critical variable

5.2.4.1 Data tables for assessment of 'Teacher' as a critical variable

Table 5.8: Results for Cohort 3

Comparison of:

Cohort 3 Year 11 (2002): Teacher X, Traditional Pedagogy
Cohort 3 Year 12 (2003): Teacher Y (Researcher), Traditional Pedagogy

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Grouping</th>
<th>N</th>
<th>PRE-INTERVENTION Cohort 3 Year 11</th>
<th>POST-INTERVENTION Cohort 3 Year 12</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>All</td>
<td>28</td>
<td>62.40</td>
<td>12.039</td>
<td>69.26</td>
<td>15.423</td>
<td>5.808</td>
<td>27</td>
</tr>
<tr>
<td>Knowledge</td>
<td>All</td>
<td>28</td>
<td>73.54</td>
<td>12.315</td>
<td>77.93</td>
<td>15.616</td>
<td>z# = 2.344</td>
<td>27</td>
</tr>
<tr>
<td>Scientific processes</td>
<td>All</td>
<td>28</td>
<td>68.50</td>
<td>10.447</td>
<td>80.07</td>
<td>13.272</td>
<td>7.917</td>
<td>27</td>
</tr>
<tr>
<td>Complex reasoning</td>
<td>All</td>
<td>28</td>
<td>45.43</td>
<td>16.107</td>
<td>50.04</td>
<td>19.919</td>
<td>3.299</td>
<td>27</td>
</tr>
</tbody>
</table>

# A Wilcoxon Signed-Ranks test was performed as the data set failed the normality assumption
Table 5.9: Results for Cohort 4

Comparison of:

Cohort 4 Year 11 (2003): Teacher X, Traditional Pedagogy
Cohort 4 Year 12 (2004): Teacher Y (Researcher), Traditional Pedagogy

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Grouping</th>
<th>N</th>
<th>PRE-INTERVENTION Control Group Year 11</th>
<th>POST-INTERVENTION Control Group Year 12</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>All</td>
<td>30</td>
<td>61.77</td>
<td>15.667</td>
<td>70.53</td>
<td>14.310</td>
<td>5.786</td>
<td>29</td>
</tr>
<tr>
<td>Knowledge</td>
<td>All</td>
<td>30</td>
<td>74.03</td>
<td>14.644</td>
<td>79.73</td>
<td>14.300</td>
<td>z# = 3.713</td>
<td>29</td>
</tr>
<tr>
<td>Scientific processes</td>
<td>All</td>
<td>30</td>
<td>69.93</td>
<td>13.946</td>
<td>78.20</td>
<td>11.993</td>
<td>5.214</td>
<td>29</td>
</tr>
<tr>
<td>Complex reasoning processes</td>
<td>All</td>
<td>30</td>
<td>41.77</td>
<td>20.721</td>
<td>53.33</td>
<td>19.229</td>
<td>4.754</td>
<td>29</td>
</tr>
</tbody>
</table>

# A Wilcoxon Signed-Ranks test was performed as the data set failed the normality assumption

The third data set used in this assessment is shown in Table 5.4 which contains:

Results for Cohort 5 (subsequently known as Control Group)

Comparison of:

Cohort 5 (Control Group) Year 11 (2000): Teacher Z, Traditional Pedagogy
Cohort 5 (Control Group) Year 12 (2001): Teacher Z, Traditional Pedagogy
5.3 Results of Study 2: Quantitative analysis of students’ perceptions of learning with the TWP

5.3.1 Introduction

The survey collected quantitative and qualitative data about the students’ experiences and perceptions of the use of the Tablet PC in their physics classes. A copy of the survey is contained in Appendix A. The anonymity of the survey respondents was assured and students were encouraged to answer openly and honestly.

All students in Cohorts 1 and 2 were invited to participate in the survey. Some were unable to participate due to ill health or because consent forms were not returned. Table 5.10 shows the numbers of participants by cohort and gender. Overall, a 93% participation rate was achieved.

Table 5.10: Survey Participation Data

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Number of students in cohort</th>
<th>Number of survey participants</th>
<th>Participation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>16</td>
<td>100%</td>
</tr>
<tr>
<td>Boys</td>
<td>11</td>
<td>11</td>
<td>100%</td>
</tr>
<tr>
<td>Girls</td>
<td>5</td>
<td>5</td>
<td>100%</td>
</tr>
<tr>
<td>Cohort 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>21</td>
<td>84%</td>
</tr>
<tr>
<td>Boys</td>
<td>20</td>
<td>17</td>
<td>85%</td>
</tr>
<tr>
<td>Girls</td>
<td>5</td>
<td>4</td>
<td>80%</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>37</td>
<td>93%</td>
</tr>
</tbody>
</table>

5.3.2 Design of the survey

Part A collected information about the ways in which the teacher used the Tablet PC during physics classes and the students’ attitudes to these activities. The frequency with which the activity occurred was reported on a five-point ordinal scale (Never, Rarely, Weekly, Frequently, Often) as defined in Table 4.3. The students’ attitudes to these activities were reported on a five-point Likert scale (Very Negative, Negative, Not Sure, Positive, Very Positive).
Part B collected similar frequency and attitude information about the ways in which students used the Tablet PC during physics classes and the students’ attitudes to these activities.

Part C collected information about students’ perceptions of learning in a classroom which featured the use of a Tablet PC and workbooks. Students were asked to report their opinion about a given statement on a five-point scale (Strongly Disagree, Disagree, Indifferent/Undecided, Agree, Strongly Agree).

In each of the Parts A, B and C of the survey, students were invited to add short responses to open ended questions (items A17, B15, B16, C14 and C15).

To put the students’ experiences in their physics lessons into the context of their broader school experience, Part D collected information about the students’ experiences of technology use in their English classes and in one other subject of their choice. The frequency with which each technology experience occurred was reported on a five-point ordinal scale (Never, Rarely, Weekly, Frequently, Often) as defined in Table 5.11. The students’ attitudes to these activities were reported on a five-point Likert scale (Very Negative, Negative, Not Sure, Positive, Very Positive).

5.3.3 Types of data generated from the survey

The survey generated both qualitative and quantitative data.

Responses on Likert scales were requested for the attitudinal and opinion items and so these items provided ordinal quantitative data. A number of statistical analyses of this data were performed and are reported in this section.

The final one or two items of Parts A, B and C (items A17, B15, B16, C14 and C15) allowed students to answer open-ended questions, providing qualitative data. This data was combined with the qualitative data obtained from the interviews and focus group discussions. Students’ comments will not be reported verbatim in this chapter. Rather this data will be used to provide student quotations as appropriate in the discussion (see Chapter 6). Students’ comments were, however, catalogued using categories that were developed from the recurring themes evident in the full bank of qualitative data in the survey, interviews and focus groups (see Table 5.29).
5.3.4 Quantitative Data

5.3.4.1 Variables and Data Coding

For each survey item producing a categorical response, variables were defined and the
categorical responses were coded into numerical values. Responses to survey items
seeking frequency data were coded as shown in Table 5.11.

Table 5.11: Coding for survey frequency items

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Descriptor</th>
<th>Numerical Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>N</td>
<td>Never</td>
<td>0</td>
</tr>
<tr>
<td>Rarely</td>
<td>R</td>
<td>Rarely used in lessons (used 1 or 2 times per term)</td>
<td>1</td>
</tr>
<tr>
<td>Weekly</td>
<td>W</td>
<td>Weekly use in lessons (used 2 or 3 times per month)</td>
<td>2</td>
</tr>
<tr>
<td>Frequently</td>
<td>F</td>
<td>Frequent use in most lessons (used 2 or 3 times per week)</td>
<td>3</td>
</tr>
<tr>
<td>Often</td>
<td>O</td>
<td>Often used several times per lesson</td>
<td>4</td>
</tr>
</tbody>
</table>

Responses to survey items seeking attitudinal data were coded on a 5 step Likert Scale
as: Very Negative (VN), Negative (N), Not Sure (NS), Positive (P), Very Positive(VP) as
shown in Table 5.12.

Table 5.12: Coding for survey attitudinal items

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Numerical Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very negative</td>
<td>VN</td>
<td>1</td>
</tr>
<tr>
<td>Negative</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>Not Sure</td>
<td>NS</td>
<td>3</td>
</tr>
<tr>
<td>Positive</td>
<td>P</td>
<td>4</td>
</tr>
<tr>
<td>Very positive</td>
<td>VP</td>
<td>5</td>
</tr>
</tbody>
</table>
Responses to survey items seeking an opinion were coded as shown in Table 5.13:

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Numerical Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>SD</td>
<td>1</td>
</tr>
<tr>
<td>Disagree</td>
<td>D</td>
<td>2</td>
</tr>
<tr>
<td>Indifferent/Undecided</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>Agree</td>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>SA</td>
<td>5</td>
</tr>
</tbody>
</table>

Where a respondent did not complete all items in the survey, his/her data was included for the particular analyses where he/she had available scores (Manning & Munro, 2007).

Occasionally the intended response to an attitudinal question on the Likert Scale was not clear and required interpretation. Where a response clearly indicated a particular category, this category was recorded. Where responses were very close to a particular category, this category was recorded. Where responses were midway between categories, the response was interpreted as the category further from the "Not Sure" category as the student’s intention was to respond in a more definite way than the nearer category would indicate.

Some survey items were posed in the negative sense e.g. survey items C3, C4, C5, C8, C11, C12, and C13. These items were re-coded in the positive sense before further analysis (Coakes & Steed, 2003; Manning & Munro, 2007).

5.3.4.2 Data Screening

The integrity of the data set was assured in several ways to produce an accurate and complete data set.

The raw data was screened to remove any 'thoughtless' or 'nonsense' data (Manning & Munro, 2007). Some respondents displayed a pattern of responses that were clearly thoughtless. This happened in some sections of the survey responses for Cases 29 and 31. These responses were disregarded and treated as missing data.
The data file was also screened for data entry errors by double checking the survey responses against the data file. Out-of-range values were detected by checking for anomalous data in frequency tables (Coakes & Steed, 2003).

### 5.3.4.3 Overview of survey quantitative data analysis

The raw quantitative data from the survey was summarised in separate frequency distribution tables for each section of the survey (see Table 5.15, Table 5.18, Table 5.21 and Table 5.24).

The median was selected as an appropriate measure of central tendency for this ordinal data (Argyrous, 2000) and was calculated for each survey item.

The Chi-squared goodness-of-fit test compares the distribution of the frequency data collected in a study with the distribution that would be expected to occur by chance. It was used to assess the statistical significance of the median as a suitable quantity to represent each distribution (see Table 5.14 for the code that will be used to represent the significance) (Brace, Kemp & Snelgar, 2000; Coakes & Steed, 2003).

Three assumptions must be addressed before a Chi-squared test can be conducted: random sampling; independence of observations and; size of expected frequencies (Coakes & Steed, 2003). In all cases, these assumptions were satisfied.

**Table 5.14: Code indicating significance of Chi-squared goodness-of-fit tests**

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>***</td>
<td>Significant at the 0.1% level</td>
</tr>
<tr>
<td>**</td>
<td>Significant at the 1% level</td>
</tr>
<tr>
<td>*</td>
<td>Significant at the 5% level</td>
</tr>
<tr>
<td>-</td>
<td>Not significant at the 5% level</td>
</tr>
</tbody>
</table>

For Parts A, B and D, survey items were aggregated into summary categories and median calculations and Chi-squared analyses were conducted on the aggregated results as appropriate. The results are shown in Table 5.17, Table 5.20 and Table 5.25 - Table 5.28.

Statistical analyses were conducted to determine if any differences in attitudinal responses occurred on the basis of gender. The Mann-Whitney U test (a non-
parametric test of whether two samples are different (Brace et al., 2000) was used. The results are reported in Section 5.3.5.

A Spearman’s Rank Order Correlation (Spearman’s rho) (Manning & Munro, 2007) was used to determine if there was a significant correlation between students’ attitudes to the use of the Tablet PC and their QSA achievement scores. Although Kendall’s tau-b Test (which take ties into account) or Kendall’s tau-c Test (which does not take ties into account) would also have been appropriate with this data set, Spearman’s rho is more widely discussed in the literature so this was the method selected (Brace et al., 2000). The results are reported in Section 5.3.5.

5.3.4.4 Results of Survey Part A

5.3.4.4.1 Raw data

Table 5.15, shows the frequency distribution data, the median categories and their significance on the basis of a Chi-squared goodness of fit test.
<table>
<thead>
<tr>
<th>Item</th>
<th>Statement</th>
<th>Frequency</th>
<th>Significance</th>
<th>Median</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>The teacher used the Tablet PC in the class.</td>
<td>Often</td>
<td>***</td>
<td>0</td>
<td>0 0 0 0 0 1 36 138.270 37 4 0.000 Very Positive</td>
</tr>
<tr>
<td>A2</td>
<td>The teacher used the Tablet PC's digital pen features.</td>
<td>Often</td>
<td>***</td>
<td>0</td>
<td>0 0 0 0 1 36 138.270 37 4 0.000 Very Positive</td>
</tr>
<tr>
<td>A3</td>
<td>The teacher used digital ink on the Tablet PC to add handwritten notes/diagrams to prepared typed lesson notes.</td>
<td>Often</td>
<td>***</td>
<td>0 0 0 0 1 36 138.270 37 4 0.000 Very Positive</td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>The teacher used digital ink on the Tablet PC to add handwritten notes/diagrams to a prepared Power Point presentation.</td>
<td>Rarely</td>
<td>***</td>
<td>6</td>
<td>18 7 3 20 70 3 20.703 37 4 0.000 Positive</td>
</tr>
<tr>
<td>Item</td>
<td>Item Statement</td>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>Significance</td>
<td>Category</td>
<td>N</td>
</tr>
<tr>
<td>A5</td>
<td>The teacher used the digital pen to control computer animations.</td>
<td>Often</td>
<td>***</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>A6</td>
<td>The teacher used the digital pen to control Logger Pro software.</td>
<td>Rarely</td>
<td>-</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>A7</td>
<td>The teacher displays a movie using ClickView or a DVD.</td>
<td>Weekly</td>
<td>***</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>A8</td>
<td>The teacher accessed Internet information on the Tablet PC during the lesson.</td>
<td>Frequently</td>
<td>***</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A9</td>
<td>The teacher used Graphics Calculator software on the Tablet PC.</td>
<td>Rarely</td>
<td>***</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>A10</td>
<td>The teacher used Excel software on the Tablet PC.</td>
<td>Rarely</td>
<td>***</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Item</td>
<td>Item Statement</td>
<td>Frequency</td>
<td>Attitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median Category</td>
<td>Significance</td>
<td>Category</td>
<td>X2</td>
</tr>
<tr>
<td>A11</td>
<td>The teacher displayed a Power Point presentation on the Tablet PC.</td>
<td>Rarely</td>
<td>***</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>A12</td>
<td>The teacher stored a copy of the digital ink lesson notes for later access.</td>
<td>Often</td>
<td>*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A13</td>
<td>The teacher recalls a copy of previous digital lesson notes for review in class.</td>
<td>Often</td>
<td>***</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A14</td>
<td>The teacher provides a copy of previous digital lesson notes for student use eg if student was absent for the lesson.</td>
<td>Often</td>
<td>***</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Item</td>
<td>Item Statement</td>
<td>Frequency</td>
<td>Attitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>R</td>
<td>W</td>
<td>F</td>
</tr>
<tr>
<td>A15</td>
<td>The teacher moves around the classroom with the Tablet PC to teach from different positions.</td>
<td>17</td>
<td>15</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>A16</td>
<td>The teacher allows students to control the Tablet PC during lessons.</td>
<td>1</td>
<td>15</td>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>
5.3.4.4.2 Aggregated Data

The raw data was aggregated using four suitable categories which are defined in Table 5.16.

**Table 5.16: Survey Part A: Aggregation Categories**

<table>
<thead>
<tr>
<th>Category</th>
<th>Items</th>
<th>Item Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablet</td>
<td>A1, A2, A5, A8</td>
<td>General use of digital pen technology on Tablet PC.</td>
</tr>
<tr>
<td>Tablet/Workbook</td>
<td>A3, A12, A13, A14</td>
<td>Use of digital pen technology on Tablet PC in conjunction with electronic version of the student workbook.</td>
</tr>
<tr>
<td>Tablet/Other</td>
<td>A4, A6, A7, A9, A10, A11, A15</td>
<td>Use of the Tablet PC with other software.</td>
</tr>
<tr>
<td>Tablet/Students</td>
<td>A16</td>
<td>Student use of the Tablet PC.</td>
</tr>
</tbody>
</table>

The aggregated data was summarised in a frequency distribution table (see Table 5.17).
Table 5.17: Survey Part A: Summary statistics for aggregated data

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>Median Category</th>
<th>Significance</th>
<th>N</th>
<th>R</th>
<th>W</th>
<th>F</th>
<th>O</th>
<th>X²</th>
<th>N</th>
<th>DF</th>
<th>p</th>
<th>Attitude</th>
<th>Median Category</th>
<th>Significance</th>
<th>VN</th>
<th>N</th>
<th>NS</th>
<th>P</th>
<th>VP</th>
<th>X²</th>
<th>N</th>
<th>DF</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablet</td>
<td>Often</td>
<td>***</td>
<td></td>
<td>12</td>
<td>8</td>
<td>10</td>
<td>18</td>
<td>99</td>
<td>207.864</td>
<td>147</td>
<td>4</td>
<td>0.000</td>
<td>Positive</td>
<td>***</td>
<td></td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>67</td>
<td>69</td>
<td>182.140</td>
<td>143</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Tablet/Workbook</td>
<td>Often</td>
<td>***</td>
<td></td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>130</td>
<td>427.608</td>
<td>148</td>
<td>4</td>
<td>0.000</td>
<td>Very Positive</td>
<td>***</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>30</td>
<td>115</td>
<td>337.767</td>
<td>146</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Tablet/Other</td>
<td>Rarely</td>
<td>***</td>
<td></td>
<td>52</td>
<td>106</td>
<td>56</td>
<td>30</td>
<td>14</td>
<td>94.171</td>
<td>258</td>
<td>4</td>
<td>0.000</td>
<td>Positive</td>
<td>***</td>
<td></td>
<td>3</td>
<td>4</td>
<td>72</td>
<td>100</td>
<td>67</td>
<td>154.366</td>
<td>246</td>
<td>4</td>
<td>0.000</td>
</tr>
<tr>
<td>Tablet/Students</td>
<td>Weekly</td>
<td>***</td>
<td></td>
<td>1</td>
<td>15</td>
<td>19</td>
<td>2</td>
<td>0</td>
<td>42.865</td>
<td>37</td>
<td>4</td>
<td>0.000</td>
<td>Positive</td>
<td>***</td>
<td></td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>13</td>
<td>14</td>
<td>25.944</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
</tr>
</tbody>
</table>
5.3.4.5  Results for Survey Part B

5.3.4.5.1  Raw data

Table 5.18, shows the frequency distribution data, the median categories and their significance on the basis of a Chi-squared goodness of fit test.
<table>
<thead>
<tr>
<th>Item</th>
<th>Item Statement</th>
<th>Frequency</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>Category</td>
</tr>
<tr>
<td>B1</td>
<td>You used the Tablet PC in the class.</td>
<td>Rarely</td>
<td>###</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>B2</td>
<td>You used the Tablet PC’s digital pen features.</td>
<td>Rarely</td>
<td>###</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>B3</td>
<td>You used digital ink on the Tablet PC to add handwritten notes/diagrams to prepared typed lesson notes.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>B4</td>
<td>You used digital ink on the Tablet PC to add handwritten notes/diagrams to a prepared Power Point presentation.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B5</td>
<td>You used the digital pen to control computer animations.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B6</td>
<td>You used the digital pen to control Logger Pro software.</td>
<td>Never</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B7</td>
<td>You accessed Internet information on the Tablet PC during the lesson.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>B8</td>
<td>You used Graphics Calculator software on the Tablet PC.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B9</td>
<td>You used Excel software on the Tablet PC.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B10</td>
<td>You displayed a Power Point presentation on the Tablet PC.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>B11</td>
<td>You received a copy of the stored digital lesson notes from a lesson you missed.</td>
<td>Rarely</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive / Very positive</td>
<td>***</td>
</tr>
<tr>
<td>B12</td>
<td>You used the Tablet PC at your desk in class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>Item</td>
<td>Item Statement</td>
<td>Median Category</td>
<td>Significance</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>R</td>
</tr>
<tr>
<td>B13</td>
<td>You used the Bluetooth mouse at your desk to control the Tablet PC.</td>
<td>Never</td>
<td>19</td>
</tr>
<tr>
<td>B14</td>
<td>You controlled the Tablet PC at the front of the class during lessons.</td>
<td>Never</td>
<td>19</td>
</tr>
</tbody>
</table>
### 5.3.4.5.2 Aggregated Data

The raw data was aggregated using four suitable categories which are defined in Table 5.19.

**Table 5.19: Survey Part B: Aggregation Categories**

<table>
<thead>
<tr>
<th>Category</th>
<th>Items aggregated</th>
<th>Category Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablet/Students</td>
<td>B1,B2,B5,B7,B14</td>
<td>Students’ use of the Tablet PC.</td>
</tr>
<tr>
<td>Tablet/Students/Workbook</td>
<td>B3,B11</td>
<td>Student’ use of the digital pen technology on the Tablet PC in conjunction with the electronic version of the student workbook.</td>
</tr>
<tr>
<td>Tablet/Students/Other</td>
<td>B4,B6,B8,B9,B10,B12,B13</td>
<td>Students’ use of the Tablet PC with other software.</td>
</tr>
</tbody>
</table>

The aggregated data was summarised in a frequency distribution table (see Table 5.20).
### Table 5.20: Survey Part B: Summary statistics for aggregated data

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median Category</td>
<td>Significance</td>
</tr>
<tr>
<td>Tablet/Students Rarely ***</td>
<td>Rarely ***</td>
<td></td>
</tr>
<tr>
<td>Tablet/Students/Workbook Rarely ***</td>
<td>Rarely ***</td>
<td></td>
</tr>
<tr>
<td>Tablet/Students / Other Never ***</td>
<td>Never ***</td>
<td></td>
</tr>
</tbody>
</table>
5.3.4.6 Results for Survey Part C

5.3.4.6.1 Raw data

Table 5.21 shows the frequency distribution data, the median categories and their significance on the basis of a Chi-squared goodness of fit test.
Table 5.21: Survey Part C: Summary statistics for raw data

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Statement</th>
<th>Opinion</th>
<th>Median Category</th>
<th>Significance</th>
<th>Category</th>
<th>SD</th>
<th>D</th>
<th>A</th>
<th>SA</th>
<th>(X^2)</th>
<th>N</th>
<th>DF</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>I think that Physics concepts are easier to understand when the teacher uses the Tablet PC to help to explain them.</td>
<td>Agree</td>
<td>***</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>18</td>
<td>14</td>
<td>37.333</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>I enjoy Physics classes more when the Tablet PC is used.</td>
<td>Strongly Agree</td>
<td>***</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>19</td>
<td>54.278</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Using the Tablet PC in Physics classes saves a lot of time.</td>
<td>Agree</td>
<td>***</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>15</td>
<td>25</td>
<td>28.444</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>I have no difficulty reading the hand written notes that the teacher writes in digital ink on the Tablet PC.</td>
<td>Agree</td>
<td>***</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>12</td>
<td>9</td>
<td>10.111</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>I prefer to take lesson notes when the teacher writes them using the Tablet PC rather than the whiteboard.</td>
<td>Agree</td>
<td>***</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>16</td>
<td>14</td>
<td>29.278</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>I think that use of the Tablet PC would assist my learning in other science classes.</td>
<td>Agree</td>
<td>***</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>18</td>
<td>10</td>
<td>7.056</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>I think that use of the Tablet PC would assist my learning in English lessons.</td>
<td>Disagree / Indifferent / Undecided</td>
<td>*</td>
<td>5</td>
<td>13</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>9.558</td>
<td>36</td>
<td>4</td>
<td>0.049</td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>I think that use of the Tablet PC would assist my learning in Mathematics lessons.</td>
<td>Indifferent / Undecided</td>
<td>*</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>10</td>
<td>7</td>
<td>9.833</td>
<td>36</td>
<td>4</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td>C9</td>
<td>I think that use of the Tablet PC would assist my learning in a humanities class e.g. history.</td>
<td>Indifferent / Undecided</td>
<td>***</td>
<td>3</td>
<td>3</td>
<td>21</td>
<td>8</td>
<td>1</td>
<td>36.778</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C10</td>
<td>I prefer to write lesson notes in the prepared workbooks rather than in a blank notebook.</td>
<td>Strongly Agree</td>
<td>***</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>20</td>
<td>35.389</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C11</td>
<td>Writing lesson notes in the prepared workbooks is easier when the teacher uses the Tablet PC.</td>
<td>Agree</td>
<td>***</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>20</td>
<td>15</td>
<td>50.944</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C12</td>
<td>A Tablet PC is better than an ordinary laptop computer.</td>
<td>Agree / Strongly Agree</td>
<td>***</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>18</td>
<td>37.056</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>C13</td>
<td>It is better to use a Tablet PC in class than an interactive whiteboard.</td>
<td>Agree</td>
<td>***</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>13</td>
<td>14</td>
<td>25.944</td>
<td>36</td>
<td>4</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>
5.3.4.7 Results for Survey Part D

5.3.4.8 Raw Data

Table 5.22 shows the frequency distribution data, the median categories and their significance on the basis of a Chi-squared goodness of fit test for Items D1-D9 English classes.

For items D10-D18, students were free to choose one other subject they studied. Consequently many different subjects were reported and the numbers for each subject are small. It was not appropriate to perform Chi-squared tests on this data so the frequency and median data are reported in Table 5.24 with the caveat that these results are not statistically significant but may serve to provide a general overview of the level of technology use in other subjects at the research site.

The abbreviations used in this table are documented in Table 5.23.

The raw data for items D10-D18 for the various subjects have been aggregated into faculty groups including arts (see Table 5.25), mathematics (see Table 5.26), sciences other than physics (see Table 5.27) and technology (see Table 5.28) in order to observe the trends for the various faculties.
Table 5.22: Survey Part D: Summary statistics for raw data (Items D1 - D9 for English class)

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Statement</th>
<th>Frequency</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Significance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frequency</td>
<td>Significance</td>
</tr>
<tr>
<td>D1</td>
<td>The teacher uses a laptop computer and data projector to present lessons in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>D2</td>
<td>The students use the teacher’s laptop computer during lessons in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D3</td>
<td>The teacher uses an Interactive Whiteboard to present lessons in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D4</td>
<td>The students use an Interactive Whiteboard to present lessons in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D5</td>
<td>The teacher shows ClickView movies in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D6</td>
<td>The teacher uses ClickView learning objects in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D7</td>
<td>The teacher shows Power Point presentations during the lesson in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not Sure</td>
<td>***</td>
</tr>
<tr>
<td>D8</td>
<td>The teacher accesses Internet information during the lesson in your English class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
<tr>
<td>D9</td>
<td>The class goes to a computer laboratory for one-one computer access in your English class.</td>
<td>Rarely</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Positive</td>
<td>***</td>
</tr>
</tbody>
</table>
Table 5.23: Abbreviations used in Table 5.24

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full text</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number</td>
</tr>
<tr>
<td>M</td>
<td>Median</td>
</tr>
<tr>
<td>F</td>
<td>Frequency</td>
</tr>
<tr>
<td>Nev</td>
<td>Never</td>
</tr>
<tr>
<td>R</td>
<td>Rarely used in lessons (used 1 or 2 times per term)</td>
</tr>
<tr>
<td>W</td>
<td>Weekly use in lessons (used 2 or 3 times per month)</td>
</tr>
<tr>
<td>Fr</td>
<td>Frequent use in most lessons (used 2 or 3 times per week)</td>
</tr>
<tr>
<td>O</td>
<td>Often used several times per lesson</td>
</tr>
<tr>
<td>A</td>
<td>Attitude</td>
</tr>
<tr>
<td>V Neg</td>
<td>Very Negative</td>
</tr>
<tr>
<td>Neg</td>
<td>Negative</td>
</tr>
<tr>
<td>NS</td>
<td>Not Sure</td>
</tr>
<tr>
<td>Pos</td>
<td>Positive</td>
</tr>
<tr>
<td>V Pos</td>
<td>Very Positive</td>
</tr>
</tbody>
</table>
Table 5.24: Survey Part D: Summary statistics for raw data (Items D10 – D18 for various classes)
(provided as a general overview only as this data must be assumed not to be statistically significant)

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Statement</th>
<th>Response</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Maths B</th>
<th>Maths C</th>
<th>Information Technology Systems</th>
<th>Film &amp; Television</th>
<th>Modern History</th>
<th>Legal Studies</th>
<th>Drama</th>
<th>German</th>
<th>Music</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
<td>M</td>
<td>N</td>
<td>M</td>
<td>N</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>D10</td>
<td>The teacher uses a laptop computer and data projector to present lessons in your selected class.</td>
<td></td>
<td>F</td>
<td>W</td>
<td>6</td>
<td>N</td>
<td>6</td>
<td>Nev</td>
<td>6</td>
<td>Nev/R</td>
<td>3</td>
<td>Nev</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>Pos</td>
<td>5</td>
<td>Pos</td>
<td>3</td>
<td>Nev</td>
<td>1</td>
<td>Pos</td>
<td>3</td>
<td>V Pos</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D11</td>
<td>The students use the teacher's laptop computer during lessons in your selected class.</td>
<td></td>
<td>F</td>
<td>Nev</td>
<td>6</td>
<td>Nev</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>Nev/R</td>
<td>2</td>
<td>Nev</td>
<td>2</td>
</tr>
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<td></td>
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<td></td>
<td>A</td>
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<td>Pos</td>
<td>3</td>
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<td>1</td>
<td>Pos</td>
<td>3</td>
<td>Pos/V</td>
<td>2</td>
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</tr>
<tr>
<td>D12</td>
<td>The teacher uses an Interactive Whiteboard to present lessons in your selected class.</td>
<td></td>
<td>F</td>
<td>Nev</td>
<td>6</td>
<td>Nev</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>Nev/R</td>
<td>2</td>
<td>Nev</td>
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<td></td>
<td>A</td>
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<td>Pos</td>
<td>3</td>
<td>NS</td>
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<td>NS</td>
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</tr>
<tr>
<td>D13</td>
<td>The students use the Interactive Whiteboard during lessons in your selected class.</td>
<td></td>
<td>F</td>
<td>Nev</td>
<td>6</td>
<td>Nev</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>Nev/R</td>
<td>2</td>
<td>Nev</td>
<td>2</td>
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<td></td>
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<td></td>
<td>A</td>
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<td>Pos</td>
<td>3</td>
<td>NS</td>
<td>1</td>
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<td>Pos/V</td>
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</tr>
<tr>
<td>D14</td>
<td>The teacher shows ClickView movies in your selected class.</td>
<td></td>
<td>F</td>
<td>W/Fr</td>
<td>6</td>
<td>R/W</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>Nev/R</td>
<td>2</td>
<td>Nev</td>
<td>2</td>
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<td></td>
<td></td>
<td></td>
<td>A</td>
<td>Pos</td>
<td>6</td>
<td>Pos</td>
<td>8</td>
<td>NS</td>
<td>3</td>
<td>NS/V Pos</td>
<td>1</td>
<td>Pos/V</td>
<td>1</td>
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</tr>
<tr>
<td>D15</td>
<td>The teacher shows ClickView learning objects in your selected class.</td>
<td></td>
<td>F</td>
<td>R</td>
<td>6</td>
<td>Nev</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>Nev/R</td>
<td>2</td>
<td>Nev</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>Pos</td>
<td>5</td>
<td>Pos</td>
<td>8</td>
<td>NS</td>
<td>3</td>
<td>Pos/V Pos</td>
<td>1</td>
<td>Pos</td>
<td>1</td>
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</tr>
<tr>
<td>D16</td>
<td>The teacher shows Power Point presentations during the lesson in your selected class.</td>
<td></td>
<td>F</td>
<td>R</td>
<td>4</td>
<td>Nev</td>
<td>3</td>
<td>Nev</td>
<td>1</td>
<td>Nev/R</td>
<td>3</td>
<td>Nev</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>Pos/V Pos</td>
<td>6</td>
<td>NS</td>
<td>8</td>
<td>NS</td>
<td>3</td>
<td>Pos/V Pos</td>
<td>2</td>
<td>Pos/V</td>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>D17</td>
<td>The teacher accesses Internet information during the lesson in your selected class.</td>
<td></td>
<td>F</td>
<td>W</td>
<td>6</td>
<td>Nev</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>R</td>
<td>2</td>
<td>R</td>
<td>3</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>A</td>
<td>Pos</td>
<td>5</td>
<td>Pos</td>
<td>3</td>
<td>V Pos</td>
<td>1</td>
<td>V Pos</td>
<td>3</td>
<td>V Pos</td>
<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>D18</td>
<td>The class goes to a computer laboratory for one-one computer access in your selected class.</td>
<td></td>
<td>F</td>
<td>R</td>
<td>6</td>
<td>R</td>
<td>8</td>
<td>Nev</td>
<td>3</td>
<td>R</td>
<td>2</td>
<td>W</td>
<td>3</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>A</td>
<td>Pos</td>
<td>5</td>
<td>Pos</td>
<td>8</td>
<td>V Pos</td>
<td>1</td>
<td>V Pos</td>
<td>3</td>
<td>V Pos</td>
<td>2</td>
</tr>
</tbody>
</table>

**Note:** The data provided is a summary of responses from survey participants. The responses are categorized by subject area, with options ranging from strongly agree (Pos) to strongly disagree (Neg). The data is provided to give an overview of the activities observed in various classes, but it should be noted that the data is not statistically significant due to the small sample size or other methodological limitations.
<table>
<thead>
<tr>
<th>Item</th>
<th>Aggregation Category</th>
<th>Item Statement</th>
<th>Frequency</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median Frequency</td>
<td>Significance Level</td>
</tr>
<tr>
<td>D10</td>
<td>Arts Subjects</td>
<td>The teacher uses a laptop computer and data projector to present lessons in your selected class.</td>
<td>Never</td>
<td>-</td>
</tr>
<tr>
<td>D11</td>
<td>Arts Subjects</td>
<td>The students use the teacher's laptop computer during lessons in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D12</td>
<td>Arts Subjects</td>
<td>The teacher uses an Interactive Whiteboard to present lessons in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D13</td>
<td>Arts Subjects</td>
<td>The students use the Interactive Whiteboard during lessons in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D14</td>
<td>Arts Subjects</td>
<td>The teacher shows ClickView movies in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D15</td>
<td>Arts Subjects</td>
<td>The teacher uses ClickView learning objects in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D16</td>
<td>Arts Subjects</td>
<td>The teacher shows Power Point presentations during the lesson in your selected class.</td>
<td>Rarely</td>
<td>-</td>
</tr>
<tr>
<td>D17</td>
<td>Arts Subjects</td>
<td>The teacher accesses Internet information during the lesson in your selected class.</td>
<td>Never</td>
<td>**</td>
</tr>
<tr>
<td>D18</td>
<td>Arts Subjects</td>
<td>The class goes to a computer laboratory for one-to-one computer access in your selected class.</td>
<td>Rarely</td>
<td>-</td>
</tr>
<tr>
<td>Item</td>
<td>Aggregation Category</td>
<td>Item Statement</td>
<td>Frequency</td>
<td>Attitude</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median</td>
<td>Attitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Frequency</td>
<td>Significance</td>
</tr>
<tr>
<td>D10</td>
<td>Mathematics Subjects</td>
<td>The teacher uses a laptop computer and data projector to present lessons in your selected class.</td>
<td>Never</td>
<td>*</td>
</tr>
<tr>
<td>D11</td>
<td>Mathematics Subjects</td>
<td>The students use the teacher’s laptop computer during lessons in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D12</td>
<td>Mathematics Subjects</td>
<td>The teacher uses an Interactive Whiteboard to present lessons in your selected class.</td>
<td>Never</td>
<td>-</td>
</tr>
<tr>
<td>D13</td>
<td>Mathematics Subjects</td>
<td>The students use the Interactive Whiteboard during lessons in your selected class.</td>
<td>Never</td>
<td>**</td>
</tr>
<tr>
<td>D14</td>
<td>Mathematics Subjects</td>
<td>The teacher shows ClickView movies in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D15</td>
<td>Mathematics Subjects</td>
<td>The teacher uses ClickView learning objects in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D17</td>
<td>Mathematics Subjects</td>
<td>The teacher accesses Internet information during the lesson in your selected class.</td>
<td>Never</td>
<td>***</td>
</tr>
<tr>
<td>D18</td>
<td>Mathematics Subjects</td>
<td>The class goes to a computer laboratory for one-one computer access in your selected class.</td>
<td>Rarely</td>
<td>*</td>
</tr>
</tbody>
</table>
Table 5.27: Survey 1 Part D: Summary statistics for aggregated data in sciences other than physics
(Items D10 – D18: Information about technology use in the students’ science classes (other than physics))

<table>
<thead>
<tr>
<th>Item</th>
<th>Aggregation Category</th>
<th>Item Statement</th>
<th>Frequency</th>
<th>Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>D10</td>
<td>Science Subjects</td>
<td>The teacher uses a laptop computer and data projector to present lessons in your selected class.</td>
<td>Never</td>
<td>Positive</td>
</tr>
<tr>
<td>D11</td>
<td>Science Subjects</td>
<td>The students use the teacher’s laptop computer during lessons in your selected class.</td>
<td>Never</td>
<td>Not Sure</td>
</tr>
<tr>
<td>D12</td>
<td>Science Subjects</td>
<td>The teacher uses an Interactive Whiteboard to present lessons in your selected class.</td>
<td>Never</td>
<td>Not Sure</td>
</tr>
<tr>
<td>D13</td>
<td>Science Subjects</td>
<td>The students use the Interactive Whiteboard during lessons in your selected class.</td>
<td>Never</td>
<td>Not Sure</td>
</tr>
<tr>
<td>D14</td>
<td>Science Subjects</td>
<td>The teacher shows ClickView movies in your selected class.</td>
<td>Weekly</td>
<td>Positive</td>
</tr>
<tr>
<td>D15</td>
<td>Science Subjects</td>
<td>The teacher uses ClickView learning objects in your selected class.</td>
<td>Never/Rarely</td>
<td>Positive</td>
</tr>
<tr>
<td>D16</td>
<td>Science Subjects</td>
<td>The teacher shows Power Point presentations during the lesson in your selected class.</td>
<td>Never</td>
<td>Not Sure</td>
</tr>
<tr>
<td>D17</td>
<td>Science Subjects</td>
<td>The teacher accesses Internet information during the lesson in your selected class.</td>
<td>Never</td>
<td>Not Sure/Positive</td>
</tr>
<tr>
<td>D18</td>
<td>Science Subjects</td>
<td>The class goes to a computer laboratory for one-one computer access in your selected class.</td>
<td>Rarely</td>
<td>Positive</td>
</tr>
</tbody>
</table>
Table 5.28: Survey 1 Part D: Summary statistics for aggregated data in technology subjects
(Items D10 – D18: Information about technology use in the students’ Technology classes)

| Item | Aggregation Category | Item Statement | Frequency | Median | χ² | N | DF | p | Significance Level | Attitude | Frequency | Median | χ² | N | DF | p | Significance Level |
|------|----------------------|----------------|----------|--------|-----|---|----|---|-------------------|----------|-----------|--------|-----|---|----|---|---|-------------------|
| D10  | Technology Subjects  | The teacher uses a laptop computer and data projector to present lessons in your selected class. | Frequently | 2.000  | 5   | 4 | 0.736 | Positive/Very Positive | 6.000 | 4   | 4 | 0.199 |
| D11  | Technology Subjects  | The students use the teacher’s laptop computer during lessons in your selected class. | Never | 6.000  | 5   | 4 | 0.199 | Positive/Very Positive | 3.500 | 4   | 4 | 0.478 |
| D12  | Technology Subjects  | The teacher uses an Interactive Whiteboard to present lessons in your selected class. | Never | ***  | 20.000 | 5 | 4 | 0.000 | Not Sure | 8.500 | 4 | 4 | 0.075 |
| D13  | Technology Subjects  | The students use the Interactive Whiteboard during lessons in your selected class. | Never | ***  | 20.000 | 5 | 4 | 0.000 | Not Sure | 8.500 | 4 | 4 | 0.075 |
| D14  | Technology Subjects  | The teacher shows ClickView movies in your selected class. | Never | *  | 12.000 | 5 | 4 | 0.017 | Positive/Very Positive | 6.000 | 4 | 4 | 0.199 |
| D15  | Technology Subjects  | The teacher uses ClickView learning objects in your selected class. | Never | *  | 12.000 | 5 | 4 | 0.017 | Positive | 5.333 | 3 | 4 | 0.255 |
| D16  | Technology Subjects  | The teacher shows PowerPoint presentations during the lesson in your selected class. | Never | 2.000  | 5   | 4 | 0.736 | Negative | 8.500 | 5 | 4 | 0.075 |
| D17  | Technology Subjects  | The teacher accesses Internet information during the lesson in your selected class. | Frequently | 2.000  | 5   | 4 | 0.736 | Very Positive | 16.000 | 4 | 4 | 0.003 |
| D18  | Technology Subjects  | The class goes to a computer laboratory for one-one computer access in your selected class. | Often | 12.000 | 5   | 4 | 0.017 | Positive / Very Positive | 16.000 | 4 | 4 | 0.003 |
5.3.5 Gender-based differences in survey responses

For each attitudinal survey question (Items A1A–A16A, B1A-B14A, C1O-C13O), median scores were calculated separately for boys and girls. Mann-Whitney U tests (Manning & Munro, 2007) were conducted with each attitudinal survey item as the independent variable and gender as the dependent variable to determine if any differences detected in the median scores for boys and girls were statistically significant.

For items A1A-A16A which measured the students’ attitudes to the teacher’s use of the Tablet PC in physics lessons, no statistically significant differences ($p > 0.05$) on the basis of gender were present between the medians.

Similarly, for items B1A – B14A, which measured the students’ attitudes to their own use of the Tablet PC in physics lessons, no statistically significant differences ($p > 0.05$) on the basis of gender were present between the medians for all items apart from item B12A.

For item B12A ("Indicate your attitude when you used the Tablet PC at your desk in class."), the median response for boys ("Not Sure") was statistically different to the median response for girls ("Positive"), $U = 34.000, p = 0.036$.

Again, for items C1O – C13O, which measured the students’ learning with the TWP in physics lessons, no statistically significant differences ($p > 0.05$) on the basis of gender were present between the medians for all items apart from item C10O.

For item C10O ("I prefer to write lesson notes in the prepared workbooks rather than in a blank notebook."), the median response for boys ("Strongly Agree") was statistically different to the median response for girls ("Agree"), $U = 66.500, p = 0.043$. 
5.3.6 Correlation between attitudes to Tablet PC use and global scores

A Spearman’s Rank Order Correlation (Spearman’s rho) was used to determine if there was a significant correlation between students’ global scores and their attitudes to the use of the Tablet PC (Manning & Munro, 2007).

No significant correlations (p<0.05) other than those described below were found between the students’ attitudes to the use of the Tablet PC in class and the students’ global scores. This was the case for the total student group as well as for Cohort 1 and Cohort 2 individually.

The significant correlations (p<0.05) found are summarised below.

For item A1A, a significant negative correlation was found between Cohort 2 (Year 11 2007) students’ attitudes when the teacher used the Tablet PC in class and their global scores, \( r_s = -0.505, p = 0.020 \).

For Item A9, a significant negative correlation was found between Cohort 2 students’ attitudes when the teacher used graphics calculator software on the Tablet PC and their level of achievement, \( r_s = -0.661, p = 0.001 \).

For item A13A, a significant weak negative correlation was found between Cohort 2 (Year 11 2007) students’ attitudes when the teacher recalls a copy of previous digital lesson notes for review in class and their global scores, \( r_s = -0.448, p = 0.048 \).

These results indicate that the more academically weak the Year 11 students were, the more positive they became about the teacher’s use of the Tablet PC in class generally, and specifically when the teacher recalled a copy of the previous digital lesson notes for review in class or the teacher demonstrated graphics calculator procedures to the class through the Tablet PC.

For item B1A, a significant strongly positive correlation was found between Cohort 1 (Year 12 2007) students’ attitudes when they used the Tablet PC in class during lessons and their global scores, \( r_s = .880, p = 0.001 \).

For Item B2A, a significant strongly positive correlation was found between Cohort 1 (Year 12 2007) students’ attitudes when they used the Tablet PC’s digital pen features and their global scores, \( r_s = .779, p =0.001 \).

For Item B3A, a significant positive correlation was found between Cohort 1 (Year 12 2007) students’ attitudes when they used digital ink on the Tablet PC to add
handwritten notes/diagrams to prepared typed lesson notes and their level of achievement, \( r_s = .656, p = 0.015 \).

For Item B14A, a significant strongly positive correlation was found between Cohort 1 (Year 12 2007) students’ attitudes when they controlled the Tablet PC at the front of the class during lessons and their level of achievement, \( r_s = .880, p = 0.000 \).

These results for the Year 12 students all relate to the use of the Tablet PC by students. The Cohort 2 (Year 11 2007) students were rarely given the opportunity to use the Tablet PC so it is not surprising that no significant correlations \((p<0.05)\) exist for those students.

These results indicate that the more academically able the Year 12 students were, the more positive they were about using the Tablet PC in class.

5.4 Results of Study 3: Qualitative analysis of students’ perceptions of learning with the TWP

5.4.1 Introduction

Qualitative data (students’ comments) were derived from semi-structured interviews, focus group discussions and from the extended response survey items. The qualitative data will not be reported verbatim in this chapter. Rather it will be used to provide student quotations as appropriate in the discussion (see Chapter 6). It will also be analysed to generate quantitative summary data.

The qualitative data was analysed to determine the recurrent themes evident. These themes were organised into categories (see Table 5.29) that were then used to summarise the data.

The qualitative data for the survey, the semi-structured interviews and the focus group discussions have been categorised using the categories listed in Table 5.29 and are summarised in Table 5.30 by the number of comments made in each category.

Summary frequency data were also calculated to show the number of students who made comments in each category for selected data collection activities separately. These results are reported in Section 5.4.2 and Section 5.4.3.
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics</td>
<td>Comment that relates to the logistics of learning in a classroom such as being able to physically see the board.</td>
</tr>
<tr>
<td>T/WB - general</td>
<td>Comment that relates generally to the student’s experience of learning with the TWP.</td>
</tr>
<tr>
<td>T/WB - split attention</td>
<td>Comment about the student’s experience of learning with the TWP that relates specifically to the split-attention effect.</td>
</tr>
<tr>
<td>T/WB - Completion Problems</td>
<td>Comment about the student’s experience of learning with the TWP that relates specifically to the use of completion problems.</td>
</tr>
<tr>
<td>T/WB - Germane CL</td>
<td>Comment about the student’s experience of learning with the TWP that relates specifically to Germane Cognitive Load.</td>
</tr>
<tr>
<td>T/WB - Understanding</td>
<td>Comment about the student’s experience of learning with the TWP that relates specifically to an improvement in his/her understanding of the concepts presented.</td>
</tr>
<tr>
<td>T/WB - Motivation</td>
<td>Comment about the student’s experience of learning with the TWP that relates specifically to his/her motivation to learn.</td>
</tr>
<tr>
<td>T/WB - Negative Comments- general</td>
<td>A generally negative comment about the student’s experience of learning with the TWP.</td>
</tr>
<tr>
<td>T/WB - Negative Comment- none</td>
<td>Comment that the student had nothing negative to say about his/her experience of learning with the TWP.</td>
</tr>
<tr>
<td>T/WB - Suggestions to improve</td>
<td>Suggestion to improve the TWP.</td>
</tr>
<tr>
<td>T/PPT- general</td>
<td>Comment that relates generally to the student’s experience of learning with the tablet/powerpoint pedagogy.</td>
</tr>
<tr>
<td>T/PPT- Redundancy Principle</td>
<td>Comment about the student’s experience of learning with the tablet/Powerpoint pedagogy that relates specifically to the redundancy principle.</td>
</tr>
<tr>
<td>Notes/Organisation</td>
<td>Comment that relates to the student’s ability to organise himself/herself and his/her class notes.</td>
</tr>
<tr>
<td>Handwriting</td>
<td>Comment about the student’s preference for handwritten or typed documents.</td>
</tr>
<tr>
<td>Tablet vs Laptop</td>
<td>Comment expressing the student’s opinion of which technology used in teaching (laptop PC or Tablet PC) better supports his/her learning in the classroom.</td>
</tr>
<tr>
<td>Other Subjects</td>
<td>Comment about the student’s experience of learning in other subjects such as Chemistry.</td>
</tr>
</tbody>
</table>
Table 5.30: Summary of the number of students who made a comment in the given category during the survey, interviews and focus group discussions

<table>
<thead>
<tr>
<th>Category</th>
<th>Logistics</th>
<th>T/MB - general</th>
<th>T/MB - split attention</th>
<th>T/MB - Completion Problems</th>
<th>T/MB - Germane Cl</th>
<th>T/MB - Understanding</th>
<th>T/MB - Motivation</th>
<th>T/MB - Negative Comments - general</th>
<th>T/MB - Negative Comment - none</th>
<th>T/MB - Suggestions to improve</th>
<th>T/PPT - General</th>
<th>T/PPT - Redundancy Principle</th>
<th>Notes/ Organisation</th>
<th>Handwriting</th>
<th>Tablet vs Laptop</th>
<th>Other subjects</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
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<tr>
<td><strong>Number</strong></td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>6</td>
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<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>89%</td>
<td>100%</td>
<td>56%</td>
<td>33%</td>
<td>22%</td>
<td>67%</td>
<td>67%</td>
<td>78%</td>
<td>78%</td>
<td>67%</td>
<td>0%</td>
<td>11%</td>
<td>44%</td>
<td>22%</td>
<td>22%</td>
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</tr>
<tr>
<td><strong>Males</strong></td>
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<tr>
<td><strong>Number</strong></td>
<td>19</td>
<td>25</td>
<td>8</td>
<td>8</td>
<td>1</td>
<td>19</td>
<td>19</td>
<td>17</td>
<td>26</td>
<td>17</td>
<td>4</td>
<td>7</td>
<td>16</td>
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<td>5</td>
<td>28</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>68%</td>
<td>89%</td>
<td>29%</td>
<td>29%</td>
<td>4%</td>
<td>68%</td>
<td>68%</td>
<td>61%</td>
<td>93%</td>
<td>61%</td>
<td>14%</td>
<td>25%</td>
<td>57%</td>
<td>11%</td>
<td>18%</td>
<td>18%</td>
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<td>34</td>
<td>13</td>
<td>11</td>
<td>3</td>
<td>25</td>
<td>25</td>
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<td>33</td>
<td>23</td>
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<td>20</td>
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<td>37</td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td>73%</td>
<td>92%</td>
<td>35%</td>
<td>30%</td>
<td>8%</td>
<td>68%</td>
<td>68%</td>
<td>65%</td>
<td>89%</td>
<td>62%</td>
<td>11%</td>
<td>22%</td>
<td>54%</td>
<td>14%</td>
<td>19%</td>
<td>19%</td>
<td>100%</td>
</tr>
</tbody>
</table>
5.4.2 Qualitative data from the survey

Items A17, B15, B16, C14 and C15 in the survey allowed students to answer open-ended questions, providing qualitative data. The questions are shown in Table 5.31.

Table 5.31: Survey questions generating qualitative data

<table>
<thead>
<tr>
<th>Item</th>
<th>Question/Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A17</td>
<td>What other activities would you like to have the teacher do using the Tablet PC during lessons?</td>
</tr>
<tr>
<td>B15</td>
<td>In what ways can the stored lesson material from a Tablet PC lesson be used to assist your home study?</td>
</tr>
<tr>
<td>B16</td>
<td>What other activities would it be good for students to do using the Tablet PC during lessons?</td>
</tr>
<tr>
<td>C14</td>
<td>The things I like about the use of the Tablet PC in class are:</td>
</tr>
<tr>
<td>C15</td>
<td>The things I do not like about the use of the Tablet PC in class are:</td>
</tr>
</tbody>
</table>

Responses to these items were recorded verbatim with the exception that typographical and punctuation errors were corrected to clarify responses. Data from Items A17 and C14 were further analysed to produce frequency summary data.

5.4.2.1 Summary data for Survey Item A17

The qualitative data for Survey Item A17 have been categorised using the categories listed in Table 5.29 and are summarised in Table 5.32 by the number of comments made in each category.
Table 5.32: Summary of Qualitative Responses to Survey Item A17: “What other activities would you like to have the teacher do using the Tablet PC during lessons?”

<table>
<thead>
<tr>
<th>Gender</th>
<th>T/WB - Negative Comments</th>
<th>T/WB - Suggestions</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>26</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Percentage</td>
<td>52%</td>
<td>4%</td>
<td>16%</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>19</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Percentage</td>
<td>49%</td>
<td>3%</td>
<td>18%</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Percentage</td>
<td>64%</td>
<td>9%</td>
<td>9%</td>
</tr>
</tbody>
</table>

5.4.2.2 Summary data for Survey Item C14

The qualitative data for Survey Item C14 have been categorised using the categories listed in Table 5.29 and are summarised in Table 5.33 by the number of comments made in each category.

Table 5.33: Summary of Qualitative Responses to Survey Item C14: “The things I like about the use of the Tablet PC in class are:"

<table>
<thead>
<tr>
<th>Gender</th>
<th>Workbooks</th>
<th>Access to Internet / Animations</th>
<th>T/WB - Understanding</th>
<th>T/WB - Motivation</th>
<th>Logistics</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>Total</td>
<td>35</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Percentage</td>
<td>38%</td>
<td>12%</td>
<td>11%</td>
<td>10%</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>Males</td>
<td>Total</td>
<td>23</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Percentage</td>
<td>38%</td>
<td>11%</td>
<td>15%</td>
<td>13%</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>Females</td>
<td>Total</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Percentage</td>
<td>40%</td>
<td>13%</td>
<td>3%</td>
<td>3%</td>
<td>20%</td>
<td>100%</td>
</tr>
</tbody>
</table>
### 5.4.2.3 Summary data for all survey qualitative items (A17, B15, B16, C14, C15)

The qualitative data for Survey Items A17, B15, B16, C14 and C15 have been categorised using the categories listed in Table 5.29 and are summarised in Table 5.32 by the number of comments made in each category.

#### Table 5.34: Summary of Qualitative Responses to all survey qualitative items (Items A17, B15, B16, C14, C15)

<table>
<thead>
<tr>
<th>Category</th>
<th>Females</th>
<th>Males</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Number</td>
<td>Number</td>
</tr>
<tr>
<td>Logistics</td>
<td>7</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>T/WB Combo-General</td>
<td>4</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>T/WB-General</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T/WB-split attention</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>T/WB-Completion Problems</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>T/WB-Germane CL</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>T/WB-Under-standing</td>
<td>0</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>T/WB-Motivation</td>
<td>0</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>T/WB-Negative Comments-General</td>
<td>0</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>T/WB-Negative Comments-none</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T/WB-Suggestions to Improve</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>T/PPT-General</td>
<td>7</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>T/PPT-Redundancy Principle</td>
<td>6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Notes/Organisation</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Handwriting</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tablet vs Laptop</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other subjects</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grand Total</td>
<td>19</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>Percentage Females</td>
<td>78%</td>
<td>67%</td>
<td>70%</td>
</tr>
<tr>
<td>Percentage Males</td>
<td>44%</td>
<td>75%</td>
<td>67%</td>
</tr>
<tr>
<td>Percentage Total</td>
<td>56%</td>
<td>42%</td>
<td>55%</td>
</tr>
</tbody>
</table>

*Note: The percentages are rounded to the nearest whole number.*
5.4.3 Qualitative data from the interviews and focus groups

Table 5.35 shows a summary of the numbers of students who were interviewed or who participated in a focus group, providing qualitative data. Overall, a participation rate of 59% was achieved in either interviews or focus groups. Some students were unable to participate due to ill health, time constraints or because they did not return consent forms. Time constraints also meant that each student was offered only one of these two discussion forums.

Table 5.35: Semi-structured Interview and Focus Group Participation Data

<table>
<thead>
<tr>
<th>Class in 2007</th>
<th>Students who participated in a Semi-structured Interview</th>
<th>Students who participated in a Focus Group</th>
<th>Total Participants</th>
<th>Number of Students in the Cohort</th>
<th>Overall Participation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Total</td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Year 12 (Cohort 1)</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Year 11 (Cohort 2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>16</td>
<td>6</td>
</tr>
</tbody>
</table>

The audio recordings were transcribed. The scripted questions and the additional questions that frequently arose are shown in Table 5.36.

The qualitative data for semi-structured interviews and focus group discussions have been categorised using the categories listed in Table 5.29 and are summarised in Table 5.37 by the number of comments made in each category.
Table 5.36: Interviews and Focus Groups: Scripted questions and frequently asked unscripted questions

<table>
<thead>
<tr>
<th>Scripted Questions</th>
<th>Unscripted questions that frequently arose in response to students’</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Does the use of technology play a big part in your life generally? Explain.</td>
<td></td>
</tr>
<tr>
<td><strong>2.</strong> Does the use of technology play a big part in your current school subjects? Explain.</td>
<td></td>
</tr>
<tr>
<td><strong>3.</strong> Has the use of the Tablet PC in Physics lessons helped your learning? How?</td>
<td><strong>3.01</strong> Of the teaching styles you have experienced in Physics (traditional, Tablet and PPT/handouts and Tablet/Workbooks), which style of teaching do you prefer?</td>
</tr>
<tr>
<td></td>
<td>3.02 In Term 1 we used PowerPoint on the Tablet PC and handouts. Later (during Terms 3 and 4) we used the booklet and the Tablet. How did these compare?</td>
</tr>
<tr>
<td></td>
<td>3.03 In Term 2 we didn’t use the tablet at all. We just used the good old ordinary whiteboard to give you a taste of what traditional Physics lessons were like. How did that compare with using the Tablet and workbooks?</td>
</tr>
<tr>
<td></td>
<td>3.04 When we work through examples in class, we work together to get each line of the solution. With the tablet, I could have the whole answer to a question already there and just display it to you. Would you prefer that or do you like the way we develop each line in order?</td>
</tr>
<tr>
<td></td>
<td>3.05 Did you find having colourful Power Points with lots of nice images appealing. Was it helpful to your learning?</td>
</tr>
<tr>
<td></td>
<td>3.06 How does teaching using a Tablet PC compare with teaching using an ordinary laptop PC?</td>
</tr>
<tr>
<td></td>
<td>3.07 Which do you prefer for learning in Physics: the tablet and the projector combination or an interactive whiteboard.</td>
</tr>
<tr>
<td></td>
<td>3.08 I could use the Tablet to type notes rather than handwrite them. Also the worked solutions I provide for revision problems could be typed rather than handwritten. Which do you prefer: typed or handwritten?</td>
</tr>
<tr>
<td></td>
<td>3.09 Would having all the notes and worked examples printed out in the workbooks so you could just listen and not have to write be better for your learning?</td>
</tr>
<tr>
<td></td>
<td>3.10 Are you well organised? Does having the booklet help with organising things?</td>
</tr>
<tr>
<td></td>
<td>3.11 Would just having the tablet without the workbooks be better ie would you rather write your notes in a notebook?</td>
</tr>
<tr>
<td></td>
<td>3.12 Would having the workbook without the tablet be better?</td>
</tr>
<tr>
<td>Scripted Questions</td>
<td>Unscripted questions that frequently arose in response to students’ comments</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4. What are the problems for learning when a Tablet PC is used in Physics lessons? Why?</td>
<td></td>
</tr>
<tr>
<td>5. Does the use of the Tablet PC improve your enthusiasm for learning? Why?</td>
<td></td>
</tr>
<tr>
<td>6. In what ways should the Tablet PC be used in class next year/term to best improve your learning?</td>
<td></td>
</tr>
<tr>
<td>7. If your best friend wanted to study Physics next year, what would you tell him/her about the Tablet PC?</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.37: Summary of Qualitative Responses during the interviews and focus group discussions

<table>
<thead>
<tr>
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<td>33%</td>
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<td>100%</td>
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<tr>
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<td>9</td>
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<td>8</td>
<td>13</td>
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</tr>
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<td>Percentage</td>
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<td>45%</td>
<td>25%</td>
<td>10%</td>
<td>90%</td>
<td>95%</td>
<td>40%</td>
<td>85%</td>
<td>45%</td>
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<td>Total</td>
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<td>92%</td>
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</table>
Chapter 6: Discussion

6.1 Introduction

This discussion will address the research questions by testing the research hypotheses against the evidence gathered in the three research studies.

The evidence relating to the central question, “Does the TWP produce superior learning outcomes for students studying high school physics relative to that achieved with the use of traditional pedagogy?” will be discussed first. Hypothesis 1 will be tested first to establish whether the TWP resulted in improved learning outcomes for all students in their global scores and then separately for their CRP scores (far transfer tasks), and their K and SP scores (near transfer tasks). Evidence of differences in the effect of the TWP on the basis of type of assessment (i.e. near or far transfer tasks) and on the basis of gender will then be considered to test Hypothesis 2.

The observed effects of the TWP on learning outcomes and any observed differences on the basis of assessment type and gender will be discussed. Evidence from students’ responses will be analysed to determine whether students’ perceptions are consistent with quantitative trends. This will allow Hypothesis 3 to be tested. Students’ responses will be further investigated to contrast their experiences of learning with the TWP with their experiences of learning in a traditional physics class and in their other school subjects.

Other aspects of the research questions require a consideration of the observed effects in the light of learning theory. Cognitive load theory will be used to determine whether there is a valid theoretical basis for the observed effects.

If theory and the students’ perceptions are consistent with the observed effects of the TWP on learning outcomes, the research conclusions will be strengthened through triangulation.

Throughout the discussion, ‘significant’ findings will refer to findings with demonstrated statistical significance at the 5% level (i.e. $p<0.05$). ‘Not significant’
findings will refer to a demonstrated lack of statistical significance at the 5% level (i.e. $p \geq 0.05$) for the findings. For brevity, the level of significance will not be quoted after each statement of significance.

6.2 The effect of the TWP on learning outcomes
(an analysis of quantitative data from Study 1)

6.2.1 Introduction

The following sections will analyse the trends in global scores and also the trends evident for each individual criterion (K, SP and CRP). Such analyses will be conducted for the whole cohort and then repeated separately for boys and girls.

All comments made will be based on the statistical evidence provided by their standard deviations (SD) and their paired-samples t-tests which are reported in the tables in Sections 5.2.2, 5.2.3 and 5.2.4. For ease of reference and to reduce split-attention, graphs illustrating the comparisons in terms of their means (M), their standard deviations (SD) and their paired-sample t-test statistics ($t$, df, p) will be displayed in the sections where associated comments are made. For clarity and brevity, such statistics will not be quoted directly in the text. Rather reference will be made to the graph where this information can be seen clearly.

6.2.2 Choice of Control Group

In Section 4.7.3, issues underlying the choice of a control group were raised. It was assumed that a major variable that should be controlled was the cohorts’ teacher, and the experimental design was developed with Cohort 5 as the control group on the basis that this assumption was true.

Data was collected to test this hypothesis and is reported in Section 5.2.4.1. Figure 6.1 shows a graph summarising this data.

Cohorts 3 and 4 both demonstrated significant improvements in students’ grades globally and in all three criteria in going from Year 11 to Year 12 when the teacher changed from Teacher X to Teacher Y (the means, standard deviations and paired-sample t-test statistics for these eight comparisons are quoted in Figure 6.2, Figure 6.3, Figure 6.4 and Figure 6.5).
For Cohort 5 (labelled as the Control Group), the only significant variation in the students’ global results between Year 11 and Year 12 was in the Scientific Processes criterion (see Figure 6.2, Figure 6.3, Figure 6.4 and Figure 6.5). Because this trend was also observed in Cohorts 3 and 4, it is likely that it is due to maturation rather than to the change in teacher.

These comparisons show that a change in teacher significantly affected the students’ scores. Thus, the hypothesis was proven correct and the research plan is valid. For experimental validity, the same teacher must have taught the class before and after any intervention to be studied.

This evidence also suggests that for a cohort to provide a valid Control Group, it must have been taught by the same teacher in Year 11 and Year 12. The 2000/2001 cohort was the most recent cohort to satisfy this requirement so it has been selected as the control group.
Figure 6.1: Summary of comparisons of Year 11 and Year 12 scores showing the effect of a change of teacher (all students)
(Summarises paired-sample t-test data selected from Table 5.8, Table 5.9 and Table 5.4)
Figure 6.2: Comparison of Year 11 and Year 12 Scores showing the effect of a change of teacher on global scores (all students)
(Shows paired-sample t-test data selected from Table 5.8, Table 5.9 and Table 5.4)
Figure 6.3: Comparison of Year 11 and Year 12 Scores showing the effect of a change of teacher on CRP scores (all students)
(Shows paired-sample t-test data selected from Table 5.8, Table 5.9 and Table 5.4)
Figure 6.4: Comparison of Year 11 and Year 12 Scores showing the effect of a change of teacher on SP scores for all students
(Shows paired-sample t-test data selected from Table 5.8, Table 5.9 and Table 5.4)
Figure 6.5: Comparison of Year 11 and Year 12 Scores showing the effect of a change of teacher on K scores for all students
(Shows paired-sample t-test data selected from Table 5.8, Table 5.9 and Table 5.4)

A Wilcoxon Signed-Ranks test was performed as the data set failed the normality assumption
6.2.3 Interventions 1 and 2

For Intervention 1, the intervention group was Cohort 1 who learned with traditional pedagogy in Year 11 and with the TWP in Year 12. Comparisons of pre-intervention and post-intervention scores are made for Cohort 1. Similar comparisons across the same time periods were made for Cohort 2 and for the Control Group. Similarities and differences between the comparisons made for the three groups will be analysed to determine the effect of the TWP on the students’ learning.

For Intervention 2, the intervention group was Cohort 2 who learned with traditional pedagogy in Year 11 Term 2 and with the TWP in Year 11 Semester 2 onwards. Comparisons of pre-intervention and post-intervention scores were made for Cohort 2. Similar comparisons across the same time periods were made for Cohort 1 and for the Control Group. Similarities and differences between the comparisons made for the three groups will be analysed to determine the effect of the TWP on the students’ learning.

6.2.4 Comparisons for all students

The results of the comparisons for all students in Intervention 1 are shown in data tables in Section 5.2.2. A summary of the comparisons are also displayed graphically in Figure 6.6.

The results of the comparisons for all students in Intervention 2 are shown in data tables in Section 5.2.3. A summary of the comparisons is also displayed graphically in Figure 6.7.
Figure 6.6: Summary of comparisons of pre-intervention and post-intervention scores for Intervention 1 (all students)
(Summarises paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.7: Summary of comparisons of pre-intervention and post-intervention scores for Intervention 2 (all students)
(Summarises paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.4.1 Trends in all students’ global scores

Figure 6.8 and Figure 6.9 show comparisons of pre-intervention and post-intervention global scores for all students in Interventions 1 and 2 respectively, including means, standard deviations and the paired-sample t-tests statistics which were reported in data tables in Sections 5.2.2 and 5.2.3.

Comparisons of the Intervention 1 data shows that the global scores for the intervention cohort (Cohort 1) improved significantly after they had learned with the TWP for one year (see Figure 6.8). No similar significant improvement was evident in the Intervention 2 data for Cohort 2 after they had learned with the TWP for only six months (see Figure 6.9). However for this group, a significant improvement in global scores showed up in the Intervention 1 data after they had learned with the TWP for another year (see Figure 6.8). No significant improvement in global scores was observed in the Control Group’s data for either Intervention 1 (see Figure 6.8) or Intervention 2 (see Figure 6.9) or in Cohort 1’s data for Intervention 2 when this group learned only with traditional pedagogy (see Figure 6.7).

These comparisons indicate that the observed improvements for Cohorts 1 and 2 were indeed due to the use of the TWP for an extended period of time rather than to the students’ growing maturity and experience as they progressed through the two year course.

The evidence is clear that the use of the TWP in teaching physics has caused a significant improvement in learning outcomes. Before reasons for the improvement are sought in the other evidence available, the nature of the improvements will be analysed in more detail to determine in which individual criteria improvements occurred.
Figure 6.8: Comparisons of pre-intervention and post-intervention global scores for Intervention 1 (All students)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.9: Comparisons of pre-intervention and post-intervention global scores for Intervention 2 (all students)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
**6.2.4.2 Trends in all students’ CRP scores**

Figure 6.10 and Figure 6.11 show comparisons of pre-intervention and post-intervention CRP scores for all students in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

The TWP was designed to reduce the cognitive load experienced by students as they learn physics, an inherently complex subject. In this way, the incidence of cognitive overload should be reduced and students’ success rate in processing the multiple interacting elements necessary to understand physics should be increased. It was hypothesized that this deeper understanding would result in the students’ improved performance in the far transfer assessment items embodied in the CRP criterion. Evidence for such an improvement in this criterion will now be considered.

The Intervention 2 CRP data (see Figure 6.11) show that the only cohort to demonstrate a significant improvement in their CRP scores was the intervention group, Cohort 2. The improvement was evident even though the students had only been learning with the TWP for six months. The control group and Cohort 1 had not yet experienced learning with the TWP and neither showed any significant change in their CRP scores (see Figure 6.11).

The Intervention 1 data (see Figure 6.10) shows that the only cohort to demonstrate a significant improvement in their CRP scores at this stage of the course was the intervention group, Cohort 1 who had learned with traditional pedagogy for one year and then with the TWP for one year. Cohort 2 showed no significant change at this stage (see Figure 6.11) but had already improved significantly when they were first introduced to the TWP during Intervention 2 (see Figure 6.11) and this data provided evidence that their CRP scores remained at the elevated level throughout Year 12. The Control Group, in contrast, showed no evidence of significant improvement in CRP scores at any stage even though the students grew in maturity and experience as they progressed through the two year course (see Figure 6.10 for Intervention 1 and Figure 6.11 for Intervention 2).

In summary, the data show that both intervention groups experienced a significant improvement in their CRP scores after learning with the TWP for as little as six months.
Learning with traditional pedagogy produced no significant improvement in CRP scores at any stage of the two year course. This reflects findings from the literature (e.g. Larkin, et al., 1980). A clear link has thus been established between the use of the TWP in physics classes and significant improvements in all students’ scores on far-transfer tasks. Reasons for this link will be sought in the students’ responses to the survey and interviews and focus groups.
Figure 6.10: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 1 (all students)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.11: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 2 (all students)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.4.3 Trends in all students’ SP scores

Figure 6.12 and Figure 6.13 show comparisons of pre-intervention and post-intervention SP scores for all students in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

SP tasks are near transfer tasks related to the gathering, processing and communication of primary and secondary data. Evidence of trends in scores in this criterion will now be considered.

Intervention 1 data shows significant improvements in this criterion for all three cohorts (see Figure 6.12) while Intervention 2 data shows no significant improvement in this criterion for any of the three cohorts (see Figure 6.13).

Thus it can be concluded that there is no difference between the cohorts in SP score trends regardless of whether traditional pedagogy or the TWP is used.
Figure 6.12: Comparisons of pre-intervention and post-intervention SP scores for Intervention 1 (all students)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.13: Comparisons of pre-intervention and post-intervention SP scores for Intervention 2 (all students)

(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)

**# A Wilcoxon Signed-Ranks test was performed as the data set failed the normality assumption**

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<th>Criterion</th>
<th>Traditional Pedagogy (Cohort 1 Year 11 Term 2)</th>
<th>Tablet/Workbook Pedagogy (Cohort 2 Year 11 Semester 2)</th>
<th>Traditional Pedagogy (Control Group Year 11 Term 2)</th>
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<td><strong>Mean Score (%)</strong></td>
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<td><strong>55.94</strong></td>
<td><strong>50.38</strong></td>
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<td><strong>Standard Deviation</strong></td>
<td><strong>17.070</strong></td>
<td><strong>12.632</strong></td>
<td><strong>15.522</strong></td>
<td><strong>10.191</strong></td>
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</tbody>
</table>

- No significant change at 5% level
- Significant difference at 5% level
- Significant difference at 1% level
- Significant difference at 0.1% level
- Z(15)= -1.392, p=0.164
- t(15)= -0.165, p=0.871
- t(32)= -1.489, p=0.146

Control Group n = 34
Cohort 1 n = 16
Cohort 2 n = 16
Intervention Group

Scientific Processes

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 2 Year 11 Term 2 and Year 11 Semester 2 Scores (All students)
6.2.4.4 Trends in all students’ K scores

Figure 6.14 and Figure 6.15 show comparisons of pre-intervention and post-intervention K scores for all students in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

K tasks are near transfer tasks involving the recall and simple application of knowledge in rehearsed situations. Evidence of trends in scores in this criterion will now be considered.

The K scores showed the same trends as the global scores (see Figure 6.14). No similar significant improvement was evident in the Intervention 2 data for the intervention group (Cohort 2) after they had learned with the TWP for only six months (see Figure 6.15). However for this group, a significant improvement in K scores showed up in the Intervention 1 data after they had learned with the TWP for another year (see Figure 6.14).

No significant change in K scores was observed in the Control Group’s data for Intervention 1 (see Figure 6.14) or Intervention 2 (see Figure 6.15). In addition, Cohort 1’s data for Intervention 2 showed no significant change in K scores (see Figure 6.15).

These analyses indicate that the observed improvements for Cohorts 1 and 2 were indeed due to the use of the TWP for an extended period of time rather than to the students’ growing maturity and experience as they progressed through the two year course.
Figure 6.14: Comparisons of pre-intervention and post-intervention K scores for Intervention 1 (all students)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.15: Comparisons of pre-intervention and post-intervention K scores for Intervention 2 (all students)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.5 Comparisons for Boys

The results of the comparisons for boys in Intervention 1 are shown in data tables in Section 5.2.2. A summary of the comparisons are also displayed graphically in Figure 6.16.

The results of the comparisons for boys in Intervention 2 are shown in data tables in Section 5.2.3. A summary of the comparisons is also displayed graphically in Figure 6.17.
Figure 6.16: Summary of Comparison of pre-intervention and post-intervention scores for Intervention 1 (boys) (Summarises paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.17: Summary of Comparison of pre-intervention and post-intervention scores for Intervention 2 (boys)
(Summarises paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.5.1 Trends in boys’ global scores

Figure 6.18 and Figure 6.19 show comparisons of pre-intervention and post-intervention global scores for boys in Interventions 1 and 2 respectively, including means, standard deviations and the results of the paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

The trends for boys’ global scores were identical to the trends evident in the global scores for all students so the same conclusion can be drawn (see Figure 6.18 and Figure 6.19). Improvements in the boy’s global scores for Cohorts 1 and 2 were due to the use of the TWP for an extended period of time rather than to the boys’ growing maturity and experience as they progressed through the two year course.

The evidence is clear that the use of the TWP in teaching physics has caused significant improvements in learning outcomes for boys.
Figure 6.18: Comparisons of pre-intervention and post-intervention global scores for Intervention 1 (boys)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.19: Comparisons of pre-intervention and post-intervention global scores for Intervention 2 (boys)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.5.2 Trends in boys’ CRP scores

Figure 6.20 and Figure 6.21 show comparisons of pre-intervention and post-intervention CRP scores for boys in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

The trends for boys’ CRP scores were identical to the trends evident in the global scores for all students with one exception (see Figure 6.20 and Figure 6.21). The improvement in the Cohort 1 boy’s CRP scores for Intervention 1 were not quite significant at the 5% level with \( p=0.051 \) but, given that the sample size was only 11, this will be considered was significant at the 10% level.

The same conclusion will be drawn for the boys’ CRP scores as was drawn for all students’ CRP scores. The data shows that for boys in both intervention groups, a significant improvement in their CRP scores occurred after learning with the TWP for as little as six months. Learning with traditional pedagogy produced no significant improvement in CRP scores for boys at any stage of the two year course. A clear link has thus been established between the use of the TWP in physics classes and significant improvements in boys’ scores on far transfer tasks.
**Figure 6.20: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 1 (boys)**

(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.21: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 2 (boys)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.5.3 Trends in boys' SP scores

Figure 6.22 and Figure 6.23 show comparisons of pre-intervention and post-intervention SP scores for boys in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

The trends for boys’ SP scores were identical to the trends evident in the SP scores for all students so the same conclusion can be drawn: that there is no difference between the cohorts in SP score trends regardless of whether traditional pedagogy or the TWP is used (see Figure 6.22 and Figure 6.23).
Figure 6.22: Comparisons of pre-intervention and post-intervention SP scores for Intervention 1 (boys) (Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.23: Comparisons of pre-intervention and post-intervention SP scores for Intervention 2 (boys)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 2
Year 11 Term 2 and Year 11 Semester 2 Scores
(Males)

- no significant change at 5% level
- * significant difference at 5% level
- ** significant difference at 1% level
- *** significant difference at 0.1% level

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<th>Traditional Pedagogy (Cohort 1 Year 11 Semester 2)</th>
<th>Traditional Pedagogy (Control Group Year 11 Term 2)</th>
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<td>Mean Score (%)</td>
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<td>M=69.77 SD=18.647</td>
<td>M=73.18 SD=12.352</td>
<td>M=75.09 SD=11.265</td>
<td>M=64.77 SD=11.698</td>
<td>M=60.86 SD=15.223</td>
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<td>p-value</td>
<td>t(12)=-0.141, p=0.686</td>
<td>t(10)=0.434, p=0.673</td>
<td>t(21)=-1.193, p=0.246</td>
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</table>
6.2.5.4 Trends in boys’ K scores

Figure 6.24 and Figure 6.25 show comparisons of pre-intervention and post-intervention K scores for boys in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

The trends for boys’ K scores were identical to the trends evident in the K scores for all students (see Figure 6.24 and Figure 6.25) so the same conclusion can be drawn: that the observed improvements for the boys in Cohorts 1 and 2 were due to the use of the TWP for an extended period of time rather than to the students’ growing maturity and experience as they progressed through the two year course.
Figure 6.24: Comparisons of pre-intervention and post-intervention K scores for Intervention 1 (boys)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.25: Comparisons of pre-intervention and post-intervention K scores for Intervention 2 (boys)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.6 Comparisons for Girls

The results of the comparisons for girls in Intervention 1 are shown in data tables in Section 5.2.2. A summary of the comparisons are also displayed graphically in Figure 6.26.

The results of the comparisons for girls in Intervention 2 are shown in data tables in Section 5.2.3. A summary of the comparisons is also displayed graphically in Figure 6.27.

Relatively few girls opt to study physics so the sample sizes for the girls’ subgroups were small. There were 3 girls in Cohort 1, 5 girls in Cohort 2 and 10 girls in the Control Group. With such small sample sizes, the data is not reliable and it is difficult to show the statistical significance of any trends.
Figure 6.26: Summary of Comparison of pre-intervention and post-intervention scores for Intervention 1 (girls)
(Summarises paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.27: Summary of Comparison of pre-intervention and post-intervention scores for Intervention 2 (girls)
(Summarises paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.6.1 Trends in girls’ global scores

Figure 6.28 and Figure 6.29 show comparisons of pre-intervention and post-intervention global scores for girls in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

No significant changes in girls’ global scores were observed for Intervention 1 (see Figure 6.28) or Intervention 2 (see Figure 6.29) indicating that there is no statistical evidence that use of the TWP has improved global scores for girls.

Given the small sample sizes, however, it should be noted that the observed trend in girls’ global scores was upwards for Intervention 1 data for both Cohorts 1 and 2 but not for the Control Group (see Figure 6.28). This is an indicator that improvements in the global scores for Cohorts 1 and 2 were due to the use of the TWP for an extended period of time rather than to the girls’ growing maturity and experience as they progressed through the two year course.

There is some indication but no statistical evidence at the 5% level that the use of the TWP in teaching physics has caused a significant improvement in learning outcomes for girls.
Figure 6.28: Comparisons of pre-intervention and post-intervention global scores for Intervention 1 (girls)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
Figure 6.29: Comparisons of pre-intervention and post-intervention global scores for Intervention 2 (girls)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)
6.2.6.2 Trends in girls’ CRP scores

Figure 6.30 and Figure 6.31 show comparisons of pre-intervention and post-intervention CRP scores for girls in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

For Intervention 2, a significant improvement occurred in girls’ CRP scores for the intervention group (Cohort 2) who had learned with the TWP for only 6 months but not for the girls in Cohort 1 or the Control Group who had only experienced learning with traditional pedagogy (see Figure 6.31). No significant changes were found for the Intervention 1 data for Cohort 2 indicating that the girls in Cohort 2 maintained their elevated CRP performance throughout Year 12 whilst learning with the TWP (see Figure 6.30).

Both Cohort 1 (the intervention group) and the Control Group girls’ CRP grades showed no significant change for Intervention 1 (see Figure 6.30) or Intervention 2 (see Figure 6.31). Learning with traditional pedagogy produced no improvement in girl’s CRP scores and nor did learning with the TWP for Cohort 1 girls.

In summary, the data shows that for girls in Cohort 2 but not Cohort 1, a significant improvement in CRP scores occurred after learning with the TWP for as little as six months. Learning with traditional pedagogy produced no significant improvement in CRP scores for girls at any stage of the two year course. A link has thus been established between the use of the TWP in physics classes and significant improvements in some, but not all, girls’ scores on far transfer tasks.
Figure 6.30: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 1 (girls)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 1
Year 11 and Year 12 Scores
(Females)

- no significant change at 5% level
* significant difference at 5% level
** significant difference at 1% level
*** significant difference at 0.1% level

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<tr>
<th>Criterion</th>
<th>Traditional Pedagogy (Cohort 1 Year 11)</th>
<th>Tablet/Workbook Pedagogy (Cohort 1 Year 12)</th>
<th>Traditional Pedagogy (Cohort 2 Year 11)</th>
<th>Tablet/Workbook Pedagogy (Cohort 2 Year 12)</th>
<th>Traditional Pedagogy (Control group Year 11)</th>
<th>Traditional Pedagogy (Control group Year 12)</th>
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<tr>
<td>M=45.20 SD=26.687</td>
<td>M=46.6 SD=26.726</td>
<td>M=53.13 SD=17.534</td>
<td>M=60.33 SD=16.266</td>
<td>M=47.6 SD=20.034</td>
<td>M=37.1 SD=14.725</td>
<td></td>
</tr>
</tbody>
</table>

- t(4)=0.828, p=0.454
- t(2)=0.440, p=0.703
- t(9)=-1.969, p=0.081
Figure 6.31: Comparisons of pre-intervention and post-intervention CRP scores for Intervention 2 (girls)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 2
Year 11 Term 2 and Year 11 Semester 2 Scores (Females)

- no significant change at 5% level
- * significant difference at 5% level
- ** significant difference at 1% level
- *** significant difference at 0.1% level

- t(2) = 9.250, p = 0.011
- t(4) = -0.040, p = 0.970
- t(10) = 0.659, p = 0.525

Mean Score (%) 0 10 20 30 40 50 60 70 80 90 100

- Cohort 2 n = 3 Intervention Group
- Cohort 1 n = 5
- Control Group n=10

Criterion

- Traditional Pedagogy (Cohort 2 Year 11 Term 2)
- Tablet/Workbook Pedagogy (Cohort 2 Year 11 Semester 2)
- Traditional Pedagogy (Cohort 1 Year 11 Term 2)
- Traditional Pedagogy (Cohort 1 Year 11 Semester 2)
- Traditional Pedagogy (Control Group Year 11 Term 2)
- Traditional Pedagogy (Control Group Year 11 Semester 2)
6.2.6.3 Trends in girls’ SP scores

Figure 6.32 and Figure 6.33 show comparisons of pre-intervention and post-intervention SP scores for girls in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

Intervention 1 data (see Figure 6.32) indicates a general upward trend for girls’ SP scores for each cohort but no improvements were statistically significant. Intervention 2 data (see Figure 6.33), on the other hand, indicates a general downward trend for girl’s SP scores for each cohort but only the decrease in SP scores for Cohort 2 girls was significant. The use of the TWP for 6 months has actually hindered learning in these near transfer tasks for Cohort 2 girls to a greater extent than the use of traditional pedagogy did.
Figure 6.32: Comparisons of pre-intervention and post-intervention SP scores for Intervention 1 (girls)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)
**Figure 6.33: Comparisons of pre-intervention and post-intervention SP scores for Intervention 2 (girls)**

(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)

**Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 2**  
**Year 11 Term 2 and Year 11 Semester 2 Scores**  
(Females)

- no significant change at 5% level  
* significant difference at 5% level  
** significant difference at 1% level  
*** significant difference at 0.1% level

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Mean Score (%)</th>
<th>SD</th>
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<tr>
<td>Traditional Pedagogy (Cohort 2 Year 11 Term 2)</td>
<td>M=91.00</td>
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<tr>
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<td>Traditional Pedagogy (Cohort 1 Year 11 Term 2)</td>
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<td>Traditional Pedagogy (Cohort 1 Year 11 Semester 2)</td>
<td>M=76.00</td>
<td>SD=8.456</td>
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<td>Traditional Pedagogy (Control Group Year 11 term 2)</td>
<td>M=72.73</td>
<td>SD=13.297</td>
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<tr>
<td>Traditional Pedagogy (Control Group Year 11 Semester 2)</td>
<td>M=70.09</td>
<td>SD=14.896</td>
</tr>
</tbody>
</table>

- **t(2)= -9.820, p=0.010**  
  - **t(4)= -1.268, p=0.274**  
  - **t(10)= -0.970, p=0.355**
6.2.6.4 Trends in girls’ K scores

Figure 6.34 and Figure 6.35 show comparisons of pre-intervention and post-intervention K scores for girls in Interventions 1 and 2 respectively, including means, standard deviations and the results of paired-sample t-tests which were reported in data tables in Sections 5.2.2 and 5.2.3.

No significant changes in girls’ K scores were detected for either intervention (see Figure 6.34 and Figure 6.35) for any of the three cohorts although the trend in Intervention 1 data was upwards for girls learning with the TWP and static for the girls in the control Group.

There is no clear evidence that girls’ K scores change over the two year period of the physics course regardless of whether they learn with traditional pedagogy or TWP.
Figure 6.34: Comparisons of pre-intervention and post-intervention K scores for Intervention 1 (girls)
(Shows paired-sample t-test data selected from Table 5.2, Table 5.3 and Table 5.4)

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 1
Year 11 and Year 12 Scores

(Females)
- no significant change at 5% level
* significant difference at 5% level
** significant difference at 1% level
*** significant difference at 0.1% level

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<thead>
<tr>
<th>Criterion</th>
<th>Traditional Pedagogy (Cohort 1 Year 11)</th>
<th>Tablet/Workbook Pedagogy (Cohort 1 Year 12)</th>
<th>Traditional Pedagogy (Cohort 2 Year 11)</th>
<th>Tablet/Workbook Pedagogy (Cohort 2 Year 12)</th>
<th>Traditional Pedagogy (Control group Year 11)</th>
<th>Traditional Pedagogy (Control group Year 12)</th>
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<tr>
<td>Cohort 1 n=5 Intervention Group</td>
<td>M=73.00 SD=15.297</td>
<td>M=76.40 SD=18.703</td>
<td>M=81.21 SD=4.264</td>
<td>M=90.18 SD=4.466</td>
<td>M=73.10 SD=11.986</td>
<td>M=76.40 SD=16.015</td>
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<td>Cohort 2 n=3</td>
<td>t(4)=1.111, p=0.329</td>
<td></td>
<td>t(2)=2.232, p=0.155</td>
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<tr>
<td>Control Group n=10</td>
<td>t(9)=0.767, p=0.462</td>
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Figure 6.35: Comparisons of pre-intervention and post-intervention K scores for Intervention 2 (girls)
(Shows paired-sample t-test data selected from Table 5.5, Table 5.6 and Table 5.7)

Comparison of Pre-Intervention and Post-Intervention Scores for Intervention 2
Year 11 Term 2 and Year 11 Semester 2 Scores
(Females)

- no significant change at 5% level
* significant difference at 5% level
** significant difference at 1% level
*** significant difference at 0.1% level

- t(2) = 0.384, p = 0.738
- t(4) = -1.142, p = 0.317
- t(10) = -1.793, p = 0.103

Mean Score (%)
6.2.7 Summary of trends in students’ learning outcomes

The evidence is clear that the use of the TWP in teaching physics has resulted in a significant improvement in global learning outcomes for all students. Traditional teaching methods did not produce any such significant improvement at the 5% level. In particular, the TWP produced significant (p<0.05) improvements in all students’ scores on far transfer tasks in physics after only six months of use whereas traditional teaching methods failed to do so at all. For near transfer tasks related to knowledge and its simple application, the use of the TWP for at least twelve months resulted in significantly improved (p<0.05) learning outcomes for all students whereas traditional teaching methods failed to do so. For near transfer tasks related to primary and secondary data collection, analysis and communication, the TWP and traditional methods were equally effective, suggesting that it may have been the result of maturation.

The same conclusions can be drawn from the boys’ data.

For girls, there is some indication but no statistical evidence at the 5% level that the use of the TWP in physics resulted in a significant improvement in global learning outcomes beyond that achieved by traditional methods. This outcome may have resulted from the difficulty of achieving significance with so few girls in each cohort (N = 3, 5 and 10) or it may provide evidence that the TWP was not as effective with girls as with boys.

For one cohort of girls, the TWP produced significant improvements (p<0.05) in their scores on far transfer tasks in physics after only six months of use whereas traditional teaching methods failed to do so at all. However this was not the case for the second cohort of girls. Neither traditional pedagogy nor the TWP was able to significantly improve the girls’ learning outcomes in near transfer tasks. In fact, there is evidence that the use of the TWP in the second semester of the course actually hindered girls’ learning in some near transfer tasks (those related to primary and secondary data) to a greater extent than did the use of traditional pedagogy.

The finding that learning with traditional pedagogy did not result in any significant improvement in learning outcomes (apart from near transfer tasks related to rehearsed data analysis tasks) over a two year period reflects the results of other
studies which found that traditional pedagogy is not an effective learning method for the empirical and formal sciences such as physics and mathematics (Paas, 1992).

6.3 Reasons for the observed improvements in learning outcomes

6.3.1 Introduction

Reasons for the observed improvements in learning will now be sought. Students’ responses in Studies 2 and 3 will be interrogated to determine the reasons they suggest for their improved learning (see Section 6.3.2). These will be discussed in terms of CLT to suggest the theoretical basis for the observed improvements (see Section 6.3.3). Literature will also be consulted to determine whether these results replicate findings by other researchers.

When referring to quantitative data generated by the survey and recorded in Sections 5.3.4.4 - 5.3.4.7, the median category of students’ responses will be quoted. Reference will only be made to data that were statistically significant at the 5% level. Reference will also be made to the results of further statistical analyses of the survey data but only when the results were significant at the 5% level (see Sections 5.3.5 and 5.3.6).

Qualitative data from Study 3 (the survey and the interviews and focus group discussions) was analysed and summarised in Section 5.4. Students’ comments will be quoted as appropriate to provide a representative view of the comments in general.

6.3.2 Evidence from students’ responses

6.3.2.1 Improved motivation

6.3.2.1.1 Students like to learn with the TWP in physics classes

Students strongly agreed that they enjoyed physics classes more when the Tablet PC was used and they agreed that the TWP provided an efficient way to learn which saved time in class and aided their understanding of physics concepts (see Table 5.21 Items C2, C3). The Tablet PC had impressed them as being better than a laptop computer and students preferred the use of the Tablet PC to the use of an interactive whiteboard or an ordinary whiteboard (see Table 5.21 Items C2, C5, C12, and C13).
Students reported having a positive/very positive attitude to the use of the Tablet PC by the teacher in physics classes (see Table 5.17) with no significant differences between responses by boys and girls (see Section 5.3.5). When students had the opportunity to use the Tablet PC themselves in physics lessons, their attitudes to these experiences were also positive (see Table 5.18 B1-B14) for both boys and girls (see Section 5.3.5) and for both academically weak and strong students (see Section 5.3.6).

*I like the workbook and tablet combination. It’s very efficient and it doesn’t waste time.*

Year 12 boy

6.3.2.1.2 Students are more motivated and better engaged when the TWP is used

Boys (68%) and girls (67%) reported improved motivation to learn and greater engagement in physics lessons when the TWP was used (see Table 5.30). When asked what they like about the TWP, boys were almost five times as likely as girls to comment positively about being more engaged in learning (Table 5.30). Students frequently mentioned the easy access to digital resources like animations and web sites as well as the use of colour.

*It’s not as boring. The colours are pretty and the writing and it’s more interesting to look at rather than having the whiteboard to look at … Being able to go off to the Internet adds to my interest … It’s great. It’s inspiring.*

Year 11 girl

*I think it (the Tablet PC) makes learning a bit more entertaining as well. With the Tablet PC we can go into animations and to search facts on the Internet at ease. It makes it more enjoyable.*

Year 11 boy

*It is so much more interesting. Instead of just getting notes … you just have so many more possibilities, like every time you do something you can access something new … It is entertaining for us at the same time instead of just doing one linear thing the whole time.*

Year 11 boy

*Sometimes physics is a joy going to because of the animation and the Internet Google stuff like the Ferrari question - that was pretty good.*

Year 11 boy

*Physics with the tablet is much better … it’s pretty good.*

Year 11 girl

*I like those physics classes with the interactive learning, the animations.*

Year 12 boy
It’s less monotonous. It definitely makes physics a lot more interesting. Year 12 boy

It’s fun, alternative, engaging, many aspects of use which appeal to many different types of learners. Year 12 boy

Several girls and one boy commented that they were already highly motivated so the TWP did not make much difference to their motivation levels.

I am already motivated so for me motivation is not such a huge factor. Year 11 girl

It doesn’t really change how I am motivated in the subject. If I go into a place where they don’t have the tablet I am still the same. Year 11 girl

6.3.2.2 Improved classroom logistics

A surprisingly high proportion of students (73%) commented about classroom logistical issues indicating that the use of the Tablet PC had resulted in numerous improvements (see Table 5.30). Students suggested that it was easier to see the notes on the projector screen than on the whiteboard because of its physical placement with less glare and because the teacher did not block the screen when writing notes. The physical arrangement of the physics classroom is shown in Figure 3.2. These comments are indicative of those made by students:

The projector screen is larger than the whiteboard. There are more colours to do stuff with - and highlighters. Year 11 boy

It is good how everyone can see it. It’s in a good spot for all to see and the teacher doesn’t have to stand in front of the board. She doesn’t get in the way. It saves you craning your neck around all the time or looking over the top of peoples’ heads. The screen is off to the side and nothing gets in the way. Year 11 girl

It’s easy to see; no glare. Year 12 girl

The TWP allowed more efficient use to be made of class time because the guided notes provided much of the foundation text so that students did not need to spend class time writing this out.

Most of the stuff is already on the computer and then it’s just put up on the screen. We can go through things faster because the teacher doesn’t need the additional time to
write up the tasks beforehand on the whiteboard. If you miss stuff or want to go over things it is there and you can always change it etc. Year 11 boy

It is a lot better ... spending more time actually focusing on what you are supposed to be learning than writing out what you are supposed to be learning. Just writing out things that are already in the book is useless and a waste of time. With the tablet you can get up there and just do it and you know what you are doing and it is simple to do and you get a good grasp of it instead of trying to drag yourself through countless hours of writing out things. Year 11 boy

When we didn’t (use the workbooks), the rate at which we actually learned things and got through what we were trying to learn was much slower than when we used the Tablet PC. I would say it (the workbook) upwards of triples or quadruples the speed at which we learn new things. Year 11 boy

That term when we didn’t have the workbooks and had to take notes in our notebooks was terrible. In particular we had lots of diagrams and things to show distances between electrostatics and all the circuit diagrams. We had to copy them down and by the time you copied them down then there were all sorts of people at different stages in the class - some people getting left behind, some people were ahead and some getting totally lost. Year 11 boy

6.3.2.3 Improved organisational support

Students, particularly boys, reported very poor organisational skills.

My organisational skills are deplorable. Year 11 boy

Their poor organisational skills manifested in two significant ways that were addressed by the TWP: they had difficulty filing all the loose handouts of resources distributed during traditional classes and they were not thorough in ensuring that they ‘caught up’ after missing a lesson.

They reported that the TWP provided organisational support by collating all resources into one booklet. The booklet contained a complete record of the term’s resources and it was obvious if they had missed information through absence because the booklet pages had not been annotated.
6.3.2.3.1 TWP has all resources collected in one workbook

Students, particularly boys, commented that they have difficulty organising the resources collected during traditional lessons (e.g. traditional notes and loose handouts).

And there were all the sheets and different things spaced through your books that you didn’t know where what you wanted was. So when we came to revision we were sort of lost trying to scramble through our sheets. Year 11 boy

This also proved to be a difficulty with the Tablet/PPT Pedagogy which was trialled early in the study. With this pedagogy, the teacher annotates PowerPoint slides while students annotate handouts of the slides (usually six slides to a page), which are supplied to cover a section of work of approximately one week’s duration. It was the student’s responsibility to organise these handouts along with other resource handouts distributed during the lesson.

Whilst students were positive about the teacher annotating the guided notes on the PowerPoint slides (see Table 5.15 Item A4), many boys reported difficulty organising the numerous handouts and preferred the simplicity of all the necessary information collected together in one workbook in the TWP.

I lost some of the sheets (in Term 1 with the PPT). Organisation was a problem. Year 11 boy

In contrast, the tablet/workbook combination was seen to provide a great organisation advantage.

Having one single booklet with everything organised is good. Year 11 boy

Yes using the Tablet PC has helped my learning because you have everything there - all the worksheets and stuff. You can do revision when you need to. I think it is great. It’s fabulous. All notes are stored on the computer. I like the workbook and tablet combination. Year 12 boy

I’m a big fan of the workbook. It has helped a lot especially with revision so you can go over it all. I am pretty disorganised. My notebook seems to be a bit disjointed because sometimes when I use it, I may miss things or I’ll leave my book or something. I am a
Kind of disorganised person. It is useful to have a workbook with all the term’s work just in one place.

Year 12 boy

One Year 12 boy had a history of laziness and disorganisation. He began taking class notes only when the TWP was introduced.

They (the tablet and workbook) work together. I’ve never ever taken notes down ever before. It’s easy to note the work in the workbook and just fill in the answers. Everyone writes the same thing.

Year 12 boy

Based on such feedback, use of the Tablet/PPT Pedagogy was discontinued in favour of the TWP.

6.3.2.3.2 The annotated electronic workbook can provide a copy of class notes when lessons are missed

Students were very positive that the digital copy of the annotated workbook was available for later use (see Table 5.17 aggregated category ‘Tablet/Workbook’). The fact that the teacher kept a digital record of the workbook notes was almost universally identified by students as a significant advantage: if a student missed a lesson through illness for example, he/she could obtain a printout of the lesson notes for the missed lesson. Alternatively the missed notes could be emailed to him/her. Students’ survey responses indicated that, although they had rarely received a copy of missed notes, they were positive/very positive about the possibility (see Table 5.15 Item A14 and Table 5.18 Item B11) and became increasingly so the more frequently they had benefited from this service (a Spearman’s Rank Order analysis between the frequency and attitude data for Item B11 showed that $r_s = 0.631$, $p = 0.000$).

If we are away for some days all the information is there and we don’t need to go and find a friend and copy it out of their book. Instead I ask the teacher to print off the sheets that we missed. Once the teacher emailed me the notes while I was still away. I found that really good. It was in colour and much easier to decipher and see certain pictures with details.

Year 11 boy

If lessons are missed, the notes can be printed at the beginning of the lesson which saves that lesson from being wasted with having to copy down notes.

Year 12 girl
When you miss a lesson then you know exactly what (workbook) pages you’ve missed. They (the tablet and the workbook) are a working duo. Year 12 girl

6.3.2.4 Provision of an advance organiser

The workbook provides guided notes which are a highly structured and coherently organised skeleton of the important course information. Students benefit from this advance organiser (Ausubel, 1968) which also acts to signal the work to come and provide a site map of the instructional material. It lets students know what material must be covered and they can prepare by reading ahead if they wish.

Having the booklets is good because you know what is relating to what because it is in order. Year 11 girl

Yes, I love the workbook. I am not as diligent as I probably should be in normal note taking and I find it is a lot better to use the workbook. And I can read ahead as well ... For instance I read the entire Materials chapter we did this term in the first week knowing that I was going to be quite busy and not as focused as I should be later on so I got all that done early. Year 12 boy

Another advantage of the workbooks is that you can revise and also know what is coming ahead of you. Year 12 boy

If you have the set workbook you know what to cover ... you see the whole course in advance. I like the workbook and tablet together. Year 12 girl

6.3.2.5 Structural search is reduced

The provision of guided notes in the workbook reduces the extraneous load of structural search inherent in traditional note taking (Narjaikaew, et al., 2009), particularly for novices.

It (the TWP) definitely enhances learning. It helps you keep up with the intensity. With the more academic subjects like physics you really have got to be on the ball the whole time and when you are writing down you tend to get disengaged from the actual work but the tablet does help to keep you on track the whole time. So it is good. Year 11 boy

Students strongly agreed that they prefer to write lesson notes in the prepared workbooks rather than in a blank notebook (see Table 5.20 Item C10). However, the median response for boys (“Strongly Agree”) was statistically different to the median
response for girls ("Agree"), \( U = 66.500, p = 0.043 \) (see Section 5.3.10). It is clear then that while the girls prefer to use the workbooks to record lesson notes, their preference is not as strong as that of boys.

The disadvantage experienced by any students who have not yet developed automated schemas for organised note-taking is reduced by the use of the workbooks. Conversely, the advantage that students who do have such automated schemas (typically girls) is reduced. This may be one reason why girls sometimes prefer to take notes in their notebooks.

*I kind of like making my own notes in my book and making it all pretty and stuff.*

Year 11 girl

This observation could also be considered as an example of the expertise reversal effect (Kalyuga, et al., 2003) since girls can be considered as expert note takers while boys are less expert note takers.

**6.3.2.6 Split-attention is reduced**

The TWP reduces split-attention to improve learning by incorporating the simultaneous use of electronic and hard copy workbooks. This combination works effectively in a several ways.

6.3.2.6.1 Correspondence between the teachers’ and the students’ workbooks

The teacher’s electronic workbook which is displayed to the class during lessons is identical to the students’ hard copies of the workbook. It is very clear to the students exactly what information must be recorded and where it is to be written. The students’ attention is not split between the teacher’s notes written on the whiteboard and his/her own record of those notes in his/her notebook which may look quite different.

*It's one thing to be able to look down and see what you're doing and then look up at a screen and see the teacher doing the exact same thing rather than just trying to copy and imagine what is on the whiteboard on your book in front of you.* Year 12 boy

*You are working in sync with the teacher as opposed to when you are writing stuff down (in a notebook). We were always catching up but now we can stay up to date with everything. It’s easy.* Year 12 girl
Working along with the teacher is one of the best aspects of the Tablet PC. Year 12 boy
Students agreed that taking lesson notes is easier when the teacher’s annotations on
the Tablet PC with the electronic workbook mirror the students’ workbooks (see Table
5.21 Item C5, C11) and were very positive/positive about all aspects of using the
workbook in conjunction with the teacher’s annotation of the electronic workbook
(see Table 5.17 aggregated categories: ‘Tablet’ and ‘Tablet/Workbook’). When asked if
they would like to use the workbooks without the Tablet PC, students uniformly
responded in the negative.

The teacher’s notes correlate to the space in our books so it all fits. Year 12 girl

The booklets make it easier. Plus the tablet with the teacher actually filling out in the
exact spot where you are meant to write helps a lot. Year 12 boy

It is a lot easier to be able to see just exactly where you are. And have it match up. Year 12 girl

The tablet has definitely helped my learning. The workbook helps a lot too. Being able
to relate the two and work along with the teacher on the board and because you have
exactly the same document and doing exactly the same things we can learn what to do
and how to do it. Year 12 boy

6.3.2.6.2  Diagrams and supporting text are physically integrated

When using the tablet PC, the teacher is able to annotate directly over an incomplete
diagram in the electronic workbook. Thus, diagrams and supporting text are physically
integrated, reducing split attention. Students were very positive about this specific
aspect of the TWP (see Table 5.15 Item A3).

The teacher can add to diagrams with measurements and lines that help explain. Year 12 girl

6.3.2.6.3  Spatial and temporal contiguity in the use of additional digital resources

The embedded web links in the electronic workbook allow the teacher to rapidly
display animations, video segments or Internet information. In addition, static
diagrams of critical steps in the animated images can be included in the workbook so
that explanatory information can be annotated over them during the lesson. The
temporal contiguity of immediate access and the spatial contiguity of including critical
linking information in the workbook combine to reduce the split-attention that can result when Internet and audio-visual resources are used. Students’ attitudes to the teacher accessing Internet information, animations and digital videos were either positive or very positive (see Table 5.15 Items A5, A7, A8).

The easy access to animations and other documents like that make it more enjoyable.

Year 11 boy

With its multiple functions it (the tablet) makes it a lot easier and gets the students more involved in learning ... you can go to the Internet from the Word programme or wherever you are and then you can just link off to animations and go to different places. That helps the students to comprehend what we are learning.

Year 11 boy

It’s something different, it’s exciting, it’s new. We can be going through our work and then you say, "Look at this link" and you click on it and then suddenly we are off looking at a bridge fall over or something. We can put our theory into practice and see real life aspects of it or we can look at real life stuff and then you can click off and we can see another theoretical aspect of it. It just adds different dimensions to the same thing. Otherwise we would be sealed into the one line.

Year 12 boy

It allows us to work and to view information from the net at the same time.

Year 11 boy

The tablet can be used to access a variety of things at once like Internet programs, workbook material, and movies.

Year 12 boy

Videos, the Internet etc, can all be quickly accessed.

Year 12 girl

6.3.2.6.4 The learning materials are clearly visible

Split-attention can arise when the teacher writes a solution to a problem on the whiteboard because the students’ view of the developing solution is blocked by the teacher’s body. This need not occur with the TWP because the screen can be positioned away from the teacher.

It’s good because with the tablet you can watch as the teacher works through problems. If it is on the board, the teacher always gets in the way and you can’t see what they are writing. So you really have to wait until they are finished until you can
start to watch. You can’t watch it as the teacher goes through the processes.

Year 11 boy

6.3.2.6.5 The annotated electronic workbook can be used to review lessons

A major advantage of keeping a digital record of lesson notes was that it could be used for review purposes. For example, at the start of a lesson, the previous lesson notes can be easily reviewed without split-attention. Each student can simultaneously view their own workbook and the teacher’s electronic version of the material to be reviewed. This is particularly helpful if the previous lesson was not quite completed.

Students responded very positively when asked their attitude to the teacher storing the digital lesson notes and displaying them for review as necessary (Table 5.15 Items A3 and A12).

*Notes are stored for following lessons and the teacher can easily recap previous lessons.*

Year 12 girl

*Helps to recap what was learned in a lesson.*

Year 11 girl

*One good thing with the tablet is if somebody missed something a while back you can actually go back and check it. You can’t just magically get something back up on the whiteboard.*

Year 12 boy

6.3.2.7 Redundant information is removed

The unsuccessful trial of the Tablet/PPT pedagogy early in the study has already been mentioned with respect to its failure to provide as much organisational support for students as the TWP. A second element of this pedagogy which proved less effective than that of the TWP will be discussed here.

The TWP involved the use of workbooks with the electronic version stored as a Microsoft Word document that allowed smooth scrolling through the document. Only essential information and images were included in the workbook. The electronic workbook was essentially a black and white document except when colour was necessary for clarity in some images. This made the electronic workbook look very similar to the students’ photocopied hard copy workbook.

The Tablet/PPT Pedagogy used colourful PowerPoint slides to display the same essential skeletal information and images but it also included additional images.
Students were provided with handouts of the skeleton slides (six to a page) to organise and annotate as they wished. Most students used a combination of annotated slide handouts and their own notes as a record of the lessons.

Students complained that the colourful slide backgrounds, colourful text and additional images were distracting. When asked, “Did you find having colourful PowerPoint with lots of nice images appealing? Was it helpful to your learning?” students replied:

*It’s kind of a distraction from the learning.*

*Year 11 boy*

*You see the information and you’re not drawn to it. Your eyes are drawn to the images or the colour.*

*Year 11 boy*

*At times the extra images on the PowerPoint (slides) were distracting.*

*Year 11 boy*

They preferred the simple workbook presentation of essential information only. This is the redundancy principle (Sweller, et al., 1998) in action.

*The tablet and the workbook keeps everybody focused on what there is to do. No frills, it’s just basic.*

*Year 11 boy*

Boys (40%) were much more likely than girls (17%) to express concern about the presence of redundant material in the slides (see Table 5.37). This suggests that boys are more sensitive to the distractions/added extraneous cognitive load presented by the redundant material perhaps because they are habitually operating close to cognitive overload due to their poor note taking schemas.

### 6.3.2.8 Handwriting versus typed text

Students expressed a preference for handwritten over typed solutions to problems. This observation is consistent with the researcher’s experience that physics and mathematics students prefer handwritten worked solutions to problems rather than typed worked solutions.

*It’s easier to understand (when worked solutions are handwritten rather than typed).*

*Like if you’re trying to explain how you did it it’s easier to understand if it’s in handwriting. Yes when you write over the little diagrams as well, that is also quite good.*

*Year 11 boy*
And also seeing how we would set it out if we were in a test gives us a better understanding of what we have to do for the task.  

Year 12 boy

If there is a concept that I do not understand, it is easy to grasp when explained using the Tablet PC. 

Year 11 boy

Writing is much easier to read and understand than typing. 

Year 11 boy

If hand (written) notes, it shows a more natural flow of formulas and working. 

Year 12 boy

6.3.2.9  GERMANE COGNITIVE LOAD IS INCREASED

The TWP uses several techniques to increase germane cognitive load by directing students’ attention to pertinent information.

6.3.2.9.1 Use of colour

A simple but effective method of directing students’ attention is to use coloured notations (Mayer & Moreno, 2003). The electronic workbook can be annotated using digital pens with a whole spectrum of colours and digital highlighters with fluoro colours. Thus colour coding can be used to effectively direct students’ attention to important information

You can use lots of different colours so it makes it easier to understand which makes it more enjoyable. Rather than just having limited colours you can have limitless colours. 

Year 11 boy

Colour is really good. Highlighting makes a difference. It stands out more. Year 12 girl

When you’re working with the big diagrams they can tend to get a bit cluttered with all the numbers, vectors and arrows pointing this way and that ... (the colour) makes it much easier to differentiate. 

Year 11 boy

6.3.2.9.2 Effective use of completion problems and guidance fading

The workbook contains many example problems which the teacher and class dynamically interact to solve, step by step, using a strategy that employs elements of the completion problem effect (van Merriënboer & Krammer, 1990) and the guidance fading effect (Kalyuga, et al., 2001) (see Section 3.3.2.4). The teacher will generally provide hints to prompt class discussion re the next step of the process rather than just
providing the next line of the solution. In this way, the teacher can require all members of the class to make an active contribution to the solution of problems, effectively engage students thinking processes.

This strategy is common to the TWP and the traditional pedagogy (see Section 3.3.2.4), but can be more efficiently effected in the TWP.

Boys (29%) and girls (33%) were equally positive about this approach (see Table 5.30).

*You go through it all so everyone can see what is going on. And with you writing it all down we don’t get to the end and everyone is sort of confused as to whose answers are right.*

*Year 11 boy*

*(The Tablet PC) displays solutions easier - easier to follow steps.*

*Year 11 girl*

Students were asked whether they would prefer to be provided with the complete solution to a problem or to have the teacher and students work through it together line by line. All respondents indicated a clear preference for the completion problem approach.

*The way you do it line by line is better because then we understand it. Also if you just have it in the book you might not even look at it or pay attention. But if it is done line by line you can be forced to write it down the way it is being written down (by the teacher).*

*Year 12 girl*

*Probably developing each line in order. You can work it out as you go, instead of having the answer already up there. You don’t really learn anything if that happens.*

*Year 11 boy*

*Working through each line is better because I get to think and process it as it is being written.*

*Year 11 boy*

6.3.2.9.3 Use of animations

With the TWP, links to animations are embedded in the electronic workbook and frequent use is made of them. Students’ comments about using animations were almost exclusively positive. Negative comments related only to animations sometimes being slow to load.
Students commented that the animations allowed them to develop a deeper understanding of the physics concepts more rapidly. They also mentioned the link that animations and other digital resources provide between theory and the real world.

*I like those physics classes with the interactive learning, the animations. Some sort of theory is physically explained, goes through the motions. Shows exactly how it all works.*

Year 12 boy

*The animation definitely helps for visual learners...*  

Year 12 boys

*Computerised simulators put theory into use and we see how it works.*  

Year 11 boy

*The animations are good to see how they work as well as to get the concepts and ideas all worked out.*  

Year 11 boy

*The animations are good because they put theory into practice.*  

Year 11 boy

*If you see it (the animation) flashed over and it’s all just there, you can understand it all. But if you are reading over what is written, it takes a lot longer time to get it.*  

Year 11 boy

*We do all those things on the Internet - the animations where you can change the stuff. Sometimes it helps you to get the concepts at the start and you don’t need it later when you understand what is going on.*  

Year 12 girl

Such comments provide clear supporting evidence for the multimedia principle (Mayer, 2001) and the modality effect (Low & Sweller, 2005). In the TWP, the teacher provides the audio commentary while the students attend to the images in the animations.

### 6.3.2.10 Students report improved understanding

In the survey, students agreed that physics concepts were easier to understand when the teacher used the Tablet PC to explain them (see Table 5.21, Item C1). When commenting in more detail, 68% of students mentioned that learning with the TWP improved their understanding of physics. Boys and girls expressed these sentiments with equal frequency (see Table 5.30).

*You can see how the rules interact and it (the Tablet PC) also gives you a better idea of the more complex questions and thinking about what is actually happening in a*
situation. That is the basis of a lot of physics complex questions: a deeper understanding. ... it (the TWP) does make understanding the concepts basically a lot easier and a lot quicker because you can just see how it’s happening. You don’t have to imagine things and get things wrong. It’s there and you can see it and you can go back to it whenever you need to.

Year 11 boy

You get less of the, “What on earth is going on? I have no idea what she is going on about!” moments, so you get less lost people. So I think they get less depressed from having absolutely no idea. A lot of people when they get to the “I have no idea” stage, they just give up. With the tablet that doesn’t really happen because you can see everything as you are doing it and all the animations help you understand what is actually going on behind the numbers.

Year 11 boy

It (the TWP) enhances your learning immensely ... makes it easier to follow and to comprehend.

Year 12 girl

Yes, (the use of the Tablet PC in physics lessons has helped my learning) tremendously. If you look at my marks in Year 11 and compare them to the ones in Year 12 when you started using the tablet they have gone up hugely. I got Cs, Bs, and one or two As last year and this year I got almost straight As. I have been pretty steady in all my other subjects ... no huge improvement as has happened in physics. The only reason I can think of is the tablet. It must be it. So you can see it in the marks and I am also finding physics a lot more fun and interesting when you are using the tablet.

Year 12 boy

These comments are indicative of better schema development and deeper conceptual understanding as a result of learning with the TWP.

6.3.2.10.1 Academic success as a correlate with attitude to aspects of the TWP

A significant negative correlation was found between Year 11 students’ attitudes when the teacher used the Tablet PC in class and their global scores, $r_s = -0.505$, $p = 0.020$ (see Section 5.3.6 Item A1 for Spearman’s Rank Order Correlation data). In other words academically weaker Year 11 students were more positive about the teacher’s use of the Tablet PC in class than were academically stronger Year 11 students. This indicates that the weaker academic students derived more benefit from the use of the TWP in the first year of the course than did their more academically capable peers. These students may have been academically weak because they suffered regular
cognitive overload when traditional pedagogy was used. Therefore they benefited quickly when the TWP reduced the extraneous cognitive load and hence the incidence of cognitive overload that they experienced.

This could also be an example of the expertise reversal effect (Kalyuga, et al., 2003) since the more academically able students have more expertise and do not benefit as much from learning in the highly structured environment of the TWP.

### 6.3.3 Theoretical basis in Cognitive Load Theory

Since the trends in improvements in learning outcomes for near transfer and far transfer tasks differ, it is expected that they are mediated in different ways. The reasons for the observed improvements in near and far transfer tasks will therefore be considered separately.

#### 6.3.3.1 Near transfer tasks

**6.3.3.1.1 Comments re trends for all students**

Students who learned physics with the TWP significantly improved their scores in near transfer tasks involving recall of knowledge and application in rehearsed situations more than was achieved with traditional pedagogy. This improvement in near transfer learning after the introduction of the TWP (a guided notes strategy) replicates those of other studies following the introduction of guided notes strategies (Heward, 1994). It is consistent with the concept that guided notes reduce extraneous cognitive load, minimise the occurrence of cognitive overload and enhance schema production (Narjaikaew, et al., 2009). Students’ comments reflect their experiences of reduced extraneous cognitive load (reduced structural search, reduced split-attention, removal of redundant information, improved spatial and temporal contiguity) when learning with the TWP (see Sections 6.3.2.6-6.3.2.7).

Performance on near transfer tasks is linked to the effectiveness of the examination revision process which in turn is related to the quality of the students’ record of class work (i.e. having a complete and well-organised set of lesson notes) and the quality of the revision process (i.e. motivation and time management) (Kiewra, 1987).

Students comment favourably about the organisational support provided by the TWP (see Section 6.3.2.3) in which the guided notes provide a clear record of the lessons;
the workbook collects all important resources into one booklet; and the work covered
during lessons that the students miss can be readily obtained from the teacher’s
electronic record of the lesson. This organisational support improved the quality of
the students’ revision notes. Students also commented on improved motivation (see
Section 6.3.2.1) which would have contributed to students studying more diligently for
their examinations.

6.3.3.1.2 Comments re difference between trends for boys and girls

The results for boys reflected the trend for all students but for girls no significant
change at the 5% level was detected (further research with larger numbers of girls is
required to confirm this effect).

The difference in trends for boys and girls can be understood in CLT terms because
girls are more likely than boys to possess elaborate schemas for note taking (see
Section 2.2.7.1) and good note taking skills are linked to enhanced performance on
near transfer tasks (Crawford, 1925a, 1925b). Girls cope much better with the use of
traditional pedagogy than boys because of their elaborate note taking schemas but the
use of the TWP supports boy’s note taking, reducing their relative disadvantage and
improving their near transfer performance.

Boys report more positive responses to the use of guided notes in the TWP than girls
(see Section 6.3.2.5). The same is true of academically weak students compared to
academically strong students (see Section 6.3.2.10). Both may be considered as
examples of the expertise reversal effect (Kalyuga, et al., 2003) as in each case the
students with less developed schemas respond more positively to additional support.

Kiewra (1987) confirmed the positive correlation between note taking skills and near
transfer performance and noted that another predictor of success was the quality of
revision. Girls are better organised than boys and have better time management skills
(Cranney & Kirby, 1980) and their learning is less constrained by their level of interest
(Brasell, 1987) so it is likely that girls will revise better than boys.

Boys report that the TWP improves their motivation levels (see section 6.3.2.1.2) as
well as their organisation of notes (see Section 6.3.2.3). Thus the TWP improves boys’
access to good revision materials and their motivation to use them and hence their
near transfer performance. This motivational link is indicated in this research but requires further research to be firmly establish

6.3.3.2 Far transfer tasks

6.3.3.2.1 Comments re trends for all students

The quantitative analysis of students’ scores in Section 6.2.4.2 established a clear link between use of the TWP in physics classes and significant improvements in all students’ scores on far transfer tasks. Learning with traditional pedagogy produced no significant improvement in CRP scores at any stage of the two year course. Students reflected this finding by commenting that their understanding of physics concepts was better when they learned with the TWP (see Section 6.3.2.10).

The finding that traditional pedagogy is not optimal in teaching for understanding is reflected in literature (see Section 3.3.1.2). The essential elements of traditional instructional methods, traditional note-taking and the extensive use of conventional practice problems can inhibit schema acquisition because they generate excessive levels of extraneous cognitive load (Boch & Piolet, 2004; Sweller, 1988). Additionally, traditional techniques often do not motivate students to invest the mental effort required for success in learning complex materials (R. E. Clark, et al., 2006) so attempts to impose germane cognitive load may be unproductive.

Students’ comments suggest that the TWP improved their understanding because it provided instructional techniques and materials which leveraged CLT principles to efficiently manage cognitive load, enhance schema production and promote deeper understanding of the physics concepts learned. Comments made about learning with the TWP related to reduced intrinsic cognitive load, reduced extraneous cognitive load, increased germane cognitive load and improved motivation.

6.3.3.2.1 Reduced intrinsic cognitive load

Students’ comments in Section 6.3.2.4 relate to the benefits of using the guided notes as an advance organiser to reduce intrinsic cognitive load. The TWP also reduced intrinsic cognitive load by carefully sequencing the material presented from simple to complex whole task strategies to introduce complex material gradually and by providing examples involving increasingly complex real world applications (van
Merriënboer, et al., 2002). However, this strategy was also employed by the researcher in her traditional pedagogy (see Section 3.3.2.2) and this may account for why the students did not explicitly comment on this aspect of the pedagogy.

6.3.2.1.2 Reduced extraneous cognitive load

Reduced extraneous cognitive load was evident in comments about reduced structural search (see Section 6.3.2.5), reduced split-attention, and the absence of redundant information from the workbooks.

Students responded positively to the use of guided notes and their comments consistently implied that the use of guided notes was beneficial because it reduced structural search (see Section 6.3.2.5).

Comments implying reduced split-attention (see Section 6.3.2.6) related to: the correspondence between the teacher’s and the students’ workbooks; the physical integration of diagrams and supporting text; the spatial and temporal contiguity of instant access to digital resources using hyperlinks; the learning materials being clearly visible as they were discussed by the teacher; and the ability to use the digital record of the guided notes for review purposes.

The TWP was preferred by students over the Tablet/PPT Pedagogy in part because the instructional materials removed the distractions of unnecessary colour, images and ‘seductive details’ (see Sections 3.3.2.3 and 6.3.2.7). Students preferred to learn without such redundant materials present.

The TWP had the teacher provide the audio commentary to the visual information provided through the Tablet PC (e.g. animations, developing worked solutions), reducing extraneous cognitive load by harnessing the dual channel capabilities of working memory (see Sections 3.3.2.3 and 2.2.5.4.3). Several students commented that they did not learn well when the teacher’s body blocked their view of the learning materials and they missed the visual information accompanying the audio commentary (see Section 6.3.2.6.4).

One aspect of the TWP designed to reduce extraneous cognitive load was not mentioned explicitly by students: the provision of fully worked solutions to all conventional problems set for homework or revision. This strategy allows students to select the level of support they require according to their expertise (see Section
3.3.2.3. It is not clear how effective students considered this strategy to be and further research is required to establish this as an effective aspect of pedagogy.

6.3.3.2.1.3 Increased germane cognitive load

The successful imposition of germane cognitive load was evident in students’ comments when they discussed the use of colour and animations, and the effective use of completion problems and guidance fading. The Tablet PC and guided notes combination in the TWP was reported as a highly effective strategy for directing attention (see Section 6.3.2.9).

The role of motivation in enhancing the effect on learning of increasing germane cognitive load is important (van Merriënboer & Sweller, 2005) (see Section 2.2.5.5.4). Students commented that their motivation to learn and their engagement with the learning materials had increased with the TWP (see Section 6.3.2.1).

6.3.3.2.1.4 Handwriting and schema production and retrieval

Section 6.3.2.8 reports that students prefer the teacher to annotate the electronic workbook with handwritten notes rather than typed notes and to provide worked solutions that look like the handwritten solution students must produce in an examination.

Perhaps students have automated schemas for the recognition and production of handwritten text. If so, they would experience less cognitive load when interacting with handwritten learning materials (provided they are legible). Anthony, Yang and Koedinger (2006) found that using a handwriting interface rather than a keyboard interface for mathematics instructional programmes produced better learning. They suggested that the use of handwriting may result in decreased extraneous cognitive load and also that handwriting helps students to better grasp two dimensional spatial relationships in mathematics. Such spatial relationships are also very important in physics. Use of the Tablet PC allows the teacher to naturally and effortlessly represent such spatial relationships in the workbook annotations. Kim et al. (2004) in a survey of university students’ note taking habits and preferences, found that students value the flexibility of placement and the amount of expression possible with handwritten text.
There may be a link between students’ interactions with handwritten learning materials and their ability to quickly identify and recall the particular schemas required for a given assessment task. The process of meaningful learning embeds retrieval cues or ‘hooks’ within schemas to allow the schemas to be quickly recalled whenever stimulus cues trigger the ‘hooks’ (R. C. Clark, et al., 2006). When a schema is developed by interacting with handwritten materials, perhaps the embedded ‘hooks’ are also related to handwriting and are readily retrieved as students handwrite solutions to examination questions.

The relationship between handwriting and schema production and retrieval requires further research to determine if the suggested links are valid.

6.3.3.2 Comments re difference between trends for boys and girls

The improvement in all students’ far transfer scores after instruction with the TWP for as little as one semester has been clearly documented. The evidence of improved scores on far transfer tasks for boys is also clear but for girls the results are mixed (see Section 6.2.7). Traditional pedagogy did not produce any significant improvement \( p<0.05 \) in girl’s far transfer scores. The use of the TWP with girls produced a significant improvement for one cohort of girls but not for the other. The mixed results for girls may simply reflect the unreliability of statistics for such small group sizes or it may indicate that the effect for girls was not as strong as for boys. Further research with larger female groups is required to clearly establish the trend for girls.

CLT links far transfer performance with efficient schema production and hence with the efficient management of cognitive load. Students’ comments suggest that the TWP has enhanced the management of cognitive load (see 6.3.3.2.1) and so it may be expected that schema production and far transfer performance would improve for all students after use of the TWP.

This is reflected in students reporting positive/very positive attitudes to the use of the TWP with no significant differences between responses by boys and girls (see Section 6.3.2.10). Girls and boys were also equally as likely to report improved understanding of physics concepts with the TWP (see Section 6.3.2.10).

The balance of evidence suggests that boys’ and girls’ understandings of physics concepts and their far-transfer performances improved when the TWP was introduced
after they had learned with traditional pedagogy. Boys and girls benefited from the improved management of cognitive load possible with the TWP and the consequent enhancement of schema formation and elaboration. The poor management of cognitive load with traditional pedagogy seemed to have impaired conceptual learning for girls as well as boys even though girls experienced less extraneous cognitive load from traditional note taking than boys (see Section 2.2.7).

6.4 Students’ attitudes to the TWP

Students expressed a high degree of satisfaction with the TWP. 89% of students indicated that they did not wish to change any aspect of its use (see Table 5.30). Some were concerned about simple logistical or technical issues but were satisfied overall. Some were satisfied overall but had some suggestions for improvements. One girl had fundamental objections to the TWP because she preferred to take notes in a notebook.

Of the suggestions students made about ways in which the TWP could be improved, some were able to be immediately implemented as the study continued. In some cases students made suggestions that directly conflicted with suggestions made by other students. A representative sample of suggestions is included here.

6.4.1 Students’ satisfaction with the TWP

The majority of students were satisfied with the TWP as it was applied in this study. 89% of students (78% of girls and 93% of boys) indicated that they had nothing negative to say about the TWP (see Table 5.30).

In response to Survey item A17, “What other activities would you like to have the teacher do using the Tablet PC during lessons?” one boy’s comment was typical:

*There doesn’t need to be any more activities because we already do everything that could help us.*

In response to the interview question “In what ways should the Tablet PC be used in class next year/term to best improve your learning?” students said:

*I’d say the same way that is has been used this year. It is really great. No I can’t offer any suggestions to improve it. Just because I have been doing so well. I can’t think of any way to improve it.*

Year 12 boy
I think that if you use it in the exact same way that it was used this year it would be most successful. That is how I feel probably because it has been most successful for me in that way.

Year 12 boy

Same way - it's good.

Year 12 girl

It is pretty good how we have it now. I'd like to keep it the same for next year. There are not really any improvements that I would like to make.

Year 11 girl

I think it is fine how it is.

Year 11 boy

Same way - definitely with the booklet.

Year 11 boy

When asked, “What are the problems for learning when a Tablet PC is used in physics lessons?” the following comments were made:

None. It’s a beautiful way to learn. I think it’s really good.

Year 11 boy

(The four other students in the focus group agreed with him.)

I don’t actually have any. I think in every way it is better than it was last year for me. My marks have increased that’s for sure.

Year 12 boy

6.4.2 Students’ dissatisfaction with the TWP

Despite the vast majority of students expressing no dissatisfaction with the TWP, on further questioning 65% of students (78% girls and 61% boys) made a negative comment of some kind (see Table 5.30).

6.4.2.1 Simple logistical problems

Many students mentioned simple logistical problems like the tablet PC freezing or sometimes being slow to load animations or the data projector flashing them in the eyes as they passed in front of it. Several students mentioned that the teacher’s digital hand writing was sometimes difficult to read or that the teacher sometimes had difficulty controlling the Tablet PC’s scrolling function. However, the handwriting issue was not serious because the median response to the survey statement “I have no difficulty reading the hand written notes that the teacher writes in digital ink on the Tablet PC.” was ‘Agree’ (see Table 5.21 Item C4).

Typical comments include:
I personally have trouble with your writing, but also scrolling down and the computer goes to one hundred different pages. Year 12 girl

The only problem I can think of is sometimes technology failure. That has only happened once this term. Yes, the tablet can lock up or the screen flips. That is all fixed in a few minutes but it makes the lesson a bit disjointed. The flow of the lesson doesn't continue - that is a bit of a problem as opposed to using a good old whiteboard marker. The advantages of the tablet definitely outweigh the problems, though. Year 12 boy

The projector blinds your eyes when walking past the screen. Year 11 girl

The time that we save in class not having to do a lot of the hack copying down, we spend it doing worked examples and people asking questions. We do less pracs. The pracs are useful so more pracs would be better. Year 12 boy

Most of these concerns were addressed during the course of the study. For example, the data projector was mounted on the ceiling, a tablet PC with a faster processor was purchased, the balance between theory and practical work was improved and the teacher improved her handwriting.

6.4.2.2 Fundamental concerns

Two more serious issues also arose. The first was that the TWP did not suit several students’ learning styles and the second was that the tablet had limited ‘screen real estate’.

6.4.2.2.1 TWP’s relationship to learner’s learning styles

One girl was concerned that the fundamental nature of the TWP did not suit her learning style. Even so, there were aspects of the TWP that she liked.

I find I learn better when I have to write out notes rather than what we have been doing with the booklets. It is a bit like reading and comprehension and filling in the gaps. I’d rather write the whole sentence. But I like having the questions already in the booklet and the diagrams. But sometimes some of the notes about the general overview of what all the things are, it’s a bit easier when you write it out yourself. Year 12 girl
6.4.2.2 Scrolling and split-attention

Another girl was concerned that only one page of the workbook was visible at any one time and that the previous work disappeared as the page scrolled down.

You can’t see the notes that have been written above because it scrolls down, instead of reading across like on a regular whiteboard. 

Year 12 girl

This comment may simply result from the student not being able to copy the notes down quickly enough before the teacher scrolls on. This was the case for one boy who made a similar comment and who frequently requested the teacher to scroll back during lessons because he had not yet written down the notes.

The teacher moves on too quick. 

Year 11 boy

Alternatively, it may be the expression of a deeper issue of split-attention if the information that has disappeared after scrolling needed to be understood in conjunction with the currently visible information. The Year 12 girl correctly identified the whiteboard as being a superior teaching tool in terms of its ability to display a lot of information at one time, a point made quite clearly by Harlow et al. (2005).

The Tablet/PPT Pedagogy (see Section 4.6.3) which was trialled early in the study, was rejected, in part, because students disliked the way that the information on the previous slide was removed from their view immediately in order to display the next slide. This resulted in a split-attention effect (Sweller, et al., 1990) as the previous information had to be held in working memory while the new information was attended to. Students preferred the ability to scroll smoothly through the information with the Microsoft Word document in the TWP so that at least some of the previous information was visible when new information was displayed.

I prefer Word to PPT because as soon as you click it and it’s the next slide you sort of go OK what’s the last thing? You sort of forget it, like it’s not there anymore. It is gone from your vision so is not processing around in your brain anymore. With the word document it scrolls gradually. You can still see what has gone before. When you have the word document and you are scrolling down, it is like looking on the board and looking across like that so it is not much different to traditional learning. But when you do the PowerPoint slides it is just sort of detached. 

Year 11 girl
Definitely, the book with the ink annotation is better than PowerPoint or the old whiteboard. With the PowerPoint it was a lot less easy to manipulate, and you only had this much space. But with the annotated workbook, if you need to make more space you can.

Year 11 boy

This split-attention effect with scrolling is of significant concern. It seems that this data confirms the conclusion reached by Harlow et al (2005) that, from the perspective of split-attention and ‘display real estate’, the whiteboard is the most efficient teaching tool and the use of slide software is the worst. The use of MS Word (or similar ‘scrolling’ software such as Microsoft Journal or Microsoft One Note) as in the TWP provides a happy medium that allows the teacher to exploit digital resources whilst incurring minimal split-attention provided the teacher is careful in the design and use of the workbook.

The tablet and booklet were best, then the Tablet and PowerPoints, and last the whiteboard.

Year 11 boy

6.4.3 Students’ suggestions to improve the TWP

Students were given several opportunities to suggest improvements to the TWP and 62% made a suggestion (67% girls, 61% boys) (see Table 5.30). Suggestions fell broadly into two categories: more use should be made of digital resources which show real life applications of physics; and the annotated electronic workbook should be freely available to students.

6.4.3.1 More use of digital resources to make physics real

Survey item A17 asked “What other activities would you like to have the teacher do using the Tablet PC during lessons?” Table 5.32 summarises the students’ responses. The most frequent responses suggested that more use be made of the Internet, animations and a variety of software. Boys (18%) were twice as likely as girls (9%) to make such a suggestion. Often their suggestions related to visualising physics concepts or putting theory into real world contexts.

More physics related games and movies.

Year 12 boy

Googling specific questions asked by students.

Year 11 boy

Computerised simulators to put theory into use and see how it works.

Year 11 boy
As a result of this feedback, more digital resources were included but the teacher was mindful of the need to keep an appropriate balance between virtual and real experimental work.

### 6.4.3.2 Make the annotated electronic workbook available to students

Four boys commented that the annotated digital workbook notes should be stored on the e-learning portal (the school’s on-line learning management system) for free access by students from home. They suggested that the teacher’s digital notes be printed for them so that they did not have to record their own set of workbook notes.

*Perhaps the recorded class material could be placed on the e-learning portal for use in revision because sometimes important booklet pages are lost inhibiting revision.*

**Year 12 boy**

*Print-outs of notes instead of copying them down.*

Year 11 boy

This may be more an expression of laziness than a considered suggestion to improve their learning. Alternatively, it may indicate that even with the limited note-taking required when the workbooks are used, these boys find note-taking an additional cognitive load that interferes with their processing of new information.

An additional question was put to students in interviews to test these alternatives: “Would having all the notes and worked examples printed out in the workbooks so you could just listen and not have to write be better for your learning?” Students replied:

*Worse. I like writing it down. Because then you can sort of remember writing it down when you have to write it in the exam.*

**Year 11 girl**

*You don’t really learn anything if you are just ... looking at it and don’t write anything down.*

**Year 11 boy**

It seems that the germane cognitive load imposed by the necessity to write down a small volume of lesson notes is conducive to learning so long as there is not so much writing required as to impose significant extraneous cognitive load. Consequently the students’ suggestion to have the annotated electronic workbook freely available to students was not implemented because it was feared that some students would rely on obtaining this rather annotating their own booklets. Instead, the teacher limited
access to the digital notes, making them available only when the student had a genuine reason for needing them such as absence from the lesson.

6.4.3.3 Allow students to control the Tablet PC in class more often

Students reported that they were rarely given the opportunity to control the Tablet PC during physics lessons but that they were positive/very positive about using digital ink to annotate the electronic workbook (see Table 5.18, Items B1 and B3).

A significant strong positive correlation was found between Year 12 students’ attitudes when they used the Tablet PC in class during lessons and their global scores, $r_s = .880, p = 0.001$ (see Section 5.3.6 Item B1A for Spearman’s Rank Order Correlation data.). Similar correlations were obtained for Year 12 students on items B2A, B3A and B14A, all of which measure students’ attitudes to various aspects of using the Tablet PC themselves.

Clearly, the more academically able the Year 12 students, the more they enjoyed using the tablet PC themselves to display work to the class. Year 11 students were rarely given the opportunity to use the Tablet PC so had little experience in using it personally. Verbal feedback from students indicated that the less academically able students did not enjoy using the Tablet PC to display their work to the class because they were afraid that their work might not be correct.

Some students suggested that students should be allowed to use the Tablet PC in class more often.

*It would be good for the students to work out equations and put notes on the tablet.*  
Year 11 boy

*I think students should be able to get better access to it and use it more. If it was shared around the classroom and you each front up here and have a turn it would be better.*  
Year 12 girl

Other students did not want students to have more opportunities to use the Tablet PC in class and cited two main reasons: they were concerned that this would result in a less efficient use of class time; and that the text written by students may not be the ‘correct’ answer (by students’ definition!) as it would be if the teacher had written it.
Don’t let students near the tablet - it wastes time. It’s just not necessary. It doesn’t change anything. It would waste a lot more time than you doing it. The way you do it is the best way. Year 11 boy

Next year we should have the tablet and booklet but no student use of the tablet. When you go through everything on the tablet we all write down what you write and we are all sure what we have is what is really happening. But if you don’t, we all write different things, then when we are trying to revise it all gets a bit fuzzy. Year 11 boy

Students were quite polarised in their views and no consensus was reached. The major disadvantage of allowing more student access to the Tablet PC is that the germane cognitive load advantages of the teacher specifically directing students’ attention whilst operating the Tablet PC would be reduced. Further research into this aspect of the TWP is required.

6.4.3.4 Students should each have a Tablet PC

Some students suggested that each student should have his/her own Tablet PC. This is the model that was reported in literature to be most frequently used at schools and universities. However, students were realistic about the expense and the very real possibility of damage to the machines.

I think we all need tablets but the problem is you have a lot to lose if you break it. And Tablet PCs are much more expensive than say a laptop. So it could be a bit out of the price range for what you need to get to the end. The locker and the school bags are a rough affair. Anything in them gets ruined pretty quickly. Year 11 boy

The TWP was specifically designed to be a teacher-centred model with only one Tablet PC operated predominantly by the teacher so that CLT principles could be leveraged to improve student learning in physics. Having each student with a computer in a student-centred model may lead to distractions and the loss of the advantages created by the teachers’ ability to direct students’ attention in order to impose germane cognitive load and so improve learning. Consequently, quite apart from the expense and the logistical problems, this suggestion was not implemented because it was not seen as educationally beneficial for high school students. Further research into student-centred models of Tablet PC use at high school level is recommended.
One student identified another concern about this suggestion which was related to the culture of the school and the context of technology use in subjects other than physics.

*If it was just physics students (with the tablets) then all the other students would cause problems and it’s only really physics students that could justify buying a tablet with our current curriculum. A lot of teachers are more adverse towards technology than you. They are less willing to learn and change.*

Year 11 boy

This will be discussed in the next section.

### 6.4.4 Students’ recommendations for use of TWP in other subjects

#### 6.4.4.1 Introduction

Students were asked whether they thought that the TWP would assist their learning in other subjects. To put this in context, they were also surveyed to gain a snapshot of the degree of technology use they experience in their personal lives and in the other subjects they study at the research site.

#### 6.4.4.2 Snapshot of students’ use of technology in their personal lives

Students spend a lot of their free time interacting with technological devices. When asked, ‘Does the use of technology play a big part in your life generally?’ students universally responded that it did. Both boys and girls commented frequently on the use of mobile phones, social networking sites such as MSN and My Space and the use of digital images, videos and music. This comment was typical:

*Definitely, mainly computer, mobile phone and I am using the computer basically any time I’m at home and not asleep or eating.*

Year 11 boy

These students are clearly very confident and comfortable with the use of technology in all aspects of their personal lives. They are the digital natives that Prensky (2001, p.2) describes:

*Digital Natives are used to receiving information really fast. They like to parallel process and multi-task. They prefer their graphics before their text rather than the opposite. They prefer random access (like hypertext). They function best when networked. They thrive on instant gratification and frequent rewards. They prefer games to ‘serious’ work.*
Do students’ experiences at school demonstrate that educators are exploiting these characteristics by using technology and appropriate associated pedagogy to engage them and assist them to attain the best learning outcomes possible?

### 6.4.4.3 Snapshot of students’ use of technology in subjects other than physics at the research site

With students reporting immersion in technology in their private lives, what has been their experience of technology use in their subjects at school?

Students reported that for most subjects, technology was ‘never’ used or ‘rarely’ used in the classroom although classes did ‘rarely’ visit a computer laboratory for Internet research or word processing of assignments. However, students were universally positive about whatever use of technology was offered to them (see Table 5.24).

The data reported in Table 5.22 and Table 5.24 shows this trend clearly although the small number of students reporting data in each subject makes these results more indicative than statistically significant. The subjects were then aggregated into faculty groups (see Tables Table 5.25-Table 5.28) to see the trends by faculty and to increase the data size allowing some statistically significant comments to be made. English, mathematics and the arts subjects almost never use technology in the classroom. The use of technology is, however, required for assessments (e.g. Internet research and word processing for assignments, PowerPoint for presentations and spreadsheet use in mathematics assignments) and students sometimes have time in a computer laboratory to facilitate this. Students were positive about this when it happened.

A major exception to this picture of almost non-existent use of technology in the classroom were the technology subjects (see Table 5.24 and Table 5.28) such as Film, Television and New Media (FTV), and Information Technology studies (ITS) where the curriculum revolves around computer use and the class is often in a computer laboratory for lessons in which the teacher frequently uses a computer and the Internet in teaching. Students are positive/very positive about this.

A second exception are the science subjects other than physics (see Table 5.24 and Table 5.27), particularly biology and chemistry where students report that the teacher shows ClickView Digital Video Library movies on a weekly basis and ‘rarely’ uses digital learning objects/animations. Table 5.24 shows that biology teachers specifically use the computer and the Internet in teaching on a weekly basis. Students are positive
about all such instances of technology use in class. The researcher’s observations are that the marine studies teacher also made frequent use of digital resources in the classroom although no students reported data about this subject.

*Physics is much more technologically advanced. That is a positive. In biology we prepare notes and we know that we have to do notes every lesson but in chemistry the teacher writes a layout of the lesson on the board; video discussion and notes but sometimes we don’t get it all down. Whereas, if you have the set workbook you know what to cover and you don’t have to copy it all down.* Year 12 girl

*In chemistry we ... use the laptop to watch ClickView (digital video library) files. So we watched ClickView off that and that helped to show on the molecular/atomic level what is happening. We can’t do that on a white board very easily.* Year 12 boy

*My sister is in Yr 10 and she has been choosing her course for Year 11. She was strongly considering either physics or chemistry. I told her to go with physics because it a lot easier and there is a lot better learning experience with the tablet because you can learn so much better with that compared with chemistry that we hardly use any technology at all except the occasional video. The amount of interactivity is definitely decreased in as opposed to physics. So you aren’t learning as well as you could be, I think, as with something like a Tablet PC or an interactive whiteboard.* Year 12 boy

In summary then, the digital natives populating the physics classrooms at the research site reported that, apart from the specific technology subjects and sometimes in their other science subjects, their classroom learning is largely devoid of the use of technology. They did, however, like it when technology was used. It seems that their experience in physics has been unique. Given this experience, what suggestions did the physics students make regarding the use of the TWP in their other subjects?

### 6.4.4.4 Students’ recommendations for use of TWP in other subjects

While digital technology is being used to some advantage in biology and chemistry, students recommend the use of the Tablet PC to assist their learning in these subjects. In the survey, students ‘agreed’ that the Tablet PC would assist their learning in other science classes (see Table 5.21, Item C6).

Students were, however, indifferent/undecided about the usefulness of the TWP in their history, or english classes (see Table 5.21, Items C7, C9). One student suggested
that the Tablet PC would be useful in physical education classes or when students are required to make presentations.

*The Tablet PC could be used to replace the OHP (overhead projector) in PE (Physical Education) etc, or to replace the OHTs (overhead transparencies) in assignment presentations.*

Year 12 girl

Students were also indifferent/undecided about the usefulness of the TWP in their mathematics classes (see Table 5.21 Item C8).

Perhaps the fact that students are unsure about recommending the extension of the use of the TWP to any subjects other than their science subjects simply reflects their familiarity with the technology and the pedagogy in a science setting. Given the dearth of technology use in many other subjects, students may not be sure that the teachers in those subject areas would be sufficiently confident with embedding technology into the curriculum to exploit the potential of the Tablet PC in that context. There is, however, a more fundamental explanation in terms of CLT which will now be explored.

### 6.5 Implications for the use of the TWP in other educational settings

The improved learning outcomes that were achieved by the use of the TWP in physics have been linked back to CLT. In physics, the high intrinsic cognitive load of the learning materials means that effective management of cognitive loads is critical to maximising learning. Instructional techniques and materials must be carefully designed to manage intrinsic cognitive load, reduce extraneous cognitive load so that beneficial germane cognitive load can be imposed (see Section 2.2.5.2). This is critical for novices whose less sophisticated schema development makes them more prone to cognitive overload (Sweller et al., 1998). Hence, the major advantage of the TWP over traditional pedagogy in physics is the effective management of cognitive load for high school physics students who are novices.
6.5.1 TWP in other high school subjects

This argument suggests that the TWP would be effective for other high school subjects that have learning materials with high element interactivity such as chemistry, biology, engineering, and mathematics.

Students confirmed this reasoning by recommending the use of the TWP in their other science subjects but they were indifferent/undecided about its use in mathematics.

This is surprising, given that physics and mathematics, particularly the higher level options such as Mathematics B and Mathematics C (both pre-tertiary, calculus based courses) are similar in nature, involving complex calculations and high inherent cognitive load. However, the fundamental difference between the study of mathematics and physics relates to the volume of supporting information that must be recorded and understood. This is vastly greater in physics than in mathematics and may reduce the benefits of the guided notes in mathematics.

However, other elements of the TWP may be beneficial. The use of the Tablet PC rather than the whiteboard to present, organise and store an electronic version of class notes (e.g. using Microsoft One Note) would also allow textbook questions and graphics calculator software to be displayed on demand, reducing split-attention. Such an electronic journal would allow the flexibility to respond freely to student initiated enquiries which are common in mathematics lessons. Students would record the lesson notes in their own notebooks. The researcher is currently trialling such pedagogy with Year 11 and 12 Mathematics B classes.

Students were also indifferent/undecided about using the TWP in English or history classes. While challenging in other ways, arts/humanities subjects may not require the simultaneous processing of multiple interacting elements in working memory and so may not require such careful management of cognitive load. These subjects may benefit from an electronic journal pedagogy like that suggested for mathematics.

6.5.2 TWP in physics and related subjects at university level

A major difference between high school and university physics students is their existing expertise in physics. High school students are novices. Year 12 students have a little more maturity and experience than Year 11 students, but are still essentially novices as they encounter new topics that were not covered in Year 11. By the end of
a high school physics course, students should have been exposed to a wide range of physics concepts, albeit at an elementary level. University students with the prerequisite background in high school physics cannot then be considered as novices and their expertise will grow as they progress through their courses.

The expertise reversal effect (Kalyuga, et al., 2003) suggests that, as students progress through university, the benefits of the highly structured teacher-centred TWP may reduce progressively as the students’ levels of expertise increase. They would progressively benefit more from less directed student-centred pedagogy that feature one Tablet PC per student with two-way electronic communication between lecturer and students and frequent use of group project work. The same arguments could be made for other similarly cognitively complex subjects like mathematics, chemistry, engineering and computer science.

Many studies featuring student-centred pedagogies in university level physics, mathematics, engineering and computer science courses are reported in literature (see Section 2.3.3.2). Some studies of first and second year university physics, mathematics, engineering and computer science courses also feature more directed teacher-centred tablet pedagogy which is similar to the TWP but slide-based (see Section 2.3.3.1). Evidence of successful outcomes is usually provided in terms of improved student engagement and satisfaction levels (e.g. Reboli, 2007), but some present evidence of improved learning outcomes (e.g. Hojjatie, et al., 2008). These results are consistent with the predictions of the expertise reversal effect.
Chapter 7:  
Conclusions and Future Directions

7.1 Conclusions

The aim of this research was to use CLT to develop an improved way to teach high school physics, to trial the new TWP in a real classroom setting, to collect and evaluate data to assess its success and finally to link the findings back to CLT. Each of these research aims was completed successfully.

Teaching with the TWP for one year resulted in significantly better (at the 5% level) learning outcomes (as measured by global scores) for students studying high school physics than were achieved by using traditional pedagogy. Use of traditional pedagogy alone produced no significant improvement (at the 5% level) in global scores over a two year period, even though some improvement may have been expected as a result of maturation.

Differences were observed in the way the TWP affected students’ learning outcomes in near and far transfer tasks.

The same significant improvements (at the 5% level) in learning outcomes were demonstrated with far transfer scores after as little as six months instruction with the TWP. These elevated performance levels with the TWP were maintained over the longer term. The use of traditional pedagogy produced no significant change (at the 5% level) in far transfer scores over the two year period. These results are of critical importance to physics education since attaining far transfer is the major objective of most physics courses (Mayer, 2004b).

Students’ scores in near transfer tasks related to recall and application of concepts in rehearsed situations improved significantly (at the 5% level) after learning with the TWP for one year. No significant improvement (at the 5% level) occurred when students learned with traditional pedagogy over the two year period.

In other near transfer tasks related to rehearsed scientific data analysis tasks, instruction with the TWP and traditional pedagogy both caused significant
improvements (at the 5% level) in learning. This suggests that such improvements may simply have been the result of increasing maturity and experience rather than being directly related to pedagogy.

The TWP produced significantly better learning (at the 5% level) for high school physics students than traditional pedagogy as measured by global scores, far transfer scores and near transfer scores related to recall and application of concepts in rehearsed situations.

Differences in trends in learning outcomes for boys and girls were detected. The trends in boys’ global, near transfer and far transfer scores, and girls’ far transfer scores mirrored those for the whole cohort for both the TWP and traditional pedagogy. In contrast, for girls, no significant improvements (at the 5% level) were evident in global scores or near transfer scores after instruction with either pedagogy.

In assessing girls’ scores, it should be noted that the girls’ group sizes were small ($N \leq 10$). Qualitative data has been considered in conjunction with the quantitative data to allow methodological triangulation to strengthen the reported results for girls, but they should be considered as indicative rather than definitive and should be confirmed by further research.

Students’ comments suggested that the mechanisms by which their learning and engagement in physics improved with the TWP resonate with specific instructional processes developed according to CLT principles. The TWP reduces intrinsic cognitive load by providing guided notes that act as an advance organiser. It reduces extraneous cognitive load by reducing split-attention and search, increasing spatial and temporal contiguity, removing redundant materials, providing simultaneous complementary visual (electronic images of the workbook and digital resources) and audio (teacher’s commentary) information and by providing worked solutions which the students may self select in preference to problem solving. It also increases germane cognitive load by providing scaffolding, clearly directing attention, using dynamic interactions between the teacher and students to provide completion problems with faded guidance.

Differences in boys’ and girls’ comments reflected the differential trends for boys and girls in near transfer scores (significant improvements for boys but not for girls). Boys
were more positive than girls in their attitudes to the use of the workbook for note taking and organisation and they reported improved engagement and motivation when learning with the TWP. Note taking skills, organisation and motivation are predictors of success in near transfer tasks with traditional pedagogy (Kiewra, 1987) and girls are more likely to possess them than boys (Brasell, 1987; Burley, 1982; Cranney & Kirby, 1980). Hence, boys were more disadvantaged than girls by traditional pedagogy and showed greater improvement after the introduction of the TWP.

Similarities in boys’ and girls’ comments reflected their similar trends in far transfer scores (both showed significant improvement at the 5% level). Boys and girls benefited equally from the improved management of cognitive load possible with the TWP and the consequent enhancement of schema formation and elaboration. Girls and boys were equally as likely to report improved understanding of physics concepts with the TWP.

Students’ comments about learning with traditional pedagogy suggested that its management of cognitive load was poor and that frequent incidents of cognitive overload impaired their learning. This reflects the fact that traditional pedagogy produced no significant improvement (at the 5% level) in learning in global, far transfer or near transfer scores over the two year course (apart from near transfer scores related to rehearsed data analysis tasks which were also produced by the TWP and could be related to maturation).

Clearly, the results of this research are applicable to other high school physics classes and will inform educators of a better way to teach physics than traditional methods. CLT suggests that the results should also be applicable in other contexts where cognitively complex subjects must be taught to novices. Examples include high school mathematics, chemistry and biology classes and first or second year university mathematics, chemistry, biology, engineering or computer science classes. Indeed, literature reports trials of teacher-centred tablet pedagogies in these contexts (Loch & Donovan, 2006; Neal & Davidson, 2008) that have produced evidence of improved motivation and engagement but not of improved learning outcomes.

In conclusion, this research has demonstrated that the TWP provides a method of teaching high school physics that has improved learning outcomes for high school
physics students beyond that which was possible with traditional pedagogy. It has achieved this by embedding CLT principles in a teacher-centred pedagogy in which the teacher uses a Tablet PC to present lessons using curriculum materials that include guided notes in electronic form for the teacher and bound into a printed workbook for the students. The use of the TWP provides a cost effective and efficient way to improve students’ perceptions of physics, their engagement with physics and their academic success in physics. The TWP should also be effective in teaching other cognitively complex, technically oriented subjects (e.g. chemistry, biology, mathematics, engineering, computer science) at high school or university level.

7.2 Future Directions

Several suggestions for further research have already been mentioned. Further research with larger cohorts of girls is necessary to validate the results for girls. Research is needed to determine the effect on schema development when both conventional problems and their worked solutions are provided so that students may self-select the level of support needed.

The TWP should be trialled in other high school physics classes to determine if these results can be replicated. The TWP should also be trialled in other contexts such as in high school chemistry, biology or mathematics classes to see if these results are replicable in other cognitively complex subjects as suggested by CLT. Trials in these subjects at university level, particularly first year level, are also recommended.

Other models of Tablet PC use should also be trialled. For example, the researcher is currently investigating a teacher-centred pedagogy that uses the Tablet PC with Microsoft OneNote software to teach high school pre-tertiary mathematics courses. Student-centred models of Tablet PC use in high school physics should also be trialled.

A direct extension to this research would be to assess the instructional efficiency of the TWP by measuring mental effort and performance. This would allow a closer linkage of the effects obtained to CLT. Tuovinen and Paas (2004) provide a description of a 3-dimensional approach, which combines the measures of learning effort, test effort and test performance.

Whilst the emphasis of this research was on cognitive aspects of learning in the complex learning environment of a physics class, students’ comments about
motivation have identified a second mechanism which may be significant. Motivation accounts for almost as much learning variation as cognitive aptitude (R. E. Clark, et al., 2006). Paas, et al. (2005) discussed the role of motivation in linking mental effort and performance as students must be willing to invest the mental effort required to master a challenging task. They also suggested a quantitative method to calculate motivational effects. The role of motivation with the TWP should be investigated more closely.

Csikszentmihalyi’s (1975) concept of flow suggests another aspect of motivational theory that may provide the basis of further research into motivational aspects of TWP in physics. By more efficiently managing cognitive load with the TWP, the challenge level of the complex learning tasks in physics may be reduced so that for a given skill level a student is more likely to attain a state of flow in engaging with learning.

It was suggested that an additional aspect of cognitive load may have been evident with respect to students’ clear preference for handwritten notes and worked solutions rather than typed versions. Perhaps students’ schemas for reading and writing handwritten text are better automated than those for reading typed text. Perhaps handwriting more efficiently embeds ‘hooks’ for retrieval into schema. This would mean that interacting with handwritten text is better for learning than interacting with typed materials. Anthony, et al. (2006) related the use of handwriting in mathematics to decreased extraneous cognitive load and improved understanding of spatial relationships, but further research is required. The aspects of hand-writing in learning discussed here represent interesting possible extensions to cognitive theory.

Finally, there is a possibility that the encouraging results reported by research into educational uses of Tablet PCs, including this study, may be explained as novelty effects. A need exists, therefore, for longitudinal studies to discount this possibility by testing whether student motivation levels can be sustained (Wise, et al., 2006).
References


Hewlett-Packard (2004). Concordia College students learn the benefits of wireless mobility with HP Tablet PCs Retrieved 25/10/08


Appendix A:
Survey Document

Tablet Technology in Senior Physics Classes

**ID Number:**

**Name:**

Your name has been included here to allow easy distribution of survey booklets.

Please remove this page prior to submitting your completed survey booklet so that your response is not easily identified.
Tablet Technology in Senior Physics Classes

Student Survey

RESPONSE BOOKLET

You ID number appears on this survey form to allow tracking of responses over the period of the project. Project reports will be of a summary nature only and no reference will be made to individual student identities.

Your Physics teacher has had one tablet computer and a data projector to use in your Physics lessons since January 2007. This survey is designed to collect information about the ways in which this technology package has been used and your perceptions of its use.

Thank you for agreeing to complete this survey.

When instructed to do so, please complete these details:

<table>
<thead>
<tr>
<th>ID Number: (Enter ID Number)</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>School:</td>
<td></td>
</tr>
<tr>
<td>My Year 11 year is 2006/2007/2008</td>
<td>My Year 12 year is 2007/2008/2009</td>
</tr>
<tr>
<td>The subjects I currently study are:</td>
<td>Circle your favourite subject.</td>
</tr>
<tr>
<td>1. English</td>
<td>2.</td>
</tr>
</tbody>
</table>

Do not turn the page until instructed to do so by the Survey Administrator.
Section A

These questions relate to the use of the tablet computer by the teacher during Physics lessons.

Instructions

In column (i) responses, indicate how often your teacher uses the tablet computer for the stated activity in your classes.

Use this key to answer these questions:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>R</td>
<td>W</td>
<td>F</td>
<td>O</td>
</tr>
<tr>
<td>Never</td>
<td>Rarely used in lessons (used 1 or 2 times per term)</td>
<td>Weekly use in lessons (used 2 or 3 times per month)</td>
<td>Frequent use in most lessons (used 2 or 3 times per week)</td>
<td>Often used several times per lesson</td>
</tr>
</tbody>
</table>

In column (ii) responses, place a tick on the scale to indicate your attitude to the tablet computer being used in this way in your lesson.

<table>
<thead>
<tr>
<th>Very Negative (VN)</th>
<th>Negative (N)</th>
<th>Not Sure (NS)</th>
<th>Positive (P)</th>
<th>Very Positive (VP)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Items</th>
<th>Activity</th>
<th>Column (i) Responses</th>
<th>Column (ii) Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Uses the tablet computer in class.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Uses the tablet computer’s digital pen features.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>Uses digital ink on the tablet computer to add handwritten notes/diagrams to prepared typed lesson notes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>Uses digital ink on the tablet computer to add handwritten notes/diagrams to a prepared Power Point presentation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item Number</td>
<td>Activity</td>
<td>Column (I) Responses How often? (N, R, W, F, O)</td>
<td>Column (A) Responses Your attitude to this activity is ...</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>A5</td>
<td>Uses the digital pen to control computer animations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6</td>
<td>Uses the digital pen to control Logger Pro software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A7</td>
<td>Displays a movie using ClickView or a dvd.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A8</td>
<td>Accesses internet information during the lesson.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A9</td>
<td>Uses Graphics Calculator software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A10</td>
<td>Uses Excel software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A11</td>
<td>Displays a Power Point presentation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12</td>
<td>Stores a copy of the digital ink lesson notes for later access.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A13</td>
<td>Recalls a copy of previous digital lesson notes for review in class.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A14</td>
<td>Provides a copy of previous digital lesson notes for student use eg if student was absent for the lesson.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A15</td>
<td>Moves around the classroom with the tablet computer in search from different positions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A16</td>
<td>Allows students to control the tablet computer during lessons.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A17. What other activities would you like to have the teacher do using the tablet computer during lessons?
Section B

These questions relate to the use of the tablet computer by the students during Physics lessons.

Instructions

In part (i), indicate how often you have used the tablet computer for the stated activity in your classes.

Use this key to answer these questions:

- **N** Never
- **R** Rarely used in lessons (used 1 or 2 times per term)
- **W** Weekly use in lessons (used 2 or 3 times per month)
- **F** Frequent use in most lessons (used 2 or 3 times per week)
- **O** Often used several times per lesson

In part (ii), place a tick on the scale to indicate your attitude to using the tablet computer in this way during the lesson.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Activity</th>
<th>Response (I): How often? (N, R, W, F, O)</th>
<th>Response (II): Your attitude to this activity is...</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Used the tablet computer in the class.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>Used the tablet computer's digital pen features.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B3</td>
<td>Used digital ink on the tablet computer to add handwritten notes/diagrams to prepared typed lesson notes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B4</td>
<td>Used digital ink on the tablet computer to add handwritten notes/diagrams to a prepared PowerPoint presentation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item Number</td>
<td>Activity</td>
<td>Response (I)</td>
<td>Response (II)</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>B5</td>
<td>Used the digital pen to control computer animations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B6</td>
<td>Used the digital pen to control Logger Pro software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B7</td>
<td>Accessed internet information during the lesson.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B8</td>
<td>Used Graphics Calculator software.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B9</td>
<td>Used Excel software.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B10</td>
<td>Displayed a Power Point presentation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B11</td>
<td>Received a copy of the stored digital lesson notes from a lesson I missed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B12</td>
<td>Used the tablet computer at my desk in class.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B13</td>
<td>Used the Bluetooth mouse at my desk to control the tablet computer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B14</td>
<td>Controlled the tablet computer at the front of the class during lessons</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B16 In what ways can the stored lesson material from a tablet computer lesson be used to assist your home study?

B16 What other activities would it be good for students to do using the tablet computer during lessons?
Section C

These questions relate to your perceptions about the effects of using tablet computer technology in Physics classes.

Instructions

Place a tick on the scale to indicate your response to the statement made.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Statement</th>
<th>Your response to this statement is ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>I think that Physics concepts are easier to understand when the teacher uses the tablet computer to help explain them.</td>
<td>SD</td>
</tr>
<tr>
<td>C2</td>
<td>I enjoy Physics classes more when the tablet computer is used.</td>
<td>SD</td>
</tr>
<tr>
<td>C3</td>
<td>Using the tablet computer in Physics classes wastes a lot of time.</td>
<td>SD</td>
</tr>
<tr>
<td>C4</td>
<td>I have difficulty reading the handwritten notes that the teacher writes in digital ink on the tablet computer.</td>
<td>SD</td>
</tr>
<tr>
<td>C5</td>
<td>I prefer to take lesson notes when the teacher writes them on the whiteboard.</td>
<td>SD</td>
</tr>
<tr>
<td>C6</td>
<td>I think that use of the tablet computer would assist my learning in other science classes.</td>
<td>SD</td>
</tr>
<tr>
<td>C7</td>
<td>I think that use of the tablet computer would assist my learning in English lessons.</td>
<td>SD</td>
</tr>
<tr>
<td>Item Number</td>
<td>Statement</td>
<td>Your response to this statement is ...</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>C8</td>
<td>I don't think that use of the tablet computer would assist my learning in Mathematics lessons.</td>
<td>DOA-SA</td>
</tr>
<tr>
<td>C9</td>
<td>I think that use of the tablet computer would assist my learning in a humanities class eg history.</td>
<td>DOA-SA</td>
</tr>
<tr>
<td>C10</td>
<td>I prefer to write lesson notes in the prepared workbooks rather than in a blank notebook.</td>
<td>DOA-SA</td>
</tr>
<tr>
<td>C11</td>
<td>Writing lesson notes in the prepared workbooks would be easier if the teacher did not use the tablet computer.</td>
<td>DOA-SA</td>
</tr>
<tr>
<td>C12</td>
<td>An ordinary laptop computer is just as good as a tablet computer.</td>
<td>DOA-SA</td>
</tr>
<tr>
<td>C13</td>
<td>It is better to use an interactive whiteboard in class than a tablet computer.</td>
<td>DOA-SA</td>
</tr>
</tbody>
</table>
C14. The things I like about the use of the tablet computer in class are:

C15. The things I do not like about the use of the tablet computer in class are:
Section D

These questions relate to the use of computer technology in other subjects’ lessons.

Instructions

In Column (i), indicate how often the stated activity occurs during lessons in the subject indicated.

Use this key to answer these questions:

N  Never
R  Rarely (used 1 or 2 times per term)
W  Weekly (used 2 or 3 times per month)
F  Frequent (used 2 or 3 times per week)
O  Often (used several times per lesson)

In Column (ii), place a tick on the scale to indicate your attitude to using computer technology in this way during the lesson.
### Subject 1: English

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Activity</th>
<th>Column (i) Responses How often? (N, R, W, F, O)</th>
<th>Column (ii) Responses Your attitude to this activity is ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>The teacher uses a laptop computer and data projector to present lessons.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D2</td>
<td>The students use the teacher's laptop computer during lessons.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D3</td>
<td>The teacher uses an Interactive Whiteboard to present lessons.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D4</td>
<td>The students use the Interactive Whiteboard during lessons.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D5</td>
<td>The teacher shows ClickView movies.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D6</td>
<td>The teacher uses ClickView learning objects.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D7</td>
<td>The teacher shows Power Point presentations during the lesson.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D8</td>
<td>The teacher accesses internet information during the lesson.</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>D9</td>
<td>The class goes to a computer laboratory for one-on-one computer access.</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>
### Subject 2: ........................................... (write the name of another subject you study)

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Activity</th>
<th>Response (I)</th>
<th>Response (II)</th>
<th>Your attitude to this activity is ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>D10</td>
<td>The teacher uses a laptop computer and data projector to present lessons.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D11</td>
<td>The students use the teacher's laptop during lessons.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>C12</td>
<td>The teacher uses an Interactive Whiteboard to present lessons.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D13</td>
<td>The students use the Interactive Whiteboard during lessons.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D14</td>
<td>The teacher shows ClickView movies.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D15</td>
<td>The teacher uses ClickView learning objects.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D16</td>
<td>The teacher shows Power Point presentations during the lesson.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D17</td>
<td>The teacher accesses internet information during the lesson.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
<tr>
<td>D18</td>
<td>The class goes to a computer laboratory for one-one computer access.</td>
<td>VN</td>
<td>N</td>
<td>NS</td>
</tr>
</tbody>
</table>

Thank you for completing this survey.
Appendix B:
Semi-structured Interview Document

Tablet Technology in Senior Physics Classes
Semi-structured Interview
Script
Introduction

Thank you for agreeing to participate in this interview. The purpose of the interview is to understand the value and limitations of using a tablet computer in Physics classes.

Remember that participation is completely voluntary and you may withdraw at any time without penalty and without the need to give a reason.

I would like to make an audio/video recording of our conversation for later transcription and analysis. Your name will not be used and your responses will not be attributed to you personally without further permission being obtained.

Your responses are confidential and your privacy will be respected. Your honest responses are sought. It is your personal opinion that is important in this research.

Discussion Starter Questions

These interview questions will focus on your perceptions of how the use of the tablet computer has affected your learning.

1. Does the use of technology play a big part in your life generally? Explain.
2. Does the use of technology play a big part in your current school subjects? Explain.
3. Has the use of the tablet computer in Physics lessons helped your learning? How?
4. What are the problems for learning when a tablet computer is used in Physics lessons? Why?
5. Does the use of the tablet computer improve your enthusiasm for learning? Why?
6. In what ways should the tablet computer be used in class next year/term to best improve your learning?
7. If your best friend wanted to study Physics next year, what would you tell him/her about the tablet computer?

Thank you for your participation.
Appendix C:
Focus Group Script Document

Supervisor:
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Masters Research Project
Ethics Approval Number: F/07/1266

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University of the Sunshine Coast
Faculty of Science, Health and Education

Tablet Technology in Senior Physics Classes
Focus Group
Script
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