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How does the use of the Tablet PC contribute to teaching and learning goals in the secondary classroom?

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Abstract

The ubiquitous nature of computer technology in the high school learning environment gives rise to questions around the learning benefits of the application of such technology. Is this situation a challenge to be managed or an opportunity to be to be exploited? Does the application of this technology establish a new teaching and learning paradigm, offering new opportunities in student learning? Does it enhance the effectiveness of a teaching and learning framework?

A review of the literature on the use of the Tablet PC in education indicates little empirical research on the influence of Tablet PC's on learning and as a consequence, how they might be used more effectively in the learning process and in the context of a learning framework.

Through a case study methodology, the aim of this research is to investigate the utilisation of a combination of software technology, designed to facilitate recordable collaborative learning experiences, with Tablet Personal Computer technology, equipped with digital inking capacity, in the high school (secondary) mathematics classroom where the teaching and learning was focussed on the framework of Dimensions of Learning (Marzano, 1992). Software technology, designed to facilitate recordable collaborative learning experiences, with Tablet Personal Computer technology, equipped with digital inking capacity are implied when using the term "Tablet PC". The research was constructed with a view to explore the question whether, as a result of the use of the Tablet PC, there were consequent new opportunities identified which contributed to student learning, as perceived by both student and teacher. The research questions were shaped from considerations around the use of the Tablet PC in a senior mathematics classroom and whether this gave rise to learning opportunities, as identified by both students and teacher, which were attributed to, or demonstrated by, the use of the Tablet PC in their lessons.

An analysis of the results from this study identifies how students and teachers utilised digital inking and the applications of software technology in a Mathematics high school environment. Further there is provided evidence of practice which illustrated the teaching and learning potential resulting from the synergetic relationship of the Tablet PC, its associated collaborative software and the teaching and learning objectives of a constructivist model of learning.

Highlighted are two essential attributes of the Tablet PC in the classroom. The first concerned the feature of "digital inking", the use of a stylus or pen for the expression of the full range of "freeform" representations such as numbers, symbols, diagrams, drawings and other markings, captured digitally. The key here was an extension of the nature of the work captured digitally and

thus available for analysis, evaluation, review and reflection through the recording function available.

The second feature was the use of software which created the capacity to capture and replay student and teacher work and facilitate collaborative teaching and learning practices.

Discussion of the results of this study and its concern with the significance for learners who engage with the Tablet PC technology, draws on the technological benefits of digitising "freeform" representations of learning. Such representations are discussed in the context of an analysis of the opportunity they offer both teachers and students as a resource in their joint objectives of constructing meaning. The opportunity identified concerns teacher *insights* into student progress in terms of their construction of meaning. Such insights serve as feedback to teachers on the reality of how successful they have been with this objective in mind. Teacher access to such data, generated during the teaching process, can be compared to their perceived understanding of their students' construction of meaning. Such feedback for the teacher not only signals whether there is a need to revisit learning experiences before moving on to new constructs, but also provides detail and direction on either individual or general misconstructions being made.

Theories on achieving teaching and learning goals which place an emphasis on the active construction of meaning (learning) can be supported in practice by computer technology that has both broad and flexible applications and which positions teachers and learners as active participants during the teaching and learning dynamic.

For students, engagement with this particular technological combination gives rise to the prospect of receiving informed and specific timely and targeted feedback of all non-verbal work representations in the manner of "assessment for learning". Such feedback enables students the opportunity to better construct meaning by having their misconstructions addressed and where realised, mitigates their transfer into new constructs.

In capturing the essence of the pedagogical and metacognitive practices available to the teacher and the students with the utilisation of the Tablet PC and associated software this study suggests how this might empower both teachers and students in the learning process. Five main outcomes emerge:

1. The Tablet PC and associated software provided a number of enhancements.
2. Greater opportunities for collaborative worked were identified.
3. The recording aspect of the software was seen to be another important point.
4. The Tablet PC allowed for the digitisation of freeform content.

5. The Tablet PC served as an example of a “technologically assisted” way to enhance feedback between student and teacher.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

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Tablet PC, Dimensions of Learning, learning, technology, secondary, digital inking, assessment for learning.

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Chapter 1 - Introduction

In this Chapter consideration around the challenges and opportunities for both teachers and students of the use of computer technology in the class room are raised. These considerations provide a focus for the study, the aims of which are then outlined. The emerging new teaching and learning paradigm with computer technology is discussed in the context of the Digital Education Revolution. As this study is centered on the teaching and learning framework Dimensions of Learning, this framework is elaborated to further contextualise the study.

1.1. A challenge to be managed or an opportunity to be exploited?

The advent of the provision of computer technology in every Australian senior classroom, at a ratio of at least one computer to every two students and increasingly at a ratio of one computer to one student, presents both a challenge and an opportunity for educators. As a tool to assist teachers and students in the learning process, computer technology is now ever-present and as such creates a new, permanent, classroom dynamic. Teachers need to ensure that this resource serves their needs and that it is consciously used with the outcome of enhancing teaching and learning opportunities in mind.

Some commentators see the progression towards 1:1 computer technology use in the classroom in a different context. What is suggested as being clearly observable in schools today is the coinciding challenge for educators to adopt computer technology in such a way that it serves the teaching and learning intentions of educators. In doing so is to acknowledge the radical change in the “skill-sets” and outlook of students in our contemporary education environment - students described as “Digital Natives” who are being taught by “Digital Immigrants”, (Prensky 2001). The question of whether there has been in fact a "radical" change in the outlook of students in our contemporary education environment is, however, not accepted by all commentators on student technological capabilities. For example, Bennett et al. (2008), argue that calls for a major change in education based on the technological awareness of students are not well founded in research. Neither, it is suggested, is the claim that these "digital natives" learn differently compared to past generations of students, an accurate one. The perspective of this study is not that the technology of the Tablet PC in the classroom is a necessary response to a generation of learners that may or may not learn in a different manner because of their access to and use of personal technology. Rather the focus is on what the tablet technology offers in the context of what all technology purports to offer, and that is facilitating an objective, in this case assisting constructivist learning to achieve its objectives. As

Bennett (2008) points out "education has a vitally important role in fostering information literacies that will support learning". It has always been the case that learners of any age or generation rely on guidance to help them become independent learners. So what might this guidance be with Tablet PCs as part of the equation? In the situation where students have access to a personal computer for use in every lesson and for homework, both the student and the teacher operate in a new teaching and learning paradigm compared to the context where computer access was only through computer laboratories which meant that computers were only used when determined by the teacher for very specific learning experiences. Where Tablet PCs are used in the 1:1 context, not only is the personal computer available at all times but what is also now newly available is the digitisation of "freeform" representations, formerly the domain of pen and paper technology.

Starting with the contention that every child learns in a different way, for whatever reason let alone the "digital native" contention, to move towards learning which is intrinsically motivating and effective, learning may need to be customised to match each child's learning preference. What might technology's role be in allowing a more student centric approach? Some technologies are student-centric technologies that can mediate the clash between the need to standardise the way schools teach and test as opposed to the need to customise how students learn. Is the Tablet PC a step away from a monolithic technology which demands a singular instructional style for all students using technology? The extent to which it is appropriate to consider contemporary secondary school students as "digital natives" is secondary to the consideration of identifying student and teacher familiarity and adeptness with technology as a learning tool.

1.2 The aims, focus and significance of the study

The purpose of this research was, through a case study methodology, to investigate the utilisation of a combination of software technology, designed to facilitate recordable collaborative learning experiences, with Tablet Personal Computer technology, equipped with digital inking capacity in the high school (secondary) mathematics classroom where the teaching and learning was focussed on the framework of Dimensions of Learning (Marzano, 1992). The research was constructed with a view to explore the question whether, as a result of the use of the Tablet PC, there were consequent new opportunities identified which contributed to student learning, as perceived by both student and teacher.

Readily identifiable prior to the study was the extension to the technology of the personal computer offered by the Tablet PC through enabling "freeform" representations of student thinking to be captured digitally. From this observation arise the following research questions:

1. Does the extension of the digitisation of student work from the products of laptop/notebook and pen and paper technologies to the added products of Tablet PC technology, give rise to new learning opportunities?

A supplementary to this question is one which emerges as a consequence of consideration of the outcomes of the first question:

2. Is the use of laptop/notebook computer technology in education somewhat limiting thinking in students and the feedback to students as a consequence of what cannot be achieved compared with Tablet PC technology?

A final question also emerges from the outcomes of the first and this concerns teacher access to the formation as well as the product of student "freeform" representations. Prior to the development of Tablet PC technology, representations of student work were confined to the two technologies of computer and pen and paper:

3. Does the power to combine both these products of notebook/laptop technology and pen and paper technology in one mode with exposure to the technologies of digitisation and recording, offer more insightful opportunities for teachers to influence learning?

The predominant research questions here, therefore, relate to "how" and "why" the Tablet PC "package" referred to above offers new opportunities for expressions of, and insights into, learning and learning outcomes, in terms of a learner's construction of meaning.

The significance of this study is brought to light in the context of questions around the use of computer technology in the secondary education arena. For example what type of computer technology should be used - Notebook/laptop computer technology with keyboard/mouse input alone, or Tablet PC technology with keyboard/mouse and inking capacity of the Tablet PC pen? Does the former limit student thinking and the latter allow it to flourish? Is the inking capacity of the Tablet PC pen the difference around which the successful application of computer technology in secondary education stands or falls? The general idea behind these questions are touched on by Mishra and Koehler (2008) in their assertion that "one of the most important things to understand about technologies is that particular technologies have specific affordances and constraints" (p. 5). If particular technologies with their specific characteristics are more suited to certain tasks, is the Tablet PC with its digital inking capacity a more suitable technology for use in education than pen and paper or notebook/laptop computers? Oviatt (2013) argues that keyboard and mouse interfaces were "never designed as a thinking tool to support human ideation or extended problem solving" (p. 1).

The Digital Education Revolution, initiated in 2008, has assisted schools to acquire and provide secondary students with computer technologies "before assessment information is available that they actually improve student learning" (Oviatt p. 2). This study has a contribution to make towards adding to that body of assessment information.

1.3. A new teaching and learning paradigm

The use of computer technology as a tool that provides a means by which teachers may leverage teaching and students may leverage their learning, presents both opportunities and challenges. Computer technology in the hands of a majority of students is a relatively new phenomenon. Many commentators on the education scene both in Australia and nations of similar cultural backgrounds have bemoaned the industrial age paradigm that secondary school education is often viewed as being mired in, a perception that may be attributed, in part, to a lack of available computer resources in classrooms (Lee & Gaffney, 2009). The response to a paucity of computer technology resources in schools has in recent years come from governments such as those in Great Britain, New Zealand, Mexico and Singapore who have implemented initiatives designed to fund the provision of these resources, (Lee & Gaffney, 2009). In Australia a similar response took place in 2008 following the announcement of the government's Digital Education Revolution, aimed "to contribute sustainable and meaningful change to teaching and learning in Australian schools that will prepare students for further education, training and to live and work in a digital world" (DEEWR, 2011).

1.4. A greater emphasis on learning than teaching?

Mehlinger (1996) noted that the advance of computer technology occurred "at about the same time as ideas for school restructuring and findings from the cognitive sciences" (p. 17). He asserted that the potential for computer technology to transform teaching and learning is based on two main dynamics. The first of these dynamics concerned student engagement, noting that new technology would be used in schools because it appealed to students. The second dynamic concerns the prediction that "the very relationship between students and teachers will be challenged because the technologies enable learners to gain control of their own learning" (p. 18). Mehlinger asserted that there is a need to raise awareness and understanding amongst teachers around the view that the way technology is actually used is critically important. He also argued that evaluation research needs to go beyond the short-term period and look at the longer term sustainability of teaching and learning

outcomes that may be initially evident in the short term. Here the concern is around whether there will be lasting changes in how students learn and how teachers teach.

The new social paradigm created by technology in its various manifestations (the so-called 'information age') is now beginning to impact significantly on the education paradigm which until recently could be seen to be very conservative in terms of the adaptation of technology to teaching and learning. Recent government initiatives (the Digital Education Revolution) concerning computer technology and its place in classrooms has forced the question of computer technology use in education and the associated issues, much closer to the top of school change agendas than before. Such issues concern not only how computer technology should be best utilised as a tool in the teaching and learning dynamic by teachers, but also what type of computer technology achieves the desired learning outcomes.

The problem of integrating computer technology in the teaching and learning dynamic is not confined simply to a familiarisation of a new methodology available to teachers and students. It also places a greater emphasis on the need to see learning as an active construction of meaning as the teacher is gradually removed from the role as the sole source of knowledge in the classroom. As noted by Beetham and Sharpe (2007), learners are no longer situated in the teaching and learning dynamic as passive recipients of knowledge and skills, but must now be viewed as active participants in the learning process because they can access knowledge themselves (p. 2).

According to Beetham and Sharpe (2007), it would appear that the advent of computer technology has placed a stronger emphasis on the symbiotic relationship between teaching and learning, referred to as "learning in the context of teaching, and teaching that has a learning goal" (p. 2). The authors go on to reinforce this view by further defining pedagogy as being concerned with not only the theory of teaching and learning but also the practice of teaching and learning. Their claim is that the use of the term 'pedagogy' in this context initiates a dialogue between theory and practice, as well as between learning and teaching, leading to the conclusion that neither the doing (the practice of teaching and learning), nor the thinking (the theories of teaching and learning) make sense in isolation from each other.

In the context of a changing educational paradigm, against a background model of teaching and learning based on constructivist theory, what can be observed to be occurring when computer technology, and specifically the Tablet PC, is permanently and consistently in use in the secondary classroom?

1.5. The context

The study takes place in the context of a school where there is a focus on a shared understanding of how students learn and, as a consequence, how teachers should teach. This focus manifests as a methodology, a model for learning, or a framework that shapes the pedagogical process with the intention of maximising student learning outcomes both in terms of metacognition and student standards. It is based on an understanding that learning is interactional, or as Senge (2000) describes it, "learning is connection" (p. 20). Learning is thus viewed as a process as much as it is concerned with producing end results and this has implications for the management of learning, or the teaching and learning model employed.

Hopkins (2001) describes the maximising of student learning outcomes in terms of results and metacognition, as "powerful learning". Powerful learning is more than just results and scores. Powerful learning subsumes a range of cognitive and affective processes and outcomes...[Powerful learning raises student] attainment while at the same time helping students become more powerful learners, by expanding and making articulate the students' repertoire of learning strategies….[Powerful teaching identifies] "the ways in which high quality teaching promotes high quality learning (p. 100). Joyce & Showers (1991) have suggested that powerful learning experiences are not based entirely on teacher attributes of charisma, persuasion and expertise of presentation but also on the provision of powerful cognitive and social tasks and teaching students how to make productive use of them. In addition they contend that it is necessary that teachers not only believe that all children can learn and that they can teach all children, but that they also convey this message to their students. Further practices leading to powerful learning have been suggested by Joyce, Calhoun & Hopkins (2002) through content which creates opportunities to explore and build important areas of knowledge. This implies processes which facilitate the development of powerful tools for learning and a social climate, which establishes humanising social conditions.

A model of powerful teaching and learning will define the nature of the content, the learning strategies and the arrangements for social interaction. Adaptable models of powerful learning will be characterized by content being conceptual rather than particular; process being a constructive inquiry instead of passive reception; the social climate being expansive rather than restrictive and the model being applicable to a wide range of curriculum areas and types of learners. This last point, concerning applicability to curriculum as a whole and all learners, is significant in that this case study will have relevance to schools who have adopted models of learning which, whilst they may not be identical, are based on the same characteristics of powerful teaching and learning which

adapt to a wide spectrum of curriculum areas and types of learners. The heart of the matter here is that the model of learning seeks to enable the teacher to teach the student how to learn at the same time as assisting the student to acquire curriculum content.

1.6. Theoretical framework

It is the perspective of pedagogy, outlined earlier (that the practice of teaching and learning and the theories of teaching and learning need to inform each other), that shapes the case study proposed and for this reason there needs to be an understanding of the theory of teaching and learning that is adopted in the case study which is the focus of this research. The framework of teaching and learning that contextualises this study will create a lens through which the observations are analysed.

The shift in emphasis in understanding of how learning occurs from behavioural psychology, to a greater emphasis on cognitive psychology gave rise to the importance of cognitive processes in understanding how learning occurs. This perspective is fundamental to the idea that the objective of learning is achieved through teaching which reflects understandings of learning. That understanding of how learning occurs in this study involves an understanding of the constructivist model of learning.

According to Powell and Kalina (2009), constructivism is a vague concept which has a variety of meanings for many educators or teachers. They distinguish between cognitive constructivism and social constructivism, with the former described as the individual construction of ideas through a personal process (attributed to Piaget); and the latter described as the construction of ideas through interaction with the teacher and other students (attributed to Vygotsky). Both types of constructivism result in an individual construction of meaning.

1.7. The Dimensions of Learning model of teaching and learning

Briefly, the Dimensions of Learning model is a school-wide, teaching and learning framework used to navigate the education of students. The model is based on the premise that effective teaching mirrors effective learning and so implies that teaching is organised around the learning process. Effective learning is seen as a product of thinking and so the objective of teaching is to improve the quality of student thinking. It is a model of instruction that improves the quality of thinking and the

sequential logic proposes that effective thinking informs effective learning which in turn informs effective teaching.

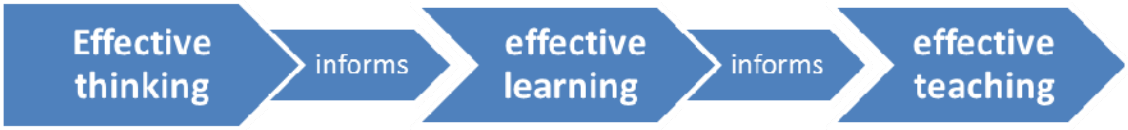

Figure 1: Thinking, Learning, Teaching sequence in Dimensions of Learning, (Marzano, 1992)

The Dimensions of Learning model notes, in the context of Dimension 1, that students' feel more comfortable and the classroom climate is more positive when they are moving from a position of knowing to a position of knowing more. Highlighted here is teacher awareness of student needs around acquiring knowledge at their own pace. Powell and Kalina, (2009) highlight the need to observe students, to comprehend their level of difficulty and teach to each student's ability level. The acknowledgement of Vygotsky's social constructivist model places an emphasis on such interaction as a factor leading to construction of meaning. Such strategies as co-operative learning and scaffolding are involved here.

An awareness of these two perspectives on constructivism provides criteria which informed the observation of student learning. At the same time they inform the observation of teaching in the light of the view that "Both Piaget and Vygotsky agreed that the teacher's role was that of a facilitator and guide and not of a director or dictator" (Powell & Kalina, 2009, p. 247). Both perspectives of constructivist learning are reflected in the teaching and learning model, Dimensions of Learning.

Hopkins' (2001; Joyce, Calhoun & Hopkins, 2002) identification of elements of effective learning is found in the Dimensions of Learning model. These include references to students effectively learning when they are able to:

- construct meaning by integrating new knowledge with previously understood knowledge;
- acquire and use a range of learning strategies (which in Dimensions of Learning includes such strategies as organizing and detecting patterns in information);
- solve problems individually and in groups; think carefully about their successes and failures, and accept that learning involves uncertainty and difficulty (Dimension 5);
- evaluate conflicting evidence and think critically (Dimension 3).

The learning strategies identified are commonly termed meta-cognition and relate to the learner's ability to take control over their own learning process. The emphasis on effective learning is that the learning takes place involving an active construction of meaning.

Brown (2007) stated that "Dimensions of Learning is a program designed to improve student's thinking skills…" and that the model is "based on the best current research in learning theory and cognitive psychology" (p. 6). A product of a collaboration between the Association for Supervision and Curriculum Development and a team of authors headed by Robert J. Marzano of the Mid-continent Regional Educational Laboratory, Dimensions of Learning translates the research and theory explained in *Dimensions of Thinking* (Marzano et al. 1988) into a practical framework that K-12 teachers can use to improve the quality of teaching and learning in any content area. These dimensions are metaphors for how the mind works during learning. Its five dimensions are not hierarchical, linear or sequential. They interact and overlap and each dimension has distinctive characteristics with the boundaries between them considered as being blurred.

The five dimensions model the learning process and are described as follows (Table 1):

Table 1: Dimensions of Learning (Marzano et al. 2008)

Dimension	Brief description
Dimension 1: **Attitudes and Perceptions**	The principle behind Dimension 1 is that students' attitudes and perceptions influence their learning.
Dimension 2: **Acquire and Integrate Knowledge**	The focus here is on the thinking needed to acquire and integrate knowledge two types of knowledge, declarative knowledge and procedural knowledge.
Dimension 3: **Extend and Refine Knowledge**	Here Learners look to develop an in-depth understanding of new declarative and procedural knowledge by extending and refining the knowledge using particular complex reasoning processes (CRPs).
Dimension 4: **Use Knowledge Meaningfully**	A teacher can help students use knowledge meaningfully by engaging students in tasks that they perceive to be relevant, interesting, engaging and that require them to use CPRs.
Dimension 5: **Habits of Mind**	There are three main areas of focus here: critical thinking, creative thinking and self-regulated thinking.

1.8. Conclusion

Educational technologies in the era of State sponsored education of the 19th century were placed in the hands of both teachers and students. Teachers with their chalk and chalkboards taught students with their chalk and slates. Developments in educational technology tended to occur in the realm of

the teacher -projectors of varying types, (slides, transparencies, film); videos; audio/visual, (radio and television) – while student technology tended to be confined to pen and paper and accessing educational technology (such as science equipment or workshop tools). The advent of the personal computer sees a technology in the hands of students which is a powerful knowledge sourcing tool. The Tablet PC iteration of the personal computer is one of the latest developments in such technology and it is fast evolving. Does its capacity to digitise the freeform product of thinking make it a technology worth having from a learning perspective? A review of the literature provides some insight into the current use of this technology in the education space.

Chapter 2. Literature Review

2.1. Introduction

In this Chapter clarification of the type of technology used at the case study site is given. This is followed with an analysis of the literature on this type of technology which begins with a focus on how the Tablet PC is differentiated from the Notebook/Laptop computer and iPad. Consideration of the affordances of the Tablet PC as outlined in the literature follows. These affordances are analysed in terms of their characteristics and whether they represent evidence of new technology being used to achieve what teachers have always looked to achieve with teaching and learning. Just exactly where, in terms of Tertiary and Secondary education arenas, this evidence emanates has implications for the significance of this study.

The Chapter concludes with the suggestion that the literature around the use of Tablet PC technology in the secondary classroom is sparse in that context, is focussed on the opportunities for teachers to be more efficient in what they currently do and gives rise to a need for teachers and students to develop new sets of skills to achieve this efficiency. Implications for the use of Tablet PC technology are evident in the literature but such implications appear to be devoid of evidence of what could be achieved that could not be achieved without the Tablet PC technology, particularly in terms of student learning expressed through a learning framework.

2.2. What is a Tablet PC?

The computer technology used at the site of the case study is a Tablet Personal Computer (Tablet PC). The characteristics and capabilities of the Tablet PC, similar in many ways to laptop PCs, are described by Berque et al. (2008) and Mantgem (2008) as a notebook computer with a display screen on which users can "write" or "digitally ink", enabling hand-drawn items or handwriting to be saved like any other computer document.

Tablet PCs are differentiated from Notebooks/Laptops in a number of ways. Firstly they have a reconfigurable screen that allows the user to employ them as a flat notebook that can be written on with a special stylus. The Tablet PCs involved in this study are touch sensitive, the "inking" feature includes advanced handwriting recognition, and the stylus can be used to operate the computer. By repositioning the screen, the Tablet PC can be used as a regular laptop with a keyboard (Figures 2 and 3).

Figure 2: Tablet PC in "Tablet" mode

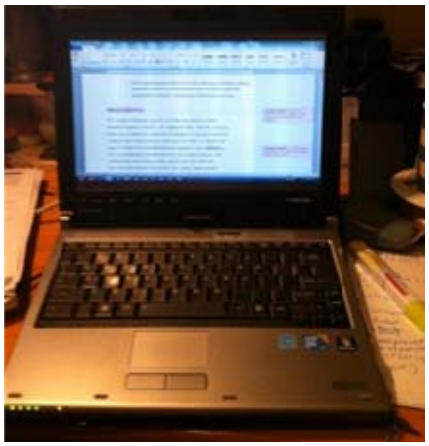

Figure 3: Tablet PC in "Laptop" mode

2.3. Affordances of Tablet PC

The literature around Tablet PCs suggests that this technology has particular attributes which enable students to work in a context different to that offered by notebook computers. Tablet PCs are thought (Mantgem, 2008) to combine the best features of laptop computers with the ease of use associated with writing.

Perhaps the key distinguishing feature of the Tablet PC lies in its high resolution inking capacity (which distinguishes it from the iPad), and how this capacity allows for greater flexibility, spontaneity and "teaching moment" opportunities which can be easily captured. IPad technology in its early iterations was viewed as having limited content creation, such as note taking (Marmarelli, 2010) and that it did not allow for any subtlety or precision in writing (Lowry, 2011).

According to Lowry (2011) the assumption behind digital ink in the early Tablet PC was that writing by hand was a more desirable method for general content input; a means of thinking in ink; and an ability to write in one's own handwriting. Various studies, mainly focused on the Tertiary sector, refer to affordances of the Tablet PC with regard to flexibility of instruction when working with content delivered in a format such as Power-point software. According to Mantgem (2008), students and teachers alike can write, draw and sketch with freedom and in doing so the affordance given is the ability for students to "tap directly into their creative brainstorming thought-processes" (p. 11). Sweeney (2008) states that the inking capacity of the Tablet PCs is intrinsically personal. His further assertion that the act of writing with an instrument such as a stylus or pen remains the preferred method of written communication for most because it is so natural and intuitive, can be considered in the context of this study. This is because students' interaction with computers prior to the introduction of Tablet PCs would be on the basis of communicating through the keyboard and mouse. The tendency to utilise the pen rather than revert to older habits of using

keyboard and mouse, and the extent to which such a choice extends students' working options will be examined.

Moore (2008) notes the affordance for the teachers with the digital ink input modality of a Tablet PC allowing the instructor to freely annotate prepared material. He asserts that the primary advantage of a Tablet PC over a laptop is the digital ink input modality. However, it is noted that the use of the digital ink by the students in the class was largely dependent on the teaching style. Other researchers (Gorgievski, 2005; Prasad, 2012; Pryor, 2008; Tofan, 2007) concur, referring to the ability to create on-the-fly examples problems and easily incorporate complex equations and simple diagrams. For the students, the digital ink input allows them to take private notes, make personal annotations on the lecture, send written examples of questions to the instructor, and solve in-class assessment activities directly on their Tablet PC screen.

The delivery of content directly to the student's Tablet PC can be replicated on a laptop computer, but with the Tablet PC the student is able to annotate, organise notes, and electronically save annotations (Tofan, 2007). Gorgievski (2005), in his study on student perception of the Tablet PC as an instructional tool for teaching Calculus, noted that students wasted less time copying and spent more time on reflecting or organising as a result of using the Tablet PC. As such better notes were being taken by students (Payton, 2008). The ability to mix ink, images and text means that products such as formulas in Mathematics or the drawing of diagrams or annotation of images imported into text in Biology, for example, can be quickly undertaken.

2.4. Research on Tablet PCs: Focus on teaching not learning

The affordances of the Tablet PC which derive from the inking capacity highlighted in the literature are many but overwhelmingly descriptive. Three key issues are at the heart of this: practicalities of teaching, affect and software applications. In this section, illustrations are provided from the literature to emphasise that the focus of research has not been on issues of understanding student learning with technology.

An example of this occurs in the literature generated by the "Workshop on the Impact of Pen-based Technology on Education" (WIPTE) conferences, which started in 2006 and is informative on the impact of Tablet PCs and pen-based technology in education. WIPTE is designed as a forum at which pen-based computing experiences, across a variety of educational disciplines, grade levels and settings are shared. Selected papers presented at the annual WIPTE conference are described as having solid evaluation data which discuss issues of broad applicability to tablet pedagogy in general (Berque et al. 2006). However, this literature reveals a tendency to focus on the descriptive

contribution that Tablet PCs make to specific aspects and contexts of learning. The issue here is that this literature focuses on descriptions of how and when and in what context the Tablet PC might be used in teaching and learning (with an emphasis on teaching). It serves as not only as a practical guide, providing advice or even lesson plans, but also as a series of discussions around techniques for supporting teaching and learning with pen-based technology. The use of the Tablet PC in education is most often described in affective contexts with an emphasis on the practicality of "how" this occurs at the expense of an analysis of the "why" the suggested outcomes occur.

An example of a focus on specific aspects of learning can be found with reference to note-taking. Malini's 2009 study, which centres on note-taking in lectures, and Payton (2008) point out that whilst written note-taking undertaken using a Tablet PC parallels note taking in a paper notebook, the Tablet PC has the added dimensions of ready access to colour inks and highlighters. Additionally, handwritten notes can be reorganised readily either through a drag and drop action or through the insertion of space into existing notes. Handwritten notes may be either integrated with images or text from Web pages or written directly onto electronic handouts. Such notes can be searched electronically. Finally, handwritten notes can be shared with teachers whilst still remaining available to the original author. This aspect of the Tablet PC, in some applications, is dependent upon software which facilitates inking, for example Mind Manager, when creating mind maps. However, the question of why using this technology to enable the note-taking aspect of learning better achieves learning goals is not explored. What is it that the teacher is modelling to students and students need to internalise that will assist their learning? If teachers and students better understand the objective here, their use of the Tablet PC may be more consciously, more purposefully and as such more successfully employed.

Other literature emphasised the context of learning. Scheckelhoff (2007) focused on gender issues and whether the Tablet PC serves to help address the concern that girls and women are not fully represented in design, development and implementation of information technology. The investigation focused on whether Tablet PCs are better for learning by girls rather than learning per se.

A third area of literature investigated whether the affordance offered by Tablet PC technology is enhanced by specific software applications that utilise the Tablet PCs inking capacity. Here the literature tends to add another layer to the "how" and "when" analysis by describing how the software facilitates the inking dimension and when it can be used. However, again the analysis does not drill down to the "why" the combination enhances learning (the consequence is implied). Tofan's (2007) rationale for choosing OneNote 2007 as a digital presentation software tool, in conjunction with a Tablet PC was described as an extremely powerful tool for teaching chemistry.

He relates how an instructor, accustomed to lecturing in a chemistry course using PowerPoint, can use OneNote in much the same way with a few added benefits, including the ability to annotate anything right away, without needing to be in slideshow mode; the ability to organize notes in various ways and to import from other Microsoft programs; the availability of a much better set of annotation tools; and the automatic saving of annotations and other changes. Of the OneNote software, Tofan notes that an important feature is the ability to combine it with the digital pen, like a Whiteboard, to write chemical symbols, formulas, and equations and solve problems in front of the class in real time, as opposed to going over a pre-typed solution in a PowerPoint presentation. The positioning of the instructor is also considered important as in this context the instructor faces the class and not the blackboard when teaching, and when using a Tablet PC, the teacher looks at the same drawing surface on which the student writes. Tofan reports that this type of interaction allows for maximum eye contact (line of sight) between the teacher and the class and saves significant lecture time. He refers to the teacher being given the familiar feeling of "writing", because he or she is using a medium that never needs to be erased. More importantly, all notes are saved electronically (and automatically) by OneNote which allows easy distribution by online posting or printing if needed. The affordances of the Tablet PC that students identified in Tofan's study focussed more on the availability of spontaneously written notes that were created during the process of the lecture and normally created on a Whiteboard which students were able to think through without needing to copy down at the same time. This meant they did not need to worry about missing something during the lecture or problem-solving sessions.

Similarly, Moore et al. (2008) note that the affordance of the Tablet PC is enhanced by software which is complementary to the Tablet PC and which thus extends its impact on learning. In the context of the traditional slide presentation, the Tablet PC with the use of DyKnow, allows for a 'hybrid' approach to lecturing. Here, it is noted, an instructor can prepare as many or as few slides as desired for the lecture in DyKnow and during the lecture slides can be annotated, (Payton in Mantgem, 2008). Again with appropriate software such as DyKnow, Classroom Presenter and Ubiquitous Presenter, the depth of collaboration can be extended by the Tablet PC. Apart from the sharing of content where the teacher's prepared content is shared with students, any real time hand written annotations by the teacher (teacher elaborations) appears on the student's real time copy, and the student can themselves add further, personal handwritten annotations (student elaboration). Further sharing (student with student or student with teacher) is also possible (Payton, 2008; Hammond & Mock in Mantgem, 2008). Again with appropriate software such as DyKnow, Classroom Presenter and Ubiquitous Presenter the depth of collaboration can be extended by the Tablet PC. The capacity to record and play-back a learning presentation is provided with another dimension where real time handwritten notes are included in the captured learning experience.

Hammond's work (2007) around sketch recognition software is based on the view that sketch recognition systems can have a profound effect on pedagogy and classroom learning by solving many of the problems stated above. In particular, sketch recognition systems can be used to allow natural interaction by providing drawing freedom; provide enhanced editing capabilities; explain drawn graphical content in an interactive way. A lot of these affordances are about more flexible and dynamic presentations. There is little in the literature that identifies the affordances to the student in terms of learning opportunities.

2.5 New technology, old habits

Several studies of the impact of Tablet PC technology reveal that the intention is to explore whether in the particular context concerned the current practices of the teacher can be enhanced or completed more efficiently with a Tablet PC. This comes into the realm of a teacher doing what they have always done but now doing it with Tablet PC technology**.** Moore's 2008 study falls into this vein in reporting on the usefulness of Tablet PCs as an effective technology for implementing established educational practices. Moore distinguishes surface learning from deep learning. However in his study Moore does not identify the theory underlying this process nor seek to investigate how the Tablet PC contributes to this underlying process other than asserting that there is greater "engagement", "interaction", "flexibility" and "integration" between teacher and student. The indication that, guided by the instructional design process in the classroom, teachers may then pose questions, present problems or exercises to the class, design inquiry activities for teams to pursue, or use many other pedagogical techniques with the goal of promoting student engagement and interaction through technology again fails to elaborate on the "why" this technology might achieve these things.

Teachers may well connect with pedagogical intentions that they have always employed and have a limited understanding of the use of the Tablet PC beyond that context. Prescod and Dong (2008) in their study on learning style trends and laptop use patterns, note that despite the enthusiastic acceptance of advanced technologies by educational institutions the extent to which the schools exploit these technologies for learning is rather uncertain. Rutherford (2004) comments that there are questions which still remain about the degree to which schools have yet to exploit the potential of computers for transforming teaching and learning. He expresses the view that to date computers have basically helped teachers and students enhance what they were doing before, resulting in a modest impact of computers on K-12 teaching and learning. A more substantial impact, he suggests, may be possible if teachers looked beyond impacts achievable without computer technology, albeit in a less efficient way.

The extent to which "new purposes" or "new pedagogies" can emerge is an important area that requires further research. Other studies have emphasised the shift in learning *from* technology to learning *with* technology (Barrios, 2004); using technology as a tool to support learning (Ingvarson & Gaffney, 2009); or the need match 21st century teaching with 21st century learning and learners (Finger, 2009; Hough, 2009).

2.6 Tablet PCs in the tertiary sector

An analysis of the literature from a context perspective also reveals a concentration around the tertiary sector (Berque et al. 2006; 2010; Malini, 2009; Moore, 2008; Moran, 2006; Galligan et al. 2010; Ant Ozok, 2012). For example, of the eighty-five paper presentations published to the annual WIPTE conference in the USA between 2006 and 2010, only fifteen related to the K-12 education sector. Scheckelhoff (2007) noted that "Tablet PC usage has been examined in limited ways that include higher education lecture courses and technology and engineering classes. Additional research is needed to determine the impact of the Tablet PC in the learning environment… including secondary schools" (p. 35). Bienkowski et al. (2005) notes that there are few articles written about the use of Tablet PCs and one-to-one computing that are focussed on the Middle and/or Senior Years of schooling. Of the many articles that have been written about the use of Tablet PCs and one-to-one computing, relatively few of these articles were data-based, and only a small number of them went beyond anecdotal reports. Bienkowski's Singapore Tablet PC Study is one of the exceptions to this generalisation on the literature associated with Tablet PCs in the Middle and Senior schooling sectors. Another is the case study conducted by Li et al. (2009) focused on a Hong Kong primary school. In both examples the studies are not referenced to a teaching and learning framework.

2.7. Learning with technology

In the general literature on Information Communication Technologies (ICT), some studies report that ICT, in combination with effective, constructivist teaching practice, produce a range of generic thinking and technology skills in students as well as producing relatively superior performance on standard state wide performance measures (Toomey et al. 2000). The rapid change in technology that is available to the teacher in the classroom offers the teacher an opportunity to develop new educational practices and pedagogies. This impetus is driven also by the advent of 1:1 computing with access to the Internet along with hand-held devices, iPads and other technological developments which have altered the concept of knowledge acquisition. The teacher is no longer

the sole repository of content and content can be 'outsourced' to allow for classrooms being reconstructed and redefined with very different modalities for teaching and learning. This revolution in communications has created broad impacts on the 21st century classroom (Moore, 2008; Toomey et al. 2000) and a focus on generic skills (Table 2). What Toomey and others do not say, however, is anything about the learning framework against which these skills and outcomes are achieved, or describe the strategy or dynamic that is observed to bring these results about. Instead we are being asked to accept that this is simply what happens.

Table 2: Generic skills (Toomey et al. 2000)

Investigating	Being creative
Searching for information	Visualising ideas
Selecting relevant information	Working cooperatively with others
Researching	Keyboarding
Organising information	Learning autonomously
Solving problems	Learning independently
Using information to support a point of view	Awareness of global issues
Sharing skills and ideas	Communicating in ways appropriate to an audience
Presenting information	Making connections between school and the real world
Deciding	

The Tablet PC shares many features of the more traditional notebook/laptop PC and as such a literature review of the impact of computer technology on student learning per se can also be attributable to situations where Tablet PCs are used. The critical difference between the Tablet PC and the notebook/laptop technology are opportunities to develop approaches which are individualised and contextualised to the particular engagement in question. This idea is represented in Figure 4, a representation of educational technology. The inner circle represents non computer technology in use in the classroom prior to the advent of the desktop computer. The educational affordances extend with the arrival of computer technology in the form of desktops and later notebook/laptop computers, represented by second, broader circle. The third, outer circle suggests extended additional educational opportunities with the use of Tablet PCs.

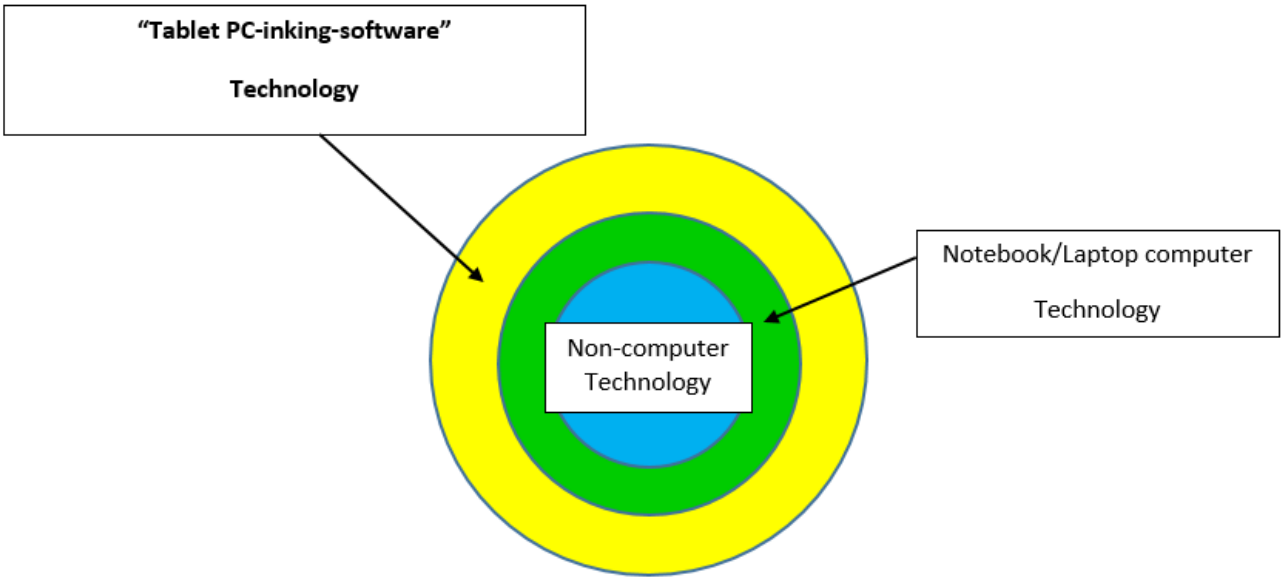

Figure 4: Learning opportunities from non-computer technology and computer technology 1

New resources or technology are generally developed with a view to facilitate or offer opportunities which did not exist previously. In the case of teaching and learning, the new resources or technology would generally be adopted with an understanding that they provide opportunities to realise already existing needs or objectives either more efficiently, effectively or thoroughly. The key to capitalising on opportunities that have not previously existed is the realisation of their implications of a change to the pedagogy employed. Logically, new opportunities mean both teachers and students doing something different to what they have always done. To do otherwise, to continue doing what has always been done, will be utilising new resources or technology for existing practices. The common factor here is the targeted outcome, the teaching and learning objective, which is improved understanding or learning by students. If the new resource or technology offers an opportunity to reach that goal to a degree greater than that prior to the point in time when the technology or resource was first introduced, then the technology may be seen to assist learning.

Some of the literature does acknowledge that the role of educational theory is important in the thoughtful pedagogical uses of technology**.** Mishra and Koehler (2006) developed a "framework for teacher knowledge" called Technological Pedagogical Content Knowledge (TPCK) that describes potential links between a teacher's mastery of subject content, pedagogy and technology. The emphasis here is on how the technology is used rather than making explicit why this might impact on learning opportunities. This work also identifies the point made here that the literature reflects a

view of technology as being separate to pedagogical content knowledge – hence the number of studies that focus on the technology of the Tablet PC, rather than its applicability to learning.

Throughout the literature, assumptions about learning are apparent without consciously acknowledging that such an aspect is an element of any teaching and learning theory. As an example, Moran (2006) and El-Gayar et al. (2011) looked at students' acceptance of the Tablet PC in teaching and learning, acknowledging implicitly the role of attitudes and perceptions for developing student learning. In the El-Gayar et al. study (2011), students' acceptance of Tablet PC was implied as a means to forecast, explain, and improve their usage pattern in education, via associated factors such as perceptions of their utility and user friendliness. This study employed a quantitative model to assess the influence of various factors on Tablet PC acceptance. El-Gayar noted that a case study approach would complement the analysis presented in his research and provide useful and insightful information to any Tablet PC implementation initiative.

Other literature suggests that the Tablet PC, as an instructional tool for large groups, is effective and efficient and enhances learning and understanding by actively involving students in the learning process (Gorgievski, 2005). In these instances the benefit is identified through students being able to move beyond note-taking, which is seen as a passive involvement in learning, to becoming actively engaged in the learning process by employing the digital ink in conjunction with traditional information presentation modes, such as Power-Point, to modify or personalise the presentation. The same point is made by Pryor (2008) who refers to student ability to freehand annotate, clarify, and highlight directly over computer documents as they are shown in class and more specifically to be interactive with the content. In a learning context this represents an active construction of meaning which enables the learner to internalise understanding.

While Moore (2008) acknowledged that there is not a direct correlation between technology use and increased learning outcomes, or better teaching or more engaged learners, he was interested in investigating who benefited from the use of Tablet PCs across the diversity of students' performance levels. In Moore's study on Distance Learning students in the Tertiary sector, students who had high cumulative GPAs (> 3.0) tended to also perform well in the Tablet PC class. Students in the 2.5-2.99 range seemed to show some slight improvement, while students with cumulative GPAs below 2.0 generally did not fare any better than their cumulative GPA suggested. Other research identifies outcomes that suggest a different direction. Ferrier (2010) in his study on the impact of Tablet PCs in a 1:1 setting with Spanish primary school students reported that students with the worst academic records are those whose results improved more in comparison with the rest of their classmates and this was likely due to the use of the Tablet PCs as a tool to give greater attention to this type of student with school difficulties. Students coming from families with more

disadvantaged socioeconomic and cultural environments considered themselves to have benefitted more in terms of academic results from the use of Tablet PCs in primary education. This may have interesting implications for education in Australia which has been identified as failing to bridge the gap between low performing students and high performing students in recent years (Gonski, 2011). A key to these consequences seems to lie with how the technology is deployed.

2.8. Conclusion

This study enquires into whether the use of Tablet PC technology creates opportunities to contribute towards student learning outcomes in the context of a learner's construction of meaning. Specifically this takes place through the lens of the teaching and learning framework Dimensions of Learning, in a high school (Year 10) mathematics classroom.

The question being posed here concerns a situation where potentially the teacher knows with greater insight, how students are constructing their knowledge and their errors, which lead students to an erroneous or incomplete construction of meaning. When these errors are discovered or identified with the Tablet PC technology, in a timely manner, the feedback from teachers, targeted at "remediation" of such constructs, can occur. The consideration here then is whether the ability to track student thinking processes as expressed in the context of capturing their own written record of their formation of their construction of meaning, better informs teachers of the errors of thinking that students are making. If so, does this offer teachers more insightful evidence upon which to correct errors in student construction of meaning? Does the Tablet PC provide teachers with evidence of student learning, in a format which was not available previously to them? If so, does such evidence enable teachers to feedback to students more effectively, efficiently and expediently than was possible before? Might such interventions by teachers with students have previously been limited by the lack of evidence of this nature and the means to communicate expediently?

Whilst much of the literature provides insights into what the Tablet PC can allow students and teachers to do that they either could not do before, or that they could do before but can now do more effectively and efficiently, it is not so informative on linking that facilitation to the learning dynamic that supports learning. This point is echoed by Peiper (2008) who noted that the current literature contains virtually no empirical research on the impact of Tablet PCs on learning. His study suggested that "as tablet use increases there will be a need to understand how Tablet PCs can be used most effectively in the learning process" (p. 7). Moore (2008) notes that more data over time will need to be collected to truly analyse the impact the Tablet PCs and interactive software are having on student learning.

What is missing in the majority of the literature is a consideration of the role that the Tablet PC plays in relation to any learning frameworks that form the context of the learning experience – that is the relationship between Tablet PC technology and learning. The contention for this study is that when considering the impact of Tablet PCs on the learning outcomes of students, however measured, unless this study is inclusive of the prevailing learning framework, based on learning theories that the teacher and student operate under, there is a danger that the technology in itself may be perceived as the magic bullet. The technology is only effective where the relationship to the learning framework is one of a capability to assist in the transition of theory into practice or theory realisation through a conscious application of the technology by teachers and students relative to a learning framework. Niyikora (2010) noted the need, when evaluating teaching and learning technologies, for the use of a theoretical framework in this process and that this was missing in the current literature about Tablet PCs in the secondary sector. If an approach to considering the question of such a relationship can be identified, then educators will have a tool with which to make judgements about the use of new technologies, as well as a better understanding of how to use such technology to realise learning goals based on a learning framework. Future developments in any technology proposed for education could be evaluated for their impact. Furthermore, most of the studies reviewed focused on generalisations of student motivation; engagement; student learning; student/teacher attitudes toward technology and classroom practices. These studies (Malani, 2009; Moran, 2006; Niyikora, 2010; Peiper, 2008; Scheckelhoff, 2007; Silvernail & Gritter, 2011) fall short in relating the observed outcomes in terms of a theoretical framework. Unless there is a theoretical grounding of the phenomena observed there is little credibility in the opportunity to abstract from conclusions drawn.

A literature review on computer technology use in education has a strong tertiary emphasis; focusses mainly on the use of one-to-one notebook/laptop computing and is generally descriptive of how the technology better facilitates teacher and student tasks. The literature on Tablet PCs technology tends also to focus on facilitating teacher and student procedures associated with learning. What is sparsely addressed is the question of whether Tablet PC technology serves as a resource for teachers in their teaching objectives and students in their learning objectives. These objectives concern the active construction of meaning - the dynamic that occurs when teachers and students apply thinking strategies, and how and whether the specific features of the Tablet PC assists in this outcome.

The case study considers whether the digital inking nature of the Tablet PC extends the pedagogy of the notebook/laptop technology. Associated with this is the consideration around how the software

used also “extends and refines” pedagogy. Both considerations are articulated through the lens of the type of learning characterised by constructivist theory and practice.

Chapter 3. Methodology

3.1. Introduction

This Chapter is concerned with the methodology used to achieve the research aims and provide insights into the research questions. Both of these aims and questions are reiterated at this point. The context and participants of the research are outlined along with considerations around ethical concerns around the research itself. The methodology of data gathering is identified as well as the approach used in the analysis of the data.

3.2. The research questions

The purpose of this research and the research questions have been outlined in section 1.2. To reiterate, the aim was to examine the opportunities for learning that the combination of software technology with the Tablet PC offers to both teachers and students. The guiding question was whether, as a result of the use of the Tablet PC, there were consequent new opportunities identified which contributed to student learning, as perceived by both student and teacher.

The research questions took the following form:

1. Does the extension of the digitisation of student work from the products of laptop/notebook and pen and paper technologies to the added products of Tablet PC technology, give rise to new learning opportunities?
2. Is the use of laptop/notebook computer technology in education somewhat limiting thinking in students and the feedback to students as a consequence of what cannot be achieved compared with Tablet PC technology?
3. Does the power to combine both these products of notebook/laptop technology and pen and paper technology in one mode with exposure to the technologies of digitisation and recording, offer more insightful opportunities for teachers to influence learning?

3.3 The context and participants

The context in which the research was undertaken was a Year 10 Mathematics class at a boys' independent school in the western suburbs of Brisbane. The class studied mathematics for five periods each week, each period consisting of forty-five minutes. Three lessons were taught as 'single lessons' while the other two were taught consecutively as a "double lesson' and so were delivered as a ninety-minute lesson. At this school the Tablet PC was used by all students from

Years 7 to Year 12 at the time of this research. The class in question was using the Tablet PC for the first time, while the school was in its third year of the Tablet PC 1:1 programme.

3.4 Ethics Application and Approval

As a senior member of staff in an administrative position it was necessary to assure students that my presence in the classroom was related solely to the case study undertaken and not in any way associated with "checking" on them.

The confidentiality and identity of individual participants, the staff, students and school, in the study was maintained at all times when discussing the outcomes of the case study. For example the school is not named; the information relating to school, staff and students and the data collected from the study was not released to any unauthorised person. Such information was not used for purposes other than for the purpose of the case study.

Consent for participation in the study was sought from the school headmaster, teacher, parents and students. There were no instances where students, or their parents, decided not to participate in the study. Participation in this study was entirely voluntary, with participants free to withdraw at any time without prejudice.

3.5 The research method

3.5.1 The use of case study methodology

The case study is an appropriate research methodology to employ in exploring the questions above for a number of reasons. Firstly, according to Yin (2014), where research questions focus on "how" and "why" questions a case study is appropriate. Other case studies concur with this view (Ioannakis I 1997; Bienkowski, et al. 2005a, 2005b; Koerner M.E., & Abdul-Tawwab 2009). In research where the researcher has little or no control over behavioural events and where the focus is contemporary, case study research is the preferred research method. The research questions here seek outcomes which either affirm or deny the propositions. In arriving at the responses to the propositions there will be a need to identify both "how" and "why" the propositions can be affirmed or denied.

Secondly this case study mirrors the characteristics of case study research as outlined by Gay (2009). That is that it is particularistic in that it is focussed on a particular situation. In this study it was the use of the Tablet PC technology in the secondary classroom. It is descriptive in that the

result of the case study will be a narrative of the situation with an analysis of its variables. It is also heuristic in that it seeks to throw light on the use of the Tablet PC in the classroom.

Case studies are also grounded and related to the reader's knowledge. As such the reader, if an educator, can readily construct meaning from the study. According to Gay et al. (2009) case study research can result in the extension and refinement of knowledge in a way which is different to the objectives of other types of research (p. 426). It is a research process focussed on a specific context which is familiar to the audience for which it is intended. The benefit to the audience of educators here is that construction of meaning is possible through relating the research outcomes to shared context experiences. So while the case study has the benefit of being of both specific and practical relevance in terms of what is learnt from it, at the same time its specificity makes its outcomes relevant outside the context of the study to the extent to which similar circumstances may or do apply. Thus the reader of such research can determine when considering the adoption of an innovation which is the subject of the research, whether the outcomes identified by the research are likely to apply in their context. In the context of this case study the innovation concerns the use of Tablet PC technology as a resource in assisting students in their construction of meaning, and assisting teachers to evaluate the success of their teaching and respond expediently where feedback assisted by the Tablet PC technology suggests otherwise.

The scope of a case study as outlined by Yin (2014) is that it is an empirical inquiry and that is what this research involves. He goes on to describe the scope of a case study in terms of being an investigation into a contemporary phenomenon which in this study was the Tablet PC within a real world context, in this case a secondary school classroom. The scope concludes with reference to the boundaries between the phenomenon and the context not being clearly evident. In this research the use of Tablet PC does involve contextual conditions such as the awareness of both teacher and student of the learning opportunities possible from particular usage of the Tablet PC. With regard to the features of a case study, Yin refers to the methodological characteristics involved, such as coping with a technically distinctive situation, where there are many variables of interest. In this case study the distinctiveness of the Tablet PC is associated with variables such as teacher, student, software and learning goals. Further features concern multiple sources of evidence. In this case study observation data, questionnaire data and interview data of the teacher and students were involved with a view to triangulating that data. Finally the case study benefits from the development of theoretical propositions to guide data collection. This study will be guided by the constructivist ideas on learning as expressed in the Dimensions of Learning teaching and learning framework.

3.5.2 Designing the case study

In designing the case study, once again the guidelines provided by Yin (2014) serve as a model. Yin identifies five components of the case study design and the first, a case study's questions, have been described in 3.3.1. With regards to the substance of the questions this study is guided by the literature review.

Earlier, in 3.3.1, reference was made in relation to the nature of the research questions to propositions being explored. The propositions here concern the possible opportunities that the use of the Tablet PC offers to student learning. This proposition provides guidelines on where to look for relevant evidence and along with the specific questions generated, assists in keeping the study within feasible limits.

Often answers to questions concerning how or why something happened, or questions concerning what happened can be difficult to determine due to the complexity of variable time frames or contexts. The case study research approach serves to mitigate this complexity with its focus on a "unit" which may be variously defined by the researcher as both a place and time. The unit of analysis or the "case" in this study is the class of Year 10 Mathematics students. The unit was defined as the class for that subject taught by a particular teacher. Students who did not fit that classification were not a part of the study.

The case study is "a choice of what is to be studied" or "an investigation of a phenomenon that occurs within a specific context" (Gay et al., 2009, p. 426). The advantages of delineating the boundaries of the study are that where there are complex variables evident, the establishment of a such a boundary reduces the complexity of answering the "how" and "why" questions and as such provides clarity to the outcomes. The complexity of this research focus into the educational potential of the Tablet PC with complementary software on student learning outcomes necessitates a case study of a single school site, and indeed class, which allows for an in-depth investigation of a single case. In doing so it was not only possible to suggest or illuminate factors but also the relationships between the factors that influence the situation. The case study, then, is in general the preferred strategy not only when "how" and "why" questions are being posed, but also when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context (Yin, 2014).

The consideration of linking data to the propositions foreshadows the data analysis of the case study. The strategy adopted in this study relies on the theoretical proposition to identify analytical priorities. In this case the theoretical proposition that the targeted use of the Tablet PC in the

classroom offers enhancements to learning, points to the relevant contextual conditions to be described and explanations of new outcomes and their relevance to learning to be examined.

The criteria for interpreting the findings of this case study were based on the technique of pattern matching. Here the findings from the case study were matched with suggested findings made prior to the collection of data. So in 2.6 a model is proposed as a representation of what is anticipated will be shown in the results analysis. This case study is exploratory in nature of that same representation.

From a case study design perspective this research met the construct validity with the use of multiple sources of evidence; establishing a chain of evidence; and key informants as reviewers of drafts of the case study report. With regards to external validity the use of a theoretical proposition seeks to address that consideration. Reliability is addressed through the adherence to case study protocol and the development of the case study database.

The collection of case study evidence from class observations, student and teacher interviews and student and teacher questionnaires provided multiple sources of evidence. This provided the opportunity to identify converging lines of inquiry. By developing convergent evidence the possibility of data triangulation helps to strengthen the construct validity of this research. A database was established consisting of captured student work, written responses to questionnaires and the recording of interviews with students and the teacher and a chain of evidence established.

The methodology of the case study sheds light on the detail of larger contextual complexities (Stake, 1978).The resulting intense focus on a single context, as in this study, allows for the explanation of the various interactions attributed to outcomes observed. The case study approach is the most appropriate methodology for such micro-research as it allows for an in-depth investigation of a single class in a single school, putting into focus the relationships among a number of factors that influenced the impact of the innovation. Examples of such outcomes can be found in the work of Ngoepe M.G. (2003), Ioannakis I. (1997), Holt and Challis (2007)

3.6 Data gathering

The case study methodology offers the approach of direct observation of the events being studied and interviews of the persons involved in the events. In order to better understand how students and their teacher of the Year 10 Mathematics class in question use the Tablet PC, three methods of generating data were developed. Two of these methods, interviews and questionnaires, were used with both the teacher and students and the third method was the observation of the teacher and class during timetabled lessons. The same online survey was sent to all students (sixteen) enrolled in the one Year 10 mathematics' class.

As part of obtaining ethical clearance from the University of Queensland for the data gathering, permissions were obtained from the Headmaster, teacher, students and parents concerned. The boys were advised that their participation was completely voluntary and that if they did not wish to participate that such a decision would have no impact on them. Indeed, if they chose to withdraw their permission to be included in the study, they were advised to express that independently, with their decision acknowledged in confidence. No withdrawals occurred. The boys were further advised that the study referred to them as individuals only where appropriate and in such cases in such a way that they would not be identifiable by other students or teachers.

3.6.1 Student and teacher interviews

According to Yin (2014) the interview is one of the most important sources of case study evidence. The questions asked were shaped by the fluidity of the interviews and as such attention needed to be kept on staying on track and looking to avoid bias in the questions. The interviews were short in duration (45 minutes was set aside for each interview). The major purpose of the interviews was to corroborate responses to the survey questions and observations made in class.

Students were interviewed in groups of two or three depending upon their ability to meet scheduled times set aside for interviews. Some students were interviewed individually, again as a consequence of their ability to meet scheduled interview times. The interviews took the form of responses to nine questions (see Appendix 3) and took place at the end of the observation period, just prior to the students' end of semester exams. The students were encouraged to answer honestly and from their perspective. The questions sought to elicit:

- The students' perception of the value of the use of the digital pen in practical terms. Here the focus of questions centered on what benefits the students perceived to be available to them in their ability, through the use of the Tablet PC, to digitally create writing, drawing and symbols gave in comparison to doing the same thing on paper. (Question 1)
- The students' use of the digital pen as a note-taking tool and their personal engagement in inking practices such as highlighting, annotating, drawing and writing in all formats. (Questions 2, 3, 4, 6.)
- The students' view of the value of digital inking to them in their work. (Questions 7, 8.)
- The question of whether or not the control students had on the flexible permanency of digital inking in their use of the Tablet PC (compared to the permanency of created text,

drawings or symbols in the use of paper as a medium for their work) was a factor in their commitment of thoughts and responses. (Question 5.)

- The students' thoughts on the option of having the ability to write and record digitally being any better than writing on paper. (Question 9.)

Responses to all questions from all groups were audio recorded and transcripts created from the recordings. The response rate from the questionnaires was 100%. The attendance of the students for interviews was also 100%.

The teacher interview was based on responses to twelve questions (see Appendix 4) which gave rise to supplementary questions. Questions here were designed to determine whether the teacher:

1. Felt that use of digital inking enabled the students to undertake work which they would not have been able to do if they were working on computer notebooks.
2. Identified any learning outcomes that were better facilitated through employing digital inking than otherwise would be the case.
3. Consciously planned lessons around the use of the digital pen.
4. Believes the use of the digital pen assists in any way to better facilitate student learning and better awareness of student learning. As such the attitude towards, and understanding of, the use of the digital pen is explored.
5. Encouraged and/or expected students to utilise the digital pen in their work during the lesson.
6. Consciously applied the use of the digital pen in the context of the teaching and learning framework in place at the school - the Dimensions of Learning.

These responses were recorded and transcripts created from these recordings.

3.6.2 Student and teacher surveys

Evidence gathered through the survey created (see Appendix 1) provided data which could then be analysed in relation to the interview and class observation data. The survey data provided an opportunity to capture both teacher and student perceptions of the use of the Tablet PC. This was useful in assisting in the interpretation of the other data gathered. Both the students and their teacher were surveyed through the use of "Survey Monkey" which allowed for flexibility in the completion of this aspect of the data gathering. On-line and individually the students completed a twenty-one question survey (see Appendix 1) towards the end of the period of observation. The questions sought to determine:

- The frequency of the use of the digital pen and whether the use of the digital pen was modelled to them and such that they were subsequently directed to this activity.
- Student use of the digital pen as a note-taking tool and their personal engagement in inking practices such as highlighting, annotating, drawing, writing both text and symbols.
- Whether students used software which facilitated digital inking and/or software which did not support digital inking.
- Students' view of the value of digital inking to them in their work.

The teacher survey was based on responses to thirty-two questions (see Appendix 2). Questions here were designed to determine:

- The degree to which students were encouraged and/or expected to utilise the digital pen in their work during the lesson.
- The teacher's attitude towards and understanding of the use of the digital pen.
- The teacher's conscious application of the digital pen in the context of the teaching and learning framework in place - the Dimensions of Learning - was discussed.

The surveys of both students and teachers were designed to cover aspects of the Tablet PC experiences observed in the Mathematics lessons.

3.6.3 Class observations and field notes

As the case study is contemporaneous and occurs in a real world setting an opportunity existed for direct observations. This methodology of evidence gathering provided insights into the use of the Tablet PC technology at work in the classroom and served as an invaluable aid for understanding the actual use of the Tablet PC. In this context the role of "participant-observation" was taken as a result of the researcher being a staff member of the school which was the focus of the case study. Whilst this role provided opportunities, for example flexibility in the scheduling of observations; it also presented challenges, for example there was less ability to work as an external observer as a supporter of the school and class being studied.

Observations of students in their Mathematics lesson occurred on a weekly basis over a period of fourteen lesson observations. These observations took the form of attending these lessons and from a position in the classroom out of the vision of the students, watching what students were doing with a particular emphasis on their use of the Tablet PC. Student interactions with the teacher were observed with a particular note taken on how the teacher utilised the Tablet PC's capacity for the utilisation of the digital pen.

Observations were recorded by two methods. Firstly a record of what was observed was made, along with reflective notes using the digital inking capacity of the Tablet PC in OneNote. The second method provided an added insight into what both students and teacher were doing. This method involved joining the class Mathematics course "session" through the software programme "Dyknow." In this way Dyknow enabled a live observation of the work being generated by all students in the class on their Tablet PC. In addition to being able to observe the development of student work, the software allowed for the capture of student work as many times as desired during the period of observation. This meant that the collection of work samples was not at the expense of the student's work momentum, neither did it deprive the students of access to their work whilst it was being examined. Examples of work produced and collected were then subject to another feature afforded by the use of the DyKnow software - the ability to view a replay of the construction of student work, including edits and erasures. So not only was there an opportunity to observe individual student actions (digital pen strokes) on their Tablet PC during each lesson observed, it was also possible to review all student work collected in this way through the replay function of DyKnow. All actions involving the digital pen could be observed and reviewed.

Data recorded consisted of a combination of written observations of student and teacher activity and the artefacts of that activity as created in the DyKnow software. Of particular interest was evidence of how the Tablet PC was being used by students and teacher in relation to the teacher's intended learning goals.

3.7 Analysis

3.7.1 Analytic strategy

As a starting point for developing an analytical strategy for the case study data, during the course of data collection from class observations, a number of memos or reflections were recorded in OneNote, as part of the field notes, which reflected preliminary interpretations or conceptualisations of data. This initial approach sat alongside the use of the theoretical proposition that led to the case study - that the use of the Tablet PC assisted student learning, to guide analytical priorities. This proposition shaped the data collection plan in that the design of the surveys and questionnaire explored this possibility and the observations looked for evidence of this possibility.

As data collection gathered momentum a more inductive strategy emerged where concepts associated with the digitisation of "freeform" representations and "assessment for learning" began to emerge. These concepts served as the organising factors of the data and were analysed to gain a further understanding of how students and the teacher used the Tablet PC and the possible implications of this use.

The nature of the data collected and the methodology of its collection is informed by two considerations. First the implicit theoretical ideas behind constructivist learning as represented in the teaching and learning framework – Dimensions of Learning. Secondly the ideas which emerged from the study, which as indicated above, were centered on the implications of the digitisation of "freeform" representations and the theory of "assessment for learning".

Subsequent interpretative comments on the data stemmed from this organisational analysis. This was achieved through comparison of the data with other material, both primary or in the literature, for example Oviatt's (2014) ideas on the digital pen technology interface; student and teacher primary data; and the ideas of Black & Wiliam on assessment for learning (1998). From this interpretation and comparison of the data a tentative hypothesis was suggested - that the use of the Tablet PC in the secondary classroom offers opportunities to enhance learning outcomes.

3.7.2 **Analytical technique**

The analytical technique used was that of explanation building where the goal was to analyse the case study data by building an explanation about the case. This explanation building took a narrative form which reflected the theoretical proposition of constructivist learning. Thus the explanation building took on an iterative nature. The final explanation around the ideas of digitisation of "freeform" representations by students and teachers and "assessment for learning" were not fully stipulated at the beginning of the study. As the case study evidence was examined the explanatory propositions were revised and the data examined again from this new perspective as a further iteration. Avoidance of the pitfalls associated with this analytical technique was necessary in the course of such an analysis. Such pitfalls include, drifting away from the original topic of interest, or unwanted selective bias over data interpretation. The conscious planning against such pitfalls included the regular reference to the original purpose of the case study, supplemented by advice from the supervisors of this study.

3.8 Conclusion

Yin (2014) contends that the case study methodology of research is a means by which to describe an object or phenomenon, which in this study concerns the use of the Tablet PC within the context of learning. The activities within a secondary school Mathematics classroom provide the appropriate contextual nature of a setting which constitutes a real-life, contemporary, human situation which is well served by a case study approach.

The intent of the case study approach into the use of Tablet PC's in the secondary classroom was to establish whether new insights and knowledge were observable in the application of the Tablet PC in the classroom and, where observed, whether these insights and new knowledge were only evident under certain terms and conditions of the use of the Tablet PC. The case study approach allowed for a methodology of gathering data, through the utilisation of the Tablet PC itself and specific software applications designed to leverage its capacity to generate digital inking that the software can capture, which could give quite unique insights into the creation of learning products by students. It is suggested that not only will this research methodology help build upon current understandings of the use of Tablet PC computer technology, but that it will offer a different dimension to current insights on the use of this particular computer technology. In this way this research approach seeks to establish whether there is evidence from this case study which both enables educationalists to reflect on current understandings and to contribute towards an explanation of such a situation as is being researched here. It is also anticipated that the case study approach would provide a basis to apply solutions to situations being explored. In this instance a better understanding of the guidelines for teachers and students necessary to fully realise the attributes of the use of the Tablet PC and its essential aspect, that of digital inking, to student learning.

Chapter 4. Results and Analysis

4.1 Introduction

The general analytical strategy to be employed in this study is that based on the theoretical proposition concerning how and why use of the Tablet PC in the senior secondary classroom offers additional opportunities to students, as learners, and teachers, as educators, and how these additional opportunities might impact on student learning. The analytical technique employed here is one of explanation building. Here the goal is to analyse the case study data by building an explanation about the case. In this approach the presumptions of "how" and "why" will be made and linked to constructivist ideas of learning, with particular reference to construction of meaning. Explanation building will thus be somewhat iterative.

4.2 Results and analysis of student interviews

4.2.1 The students' perceived value of the use of the digital pen: practical aspects.

From the interviews with students there was a general consensus that the option of using the digital pen was of value. This "value" was expressed in terms of comparisons with the use of computer notebook technology and the use of paper as means to work through Mathematics modelling and problem solving.

Specifically in terms of learning Mathematics the students often pointed to benefits offered by the digital pen as compared to a Notebook computer or working on paper. Some could be generalised to any subject, such as everything (notes, questions, text, answers) being in the same place as a result of being able to locate imported text with written responses. The ability to better organise work was also referred to.

Some references were to benefits specific to the study of Mathematics such as being able to digitally write and record mathematical symbols;

In general the pen was seen to be an easier, faster, quicker, useful tool that students could use in their work.

4.2.2 Attributes of computer technology per se:

Some responses to questions around the perceived benefits of the use of the Tablet PC made reference to attributes that could also be attributed to a "notebook" computer without the capacity to create digital inking. Examples included:

(i) The ability to create a revision document easily was referred to by one student through the copy and paste function that computers have.

(ii) The never-ending supply of writing surface that software programmes like One Note have to offer, meaning that students did not need to supply additional paper themselves, which easier, or ask their teacher for supplies, which gave them independence from the teacher.

(iii) The ability to insert space where a student needed to continue notes proximal to current notes, classified under organisation of work**.**

(iv) The ability to search the internet and/or watch Mathematics tutorial videos.

(v) Work made easier was a reference to the new situation of not having to carry books around where the digital versions were available and loaded on to the Tablet PC. More pertinent to this study were responses that indicated that students were able to engage in the construction of learning in more efficient or effective ways through being "enabled" in some way with the ability to create and capture digital writing, drawings, diagrams and symbols.

4.2.3 Digital recording of notes, drawing, diagrams or symbols:

The nature of the "value" of the Tablet PC identified by students was often expressed through the use of the words easier and quicker, which was applied to a number of outcomes associated with the students' ability to digitally record their notes, drawings or symbols. Some of these outcomes were the same as those that could be achieved on a notebook computer, but with the Tablet PC they could be achieved easier or quicker. Outcomes such as highlighting were referred to as a function of the pen by all respondents and the flexibility of formatting any work in terms of position and size, referred to as re-sizing drawings. The difference here related not only to the greater flexibility of formatting handwritten notes compared to typed notes but also to choice of where on the page notes were written. The ability to annotate work wherever it was wanted by the student allowed him to position reflective thought, clarification or additional explanation proximal to work, thus ensuring a visual link. An extension of this point was apparent in one group interview where all students in that group agreed on the point of the pen being easier to insert and record reflections, observations, understandings, key points, highlighting – as they come to mind and are being clarified – that is in the moment that those thoughts occur.

Often cited was the ability to record mathematical symbols easily. As such the pen was perceived as being very helpful in contrast to a computer notebook where the use of the keyboard for this purpose would be problematic in this study where mathematical symbols could not be typed with the keyboard.

As the digital pen can be easily converted to various colour functions and line thicknesses or to a highlighter function, the multi-dimensional aspect of the inking pen was seen to save on the need to have various coloured pencils or highlighters or "white-out" tape and so saved in the purchase of additional stationery or the need to carry such additional equipment around, when compared to using paper as the medium of recording. The ease of changing the colour of the digital pens was exploited by some students and used to differentiate between various aspects associated with a question and/or notes and to link like emphasis or sequences of understanding. In one interview a student reported his approach of colour coding declarative knowledge text distinctively, against procedure knowledge text, against his own notes, or reflections, or notes of corrections that he made. Types of notes were also categorised by colour by some students, such as writing definitions in a green ink. Another used black for formulas and red for his thinking.

4.2.4 Contrasts with the use of paper as the medium to record notes, drawings or symbols:

In terms of contrasts between using the Tablet PC and the use of paper, in one of the interviews reference was made to the way notes could be secured through backups and copies made electronically which assisted, as paper notes were often lost. Another respondent made the same comment about losing work on paper and attributed his better understanding of Mathematics to having complete sets of work available to him, which was not his experience when working on paper.

A further contrast to working with paper which was cited was the ability to erase work without any difficulty or consequent impact on the look of work set out. Formatting or re-organising notes, which is associated with the flexibility of moving notes around, was also valued. This in some ways is also associated with the value of erasing and re-writing notes aiding in the format and legibility of notes wanted. The ease of editing written work was expressed in the student interviews as below:

> *I think we started (*writing*) sooner because we were able to edit what we wrote down.*
>
> (Student 1, Group 5 interview)

And

> *You just rub it out…it's so much easier….Yes, it is (confidence giving) because it's always neater, its cleaner and the pen get smudged and everything so you look out for your Tablet*.
>
> (Student 1, Group 3 interview)

And

I would probably go with writing with the Tablet because my hand writing is not the best. So I would rather be able to handwrite where I can do it properly and because I usually use pen when I am writing on paper and if I do it on here (the Tablet) I can rub it out and make it more neat so I can actually see it, and for Maths I can understand it and understand the equation. Like if its b squared = c squared I can use that equation for later on like certain equations we use.

(Student 1, Group 2 interview)

Whilst one reason given for writing quicker digitally was counterintuitive*:*

When I am writing on paper I like to think before I write, it takes quite a time to rub it out or fix my mistakes but on the Tablets I think less when I write on the Tablets.

(Student 1 Group 4 interview)

The only issue that was raised with the use of the digital pen on the Tablet PC was the need to get used to writing on a glass surface in contrast to the practised feel of the texture of paper.

Flexibility seemed to be another value. By this was meant the ability to move notes around and create new space for inserting notes. This allowed notes to be kept in a sequence and avoided the need for any recopying of notes to maintain the correct sequence. Whilst these attributes would apply also to notes typed on a keyboard, the ability to move typed text was seen as being more limited, handwritten notes could be formatted to fit the area identified where notes were inserted after creating space. The ease of copying and pasting made the creation of documents like revision notes that much easier.

Some students liked the digital pen with its eraser function along with shapes insertions, allowed not only for neater drawings but also individualised and contextualised drawings with one consequence of the use of the digital pen reported as being the fact that drawing and the creation of graphic organisers became a stronger feature in organising notes to establish patterns of information and developing stronger understanding of content.

Others reported finding the writing much clearer and bolder with the digital pen - a reference to the ability to change line thickness. One reported having trouble writing neatly per se and the Tablet allowed him to make his writing neater with corrections.

Catering for individual writing style was illustrated in two responses. One concerned a left-handed writer who reported that his tendency was to move his hand across his written words and that on paper this often caused the writing to be smudged and required him to re-write words for clarity. The non-smudging of writing on the Tablet PC saved on this necessity. The second related to the

positioning of the writing surface which traditionally on paper is horizontal and placed on the desk. One respondent liked being able to write on a surface that could be held at any angle he wished and so enabling him to rest the writing surface on a number of other surface, for example arm, knee, propped against the table edge.

4.2.5 The "new" things that could be done with the digital pen:

The question of the value of the use of the digital pen in Mathematics lessons was further explored by asking the students what they could do with the digital pens that they couldn't have done without them. The responses given referred to the general technology of the Tablet PC as well as specifics relating to the technology with the digital pen aspect. Often the benefits of using the Tablet PC pen were expressed in terms of comparisons with typing. Other responses then made the comparisons between writing on the Tablet PC and writing on paper, from the perspectives of editing, formatting and correcting, as outlined above.

With regard to the former, the responses relating more to the general technology, references were made to the use of the DyKnow software and in particular the formatting of the DyKnow panels by the teacher in his preparation for lessons. The software allowed for the following to occur:

(i) The association, in terms of proximity, of text with response:

This was a reference to the student's ability via the use of the digital pen to place a response to a question alongside that question, where the question was transmitted to the student's Tablet PC. The distinction here is greatest when considering questions drawn from the text book. Many students, in order to achieve this proximity on paper, would have to copy the question from the text, taking up time which might be better served in the solving of the problem.
Comparisons with notebook computers again made reference to inking being more flexible in achieving this proximity, especially where error identification was prioritised.

(ii) The replay function**:**

This function was used by some students where they struggled to understand a concept. By replaying the explanation the student had the opportunity to identify at which point in the explanation he had a problem and either work it out for himself from there, or ask the teacher to explain further during the next lesson. The replay function was reported as being used in the modelling stage as well, where the panel deployed to the student with question and space to work, could be replayed by the student to view the worked solution which had been deleted and was available to the student only through the replay function. This provided the student with a further opportunity to have the process modelled to them. As for the teacher, they could identify whether a student needed to go through such a process before starting by capturing their panels and replaying

what they did, including whether they viewed the solution beforehand. This would give the teacher insight into how independent the student was in solving problems. The fact that the replay function of the DyKnow software was an option that was available to the student both in the classroom and outside widened the impact it had on student understanding.

(iii) Enabling the student to allocate more time to their construction of meaning and avoid multi-tasking:

This point was raised in reference to situations where questions, notes and text could be sent by the teacher to the student's Tablet PC and thus save the student time copying it out. One student remarked in this regard that when he was using a book, paper and pencil or pen, he had to look up to the teacher to see what he was writing in order to then copy it down and so have a record of this. With the use of the Tablet PC by both teacher and student, what the teacher was writing on his Tablet PC was appearing on his screen, negating the need to copy the writing himself. As such the student could concentrate more on the meaning of what the teacher was communicating. According to this same student, what the teacher was saying made more sense in this way because he could focus on constructing meaning rather than on copying content**.** He had to look up and copy the work or explanation down and when he was copying it down he was not cognisant of the explanation the teacher was giving. This for him was a cognitive overload because he could not achieve the two things simultaneously. This may be seen as a consequence of the teacher looking to achieve an objective of constructing meaning whilst simultaneously providing new notes or elaborations. The student focus is on capturing the notes and relying upon their detail to provide the understanding when read again at a later time.

An example given by a student of the benefit of the application of digital inking associated with the software used was being able to capture teacher elaboration on the student's Tablet PC. This allowed the student to capture the explanation in the knowledge that the teacher's freehand writing and drawing was being captured automatically. The specific illustration given was that of the teacher elaborating and explaining how a parabola works. He illustrated this through a freehand drawing on the side of the screen, which appeared on the student's Tablet PC at the same time, and the student could see what he was doing and listen to him at the same time and take his own notes on the side of the drawing at the same time. This affordance was described by one student as negating the need to multi-task as much in the class or reducing cognitive load**.** The student is aware of more than one task that needs to be completed, that is capturing the teacher's work and making sense of it at the same time, and the time frame involved in achieving this. The tension, or cognitive overload, occurs because the teacher explains as he writes – the two actions of the teacher are not

separated and require the student to engage with both at the same time. In reality, rapid task switching is the consequence but not all students are successful in achieving both objectives.

Not all students, however, conformed to this view with there being one exception. For one student the time gained from not having to copy notes was outweighed, in his view, by the improved recall he experienced by copying notes. Such a response is likely to reflect a preferred learning style and tends to suggest a memorisation technique of learning rather than recall occurring through understanding.

One unexpected aspect of the teacher being able to write on his Tablet PC and this writing being delivered to the students' Tablet PC was removing the issue of the teacher's positioning at the Whiteboard when writing, which for some students blocked their vision of the notes being written. Such students had then to wait until a clear view was available to them and then copy the notes down, but by this time the teacher was moving on to the next elaboration. This created some anxiety with some students and a break in their continuity of thought.

(iv) The expediency of feedback available with the record/replay function:

Students valued the ability to write equations and answer questions and then go back over them to see where they went wrong by viewing the teacher's solution to the problem on their own panel. In viewing the teacher solution through the replay function the student could identify the point at which they diverged from the teacher in their solution. In doing so they were able to correct themselves. Where the student recognised a point of difference but did not understand why the difference existed, he could now target his questions at a specific point in the solution process. In other words his questions became more focussed on the errors in his understanding and allowed the teacher to respond in a much more targeted and effective way, rather than having to discover the point at which the student's thought processes were at fault. In the words of the student they could go right the next time….and just correct ourselves there and then.

(v) Greater confidence in committing to writing:

Students were asked to compare writing on the Tablet PC with writing on paper. The attributes of the Tablet PC that they highlighted most, in contrast to writing on paper, focused on the ability to move text around and correct/edit it when created in a digital form on the Tablet PC. However, there were suggestions, in response to questions on the idea of committing themselves to digital inking responses, that as a result of the ease of correcting/editing on the Tablet PC there was less hesitancy and greater confidence in starting any creative text or drawings. This was in the knowledge that either could be easily corrected or replaced if the product was not considered right or neat enough or in the right place.

Some students agreed that while working with the digital pen they tended to begin writing more quickly but perhaps with less thought, classified as thoughtless writing, because they knew that it was relatively easy to correct or reformat work. This would require the students to actively review work that they had written in class. On the other hand, another student reported that because there was a tendency to write sooner and quicker, more writing was taking place. This was most likely a reference to writing by the student based on his thoughts and elaborations, a reflection prompted by reference also to the fact that students were required to copy less as text and questions were delivered to the student's Tablet PC screen. At one extreme, with regard to thoughtless writing, one student reported that he felt more tempted to drift off, doodling, because he knew he could erase doodles without imposing on his notes. Such a practice is not one created by the use of the Tablet PC but for some students it allows an old habit to be more easily disguised. Teacher monitoring through the use of the DyKnow playback function would help such habits to be identified.

(vi) Touch Screen function:

Some students utilised the "touch screen" option to drag images around but preferred to use the pen to do this as it was regarded as a more precise way of moving objects.

(vii) Working faster

This was a feeling expressed by one group who felt that without the digital pens their progress in Mathematics would have been slower because they could write quicker and easily insert space to update notes where the teacher corrected omissions in content. So with the digital pens quicker progress was the perception.

(viii) Having all the notes right there

Even where no perceived benefit was expressed by one student, the student unwittingly found a benefit. He felt that there was no additional benefit in using the digital pen – except "having all the notes right there –just made it easier."

4.2.6 "The digital pen is no better than writing on paper."

A final summarising question put to the students interviewed asked them to respond to the statement that: The digital pen is no better than writing on paper.

All responded, to various degrees, that they would disagree with the statement. Their reasons served as a summary to their earlier responses. The reasons given for disagreeing with the statement included access to the functions and the shapes and being able to have all the highlighters and the different coloured pens available on the Tablet PC. In one instance a student indicated that when

using the pen on the Tablet PC it opened a whole different world for the student to do a lot more things that could not be done on paper. He reported that with a pen, pencil and paper he actually had to draw a graph himself, but on the Tablet PC the pen allowed him to select a graph and anything he wanted to add to the graph such as the X and Y axis. It took less time for him to complete the drawing of the graph neatly and then get on to the next question. So here the time factor was being highlighted.

Those students who definitely disagreed with the statement indicated that this was because the student could do a lot more things, "a way lot more things", with a pen than can be done with a pencil and paper:

> *No I wouldn't agree. I guess both have their own advantages, but overall there is so much more than you can do with the Tablet than writing with that (ink pen). When writing with that (digital pen), you can do much more. And having one of these is space consuming (pencil case) ….having a pen on the Tablet is much easier…… I only have my pencil case for tests.*

Another response indicated that the end result was just the same but the digital pen allowed this end result to be arrived at quickly. Another student highlighted the greater degree of freedom to write, organise and personalise notes.

Only one student indicated that his preference was to write in ink on paper because that was what he was used to doing.

4.3 Results and Analysis of Teacher Interview

4.3.1 Introduction

The teacher interview provided the opportunity to obtain data on the extent to which the teacher was utilising the Tablet PC in the classroom lesson and how this was being done. In particular the teacher was conversant with the software programme DyKnow and the combination of the software programme with the Tablet PC and its capacity to allow for digital inking was of particular interest. The interview explored the teacher's awareness of the values attributed by the students to digital inking and whether these values were shared and reinforced through instruction.

4.3.2 Student values matching teacher values

(a) The Tablet PC being a practical resource

The teacher was aware of the student's positive attitude towards not having to have a pencil case of equipment:

Well, for one thing one of the things the boys always talk about is they don't need to have multiple pieces of equipment to do certain amounts of work.

(b) The ability to individualise text quickly and easily

The use of digital ink to highlight, erase or colour was noted as a means of creating notes that were more visual than they would normally be. Also noted was the ease of creation of tables and diagrams. Without digital ink the teacher viewed access to coloured ink resources to be restricted and consequently the notes more uniform in nature.

(c) The ability to be given, or to access diagrams

The reference here was to negating the need to sketch or draw a diagram or shape. The Tablet PC allowed for these to be provided to the student, or for the student to access them. This fact does not differentiate the Tablet PC from the notebook, but it was what the student was then able to do that did matter – namely freehand annotate the diagram or complete the graphic organiser - the linking of text to diagram.

(d) Symbology in Mathematics

Symbols were seen to be efficiently written with a digital pen. The teacher acknowledged that there was software where the keyboard could be used to type symbols in Mathematics but indicated that this was not with the same fluency as can be done with the pen. Here the teacher began to use the same terminology as his students, describing the use of the digital pen as enabling the students to set out work quickly and easily, and being able to edit and erase work.

(e) Embedding audio-visual resources within notes

The teacher identified this as a value in contrast to using paper. The embedding of an audio-visual stimulus is not peculiar to the use of a Tablet PC as this can also occur with notebook computers. However, where there was a difference was the use of the digital pen in the creation of the audio-visual product. It was felt that the inclusion of digital inking with such a stimulus assisted with the facilitation of reflection by the student and teaching for understanding rather than for recall. Evidence for this was provided in the references the teacher made to using software with the Tablet PC and the digital pen, to make videos about how solutions are arrived at for the purpose of sharing with other students. The role of the pen here is its flexibility in producing text, symbols and drawing to accompany audio recording and this was emphasised by the teacher.

4.3.3 Teacher directed use of the digital pen

Teacher encouragement of the use of the pen is a vital point for a number of reasons. At one level it is through such encouragement that familiarity with digital writing is achieved and stops students from switching from one format to another in the same work schedule. The teacher remarked that reflections on objectives of the lesson were required to be written with the digital pen, even though these reflections could have been typed, because they were, in a few minutes going to be using the pen to record symbols so it was just more efficient for them to handwrite rather than to change the computer into the keyboard mode.

At another level, this point of teacher encouragement of the use of the pen, was of significance where the teacher was seeking to exploit the use of the pen in conjunction with the attributes of computer technology. This concerns the planning of the lesson with the use of the digital pen in mind and so the digital pen became important to the teacher's teaching and the student's learning. Where this occurred the teacher contextualised this as emphasising a "collaborative" approach to learning between the teacher and students and indeed between students, as opposed to teacher centered exposition. Reference was made to planning for lessons with the use of technology in mind and as such planning to exploit the attributes of the technology in the learning process. Such attributes that were referred to included allowing for the updating or clarification of teacher content delivery in situ with the digital pen through editing of notes or the annotation of notes with the digital pen; the reproducibility of teacher and student notes; the ease of sharing of such notes and the sharing of work. As such the lesson was designed, according to the teacher, in less of a teacher centered exposition, such as a "power-point" presentation might be, and more of a collaborative experience.

The importance of establishing clear guidelines and expectations for the students' use of the Tablet PC, in order to achieve the desired outcomes, particularly in the early period of the use of the Tablet PC, was clearly expressed by the teacher and can be identified as an element of Dimension 1. The teacher felt that it was very important for the teacher in working with the Tablet PC, digital pen and associated software, to have established strict or formal guidelines around the processes to be put in place, particularly early on with the boys in their first use of the Tablet PC. In this instance the Year 10 students who were the focus of this study, were working with Tablet PCs for the first time and as such needed to develop the methodologies that they might otherwise have already developed, were they to have started using the Tablet PC in Year 7. So for the Year 10 students in question using the digital pen was a new experience, it was a new technology and it was a new pedagogy. As such, in many ways it was necessary for the teacher to have established that initial base line of skills for the students with the pen and have developed an initial understanding with them of not only what is

expected but also what software they will use at different times. Without such an awareness, student "choices" in this regard could quite quickly become a hindrance. The teacher's definition of such hindrances included the use of different file formats and students choosing to do their own thing with the pens such as font sizes and line thickness, potentially making it very hard to read notes. The teacher noted the need to be very careful about all of these concerns.

The teacher indicated that over the course of learning there was a need for the teacher's mind to be focussed on how best to use the technology and the pen in the classroom in the context of the teaching and learning framework in place. For example, the teacher direction to students regarding the use of the digital pen represented a link to Dimension 1 of the Dimensions of Learning framework. This link concerns both the teacher's and the student's cognisance of developing positive attitudes and perceptions about the classroom environment and the tasks to be completed. The first link concerned students experiencing a sense of comfort and order – and in particular establishing and communicating classroom rules and procedures, which was, in this instance, the procedure for the use of the digital pen, the Tablet PC and software.

With Dimension 1, the teacher reported that there was obviously a lot of work needed around how to use the pen, and so the teacher needed to be familiar with its use and what its use was going to be for the students. To be successful here the teacher reported that there had to be some very tight guidelines around what was to be done with the digital pens and how this was to be done. One of the implications here was that there was not an option for the students not to use the digital pen. Similarly, there was not an option for the students not to use the Tablet PC in the tablet writing mode.

These requirements were made compulsory, as were restrictions applied to the use of software. The students were not given an option to not use, for example, OneNote if they were asked to use OneNote. The teacher having such a tight control over the application of the digital pen meant that students could develop the skills that the teacher felt they needed to develop in a generic way. The intended outcome here was that by half-way through the year the students were all quite efficient at using the digital pen. The teacher felt that less structure than that given would have resulted in the students doing different things, such as some accessing Word software while others accessed One Note software, which would result in difficulties for the teacher in collecting work for any particular task involving different files formats. The teacher believed that such variation would have created problems. As such the teacher put in a lot of work around those expectations, even to the extent of making them use lines of a certain width in OneNote, and being quite strict about it. The reasoning given for establishing such tight structures was the view of the teacher that it was only through such structures around formatting and software use that the activities were going to work effectively and

result in a good experience for both the teacher and the students, rather than a negative experience and consequently not wanting to engage with the digital inking technology in subsequent lessons.

The emphasis here is on modelling the use of the Tablet PC and establishing how best to use the technology. Failure to do so can result in the Tablet PC becoming a hindrance to learning outcomes. Conformity to the guidelines and expectations of the use of the Tablet PC were reported as facilitating collaborative learning and the construction of meaning:

> *But once it's all in place (the guidelines and expectations of the use of the Tablet PC), and once the understandings are there about what is expected and what different colours of things mean and what software you use for different things and how it can be used it becomes a really, really collaborative way of teaching with the students and they really do appreciate when you have made a mistake that you can correct it for them on the panel for example. They appreciate that if they ask a question it can be manipulated into what you are talking about and integrated rather than just answered and move on.*

4.3.4 Facilitating the "evolution" of a lesson

Another objective for the teacher with the use of the digital pen was to allow the lesson to "evolve" according to the needs of the group, rather than working through a pre-determined lesson plan which did not accommodate any flexibility that the teacher might need in responding to student reception of the ideas or concepts.

The teacher expressed the view that there was a lot more opportunity, because of the digital inking, for the lesson to evolve on the panel or on to the digital page, rather than being a one way experience. This harks back to the teacher's view that the use of the digital pen facilitated greater collaboration between teacher and student. The reasons given here for such a view was that the teacher felt that digital inking facilitated freedom for him during the lesson to "ink" as required. Essentially "live" formative feedback. Without the use of the Tablet PC and digital ink such a situation would be resolved with the use of the Whiteboard. It would then be up to the student to copy out these qualifying notes, while listening to the teacher and often doing so in a quickness of time often associated with spontaneous responses. As identified by the students in their responses, the cognitive overload involved in getting the spontaneously created notes copied meant that they would not be constructing meaning in doing so and this cognitive process would have to take place at a later time.

The teacher made reference to spontaneous note making that occurred as the lesson evolved in response to the particular group of students in front of the teacher at the time. Particular reference

was made to “things arising” that the teacher needs to write about and/or the students need to write down, that couldn’t be anticipated and as such included in, say, a prepared power-point. Such “things arising” included annotations and graphic organisers, such as a flow chart. The teacher indicated that knowing that there was this ability to enhance, analyse, re-format or re-word previously prepared text allowed the teacher to shape the text to the constructs held by the students and in doing so facilitates the construction of meaning more efficiently and more understandably to the students. This then allows the teacher to have less of a completed lesson plan, or lesson ready on the panels, and instead a system is developed where the teacher is recording some aspects of what is being said and students are recording aspects of what they are hearing, As a result of the reproducibility and the ability to share, those notes can then be shared amongst the boys and quality notes be assembled in that way. Now the teacher does not have to plan the lesson in its entirety exactly as it is going to be beforehand, rather the teacher has the flexibility of scaffolding what is going to be done and then writing about it as the lesson allows.

The point here is that the digital inking approach, similar to the writing on the white board, allows for the lesson direction to grow ‘organically’ rather than in a pre-determined manner according to the teacher’s lesson plan notes. In recording this, as it occurs, it is far easier for the student to focus on the concept attainment as they are not required to spend time foremost in copying down the detail of the new direction that the lesson is taking. The flexibility of additional space and panels in the DyKnow software means that the problem of the limited white board space area does not come into play.

The teacher reported that it was advisable to start the lesson with a general, skeletal and scaffolded plan upon which the richness of the detail was created during the course of the lesson. The learning by the student is able to develop along with the development of the text or freeform images. How this richness of detail and learning unfolds was something that could not be predicted and probably previously would have been catered for with the Whiteboard. So there is here a substitution for the Whiteboard and a need for the teacher to be comfortable working on their Tablet PC screens as their “canvas” to undertake this “unfolding”, rather than the Whiteboard.

4.3.5 Catering for absent students

The teacher felt that the current use of the Whiteboard requires the student to record the new text or drawings and so students who are absent are required to copy a friend’s version of the Whiteboard work and do not have reference to the audio (teacher exposition) that accompanied it. For such students for whom this point is relevant, absence from such situations puts them at a disadvantage to students who are present. Specifically the teacher felt that the general tendency in catering for

students who were absent from lessons was to provide them, or make available to them to access, the resources that were the focus of the lesson. These resources would of course be the "raw" resources brought to the start of the lesson which subsequently have been, with the application of the Whiteboard, elaborated upon and shaped and embellished. The teacher's verbal elaboration would necessarily have been copied down by the student. In accessing the original resources none of these aspects would be available to the absent student. With the use of the Tablet PC and the digital pen, along with the audio recording aspect of the Tablet PC, the absent student could access the complete artefact of the evolved lesson. More importantly, the student, in experiencing the lesson as his peers would have done, can apply his own interpretations of what was done and said, rather than copying another student's perceptions. Indeed a comparison between the prepared resources and the realised resources would be insightful as to just how much information is lost to the absent student without use of the digital pen and the Tablet PC.

4.3.6 Facilitating constructivism through collaboration

Creating individual meaning and understanding in the process of learning was something that the teacher felt was well served by the technology: … *there's this collaborative aspect of what they (the students) do (which) is very important. The technology has been very good for that….*

The way in which technology assists in this process was described by the teacher as being through providing students the time and the opportunity to reflect and construct meaning. The teacher observed that there might be an explanation of how something is done, or should be done, given by the teacher but there is also a synthesis required, with all students needing to develop their own synthesis of what that explanation means to them, and how it integrates with what they know and can do. In this situation the teacher felt that the Tablet PC and the digital pen assists the students in their construction of meaning, and the students are provided with a structure to undertake this through these media. In this study this involved the teacher pre-planning the use of the "panels" in DyKnow, creating areas for specific content, or a special graphic organiser, while in other areas the students would note-take at the same time as the teacher was inking. The teacher further elaborated on this point by indicating that there was time available for the students to develop a synthesis of what they needed to be able to do. There was more leeway for them to then develop consequential understandings or aids to understandings such as diagrams, or flow charts and such like from that.

4.3.7 Feedback

Whilst providing the assistance and structure outlined above, the teacher indicated an opportunity now existed to be able to monitor how the student's construction of meaning was progressing. Reference was made to the teacher's ability to review products such as diagrams, or flow charts by

collecting panels and having a look at how their construction of meaning was developing. The teacher referred to aspects of Dimension 2 which are concerned with helping students to acquire and integrate knowledge through the organisation of declarative knowledge with graphic organisers, the aim of which is to identify patterns in the student's declarative knowledge. Such an opportunity appears to be a consequence of the teacher and the students having more time to focus on activities where the student is providing evidence of their construction of meaning. The greater time available is as a result of the time previously used for copying of notes or diagrams having been saved, through such content having been transmitted to students. The explanation of such notes can then be the focus of the student rather than being combined with the task of copying the information. The teacher felt that the time given to explanation allowed the students to pick out things that were said that struck a chord with them and seek affirmation of that. Other things that did not strike a chord could be reflected upon with a view to connecting to prior learning. Students therefore had more opportunity to construct new meaning effectively.

The Tablet PC is seen as facilitating a more efficient opportunity to reproduce text, to search text, to share text. There are opportunities to have greater oversight of student work than with the use of paper.

The teacher valued the ability to feedback to the students the correct processes involved in the problem solving of Mathematics questions, while students were engaged in the process of solving problems themselves. The exercises or problems they were working on were aimed at assessing their understanding of the processes required to solve problems. The flexibility of the teacher writing out these solutions on the teacher Tablet PC, with these solutions appearing simultaneously on the students' Tablet PC, was a strategy made much easier with the digital pen than compared to the notebook computer. As students saw the teacher's solution appearing on their screens they were then able to reflect on their own workings and through comparing the two, identify any errors in their own workings. As a consequence students were then able to re-work a piece of work during a lesson following the receipt from the teacher of the working of the solution.

The monitoring and feedback element of teaching and learning is believed by this teacher to be an aspect of deep learning which was better achieved with the use of the digital pen in comparison to using paper as the medium. Reference was made to:

> *…the reproducibility, the search-ability, the sharing, that (was) all very, very efficient, more efficient than it would be, I think. I could have more oversight of their work with the digital pen than I could with the paper materials….*

Aiding this ability to monitor and feedback on the work students were doing was the ability provided through the software to collect the work rather than relying on it being submitted and doing so at any time in the lesson without disrupting the student's focus. The teacher expressed this as a freedom which allowed the teacher to make a quick decision, or a consequential decision, to collect something, or look at something. This might not possible with the use of paper because the students have the homework to do in that book or some other work which implies that the book is tied up and the book cannot actually be obtained from them. The teacher in this circumstance can get a more ongoing assessment of how things are evolving than would be the case with the use of paper.

In this instance the teacher is really talking about a situation where traditionally writing on paper was the creation of an artefact that was very singular in its nature. The student had a copy of the work, the teacher didn't. If the teacher wanted to see that work at any stage he/she would have had to take that work on paper from them and they then would have no copy for themselves. The electronic version of the student's notes could actually be obtained at any stage in the creation of the notes and the student still has the notes in front of them and the teacher has copies at various stages according to what he/she thinks is an important time. The teacher felt that this represented a real opportunity to feedback at various stages as to how a student's understanding of a concept was developing.

The comparison being made here of course is with the alternative of using paper. The benefits associated here with the use of the Tablet PC are just as attributable to the notebook computer where typing is the only medium employed. However, where greater flexibility is desired and where replication of handwriting is the objective, then the Tablet PC is the more suitable resource for this outcome.

In the discussion concerning any extra leverage provided by the digital pen the teacher provided an interesting insight to the perceived positive aspect of using the digital pen, namely being able to move text around and re-size it while engaged in error-analysis. The students did not really articulate how moving text around and resizing it was assisting them in their learning other than that they could do this. The teacher however indicated that there was a very specific benefit here of reflecting on errors made. The teacher encouraged the students to consider any errors that they made as being an opportunity to learn more efficiently. Where errors were detected the students were encouraged to highlight that error and then drag it off to the side and perhaps shrink it down a bit and then write the correction so as to keep a record of the error and keep a larger version of the correct work. The suggestion put to the students then was that the error was to be picked up and then, through a cut and paste action, moved to a separate page or software programme, for example

OneNote. The resultant document was then classified as a mistakes log which became the source of a study reference to identify common mistakes that were being made on the different topics. The resultant document then served as something to review for preparation for an examination. The teacher contrasted this approach with the process that would take place with paper where the student would have to, outside of the classroom, re-write the errors into the error log on a separate page, in contrast to being electronically copied, moved around or resized and any other actions that couldn't be done on paper. The error notes on paper then exist in separation from the correct procedure unlike the flexibility of electronic capture which allows inserts to associate the correct procedure with the error identified.

The students in their interviews did not explicitly refer to this strategy. Whilst, as noted above, the students very frequently referred to the ability to move notes around only one student made reference to a revision document, and none made reference to an error or mistakes log. This is not to suggest that they didn't exist, rather that they were not foremost in the student's mind when asked about what they could do with the digital pen that they hadn't done, or done as well, with the keyboard.

The teacher in his interview responses did not consciously link his work with students to Dimension 1 feedback where students are led to believe they have the ability and resources to complete tasks as a result of providing appropriate feedback. This was, however, clearly evident in both the teacher and student references.

4.3.8 Providing a structure for student progress

The teacher talked about how the Tablet PC and the DyKnow software helped provide a structure for students to progress. This was achieved by designing and providing for the students DyKnow panels which signalled what particular form of thinking was required to successfully solve the problems set. The form of thinking required was being signalled to students by virtue of the colour of the panels. The teacher felt that such skeletons (outlines) templates or "priorities" were much easier to successfully deliver to students than they were before (as verbal cues) because of the visual nature of the cues. Some students are likely to fail to hear verbal cues given by teachers and are prone to attempt solutions using random strategies where they have yet to construct meaning around the appropriate strategies to apply. The visual cue provides a permanent signal which the student has access to and is ever- present. The visual cue serves to act like the training wheels on a bicycle when a young person starts to learn how to ride. For the teacher this opportunity started to provide a focus for the idea of structuring lessons, or learning sequences, in terms of different skill sets. As

one illustration of this, the teacher referred in the interview to a theory panel and indicated that its job was to deliver a Dimension 2 objective - the acquisition of knowledge.

The teacher took the opportunity to colour code his panels to be delivered to the students with a colour representing a particular aspect of declarative or procedural knowledge that the students were required to employ in order to solve the problem. In this way the teacher felt that the technology, and in particular the digital pen, allowed the teacher to be responsive to the needs of the cohort as they emerged. This represented an aspect of timely, targeted feedback, achieved through deploying appropriate panels and adjusting them accordingly. The association of colour with panel served to convey one of the Dimension 1 attributes – that being clarity of task. In the early part of the course the teacher clarified the declarative and procedural knowledge to be employed by the students by establishing an association of the form of thinking required with a particular colour. As such a particular colour of DyKnow panel, for example, flags to the student the need use a particular type of declarative or procedural knowledge. Students then had clarity about what it was that the teacher was expecting them to do and, almost as importantly for boys, served as a permanent reminder for them.

4.3.9 Aiding student construction of meaning through clarity of task - Dimension 2

The teacher referred to the ability to use the Tablet PC and the digital pen in the context of the work that students were doing at the time and indicated that the teacher was not conditioned or straightjacketed by any printed material or power-point material that would be perhaps less malleable. The teacher described teaching in the non-Tablet PC environment as being much more linear or pre-determined. Although "good teachers" would no doubt adjust their lesson plans to respond to student feedback on how the learning was going, the reality is that at the start of a lesson or during the course of the lesson, it would prove quite difficult for such a response to be resourced and individualised where the teacher has only their traditional "talk" to draw upon.

The perception of the teacher here points to a view that the use of the Tablet PC and the digital pen is an easier way of responding in the teaching and learning situation by facilitating and providing a source of resourcing, both spontaneously teacher generated. These are the Whiteboard moments referred to previously but which now are copied and deployed to the student's Tablet PC instantaneously.

In this context the flexibility provided by the Tablet PC and digital pen is highlighted by the opportunity provided to the student to record and organise disjointed revelations and constructions of meaning alongside previous reflections, into a better classified and organised set of notes. In this sense the student is able to organise notes to reveal patterns of information far more effectively than

they could on paper, unless they took the time to re-write notes after the lesson. This resonates with Dimension 2 strategies.

In the non-Tablet PC and digital pen context the teacher felt that the student's initial recorded experience of their construction of meaning, showed the lesson unfolding in a very step by step manner. Where subsequent retrospective insights emerged these could not be embedded in the notes in a logical place within the notes. As such there was no opportunity to insert what was described as consequential teaching points alongside notes on the same point of understanding.

As an illustration of this point the teacher referred to instances where the lesson had followed pre-determined lines of explanation. This was associated with required elaboration based on student responses. This resulted in accompanying notes which reflected the explanation and elaboration given, and the reflections made at the time. The teacher's strategy at the point of moving on to the next idea, with a view to being assured that the students had "got it", is to sign off by asking whether anybody had a question about any of the lines of working out. Where the response was along the lines of, "how do you get from line 2 to line 3?" the teacher remarked that all that needed to be done in such an instance was to select the working out related to that question, move that all down a tiny little bit and write in an explanation on the line above. In doing so the teacher has answered the question and recorded the answer to it which is delivered to the student. What is more, the student can further insert space and add their own reflections.

The outcome is that the retrospective explanations now appear in the notes as if they were originally given chronologically. The teacher felt that the explanation was now clearer and that the students had a better construction of meaning in the moment, but also a better record of the better understanding of meaning for future reference.

If this learning sequence was to have occurred in the context of the delivery of notes by a medium such as a "power-point" presentation, that consolidation of notes could not have happened as efficiently. If the learning sequence were recorded by pen and paper a significant amount of re-writing of content originally delivered would have to have occurred in order to embed the content and elaboration added in a logical way. The teacher added that to enable well organised, logical and classified notes to be produced more efficiently the teacher simply moves a number of lines down and puts more lines of explanation in a very efficient and effective way, as could the students, which would be far easier than when working on paper.

Here the teacher illustrates responsiveness to student feedback and is able to vary the way the explanation is expressed, or has changed the enunciation of the solution from that which was first used with the students. As such a joint construction of meaning is crystallising all the time as the

teacher gets a new input from the student. This is distinct from what sometimes occurs in teaching and learning where the teacher has a construction of meaning not shared by the student and the teacher fails to harmonise these constructions. The teacher completes the lesson with a sense of having taught the concepts or principles, but does not have clarity around whether that understanding is shared with students unless some feedback is sought after.

Where this does occur and this discord is identified, what tends to happen is that through lack of alternatives the teacher chooses to re-iterate or go to the Whiteboard again. The success of the latter approach is then hindered by the need for the student to engage initially in copying the new elaboration rather than using the time in constructing a joint meaning. With the Tablet PC and digital pen the teaching and learning can become much more of an organic process. Additional explanation, which is not anticipated when planning for the lesson, especially by less experienced teachers, or when delivering the lesson and interacting with the students, can be delivered more efficiently in terms of learning objectives.

The teacher supported the suggestion that the pen enables the teacher and the student to crystallise a shared meaning through the teacher using their formative understanding and responses to that during the actual delivery in the moment of forming meaning. What such an approach implies is that individuals and groups can be more specifically catered for in these "moments" in terms of the outcomes recorded in the form of digitally created notes and records of understanding.

The implications of this approach of "responding to individual and group needs" is that the notes and text, which are the product of such collaborative teaching and learning, would be unique to those individuals or groups. The teacher articulated this view by suggesting that whereas a different group would experience a learning sequence in a different way, so it would be that different notes would be produced at the end of the time. These notes would be based on prior knowledge and prior understandings of the different boys and their different strengths and weaknesses in the room. This contrasts with the power-point or the printed material approach would likely be a "one-size fits all" model. Such notes were described as what the students need to know and if they don't understand them then they could make their own notes or the teacher can write on the Whiteboard more explanation. These notes, however, do not become integrated into what they have received and elaborated upon previously. They become a side note or a side idea and the students would then have to be relied upon to go back and make these integrations. Using the Tablet PC and the digital pen allows such notes, created by the teacher or the student or by both, to be integrated more efficiently at the time of their creation.

For the teacher the Tablet PC and digital pen is not considered to be difficult to utilise. Further claims are made that the use of the digital pen use avoids the creation of parallel, separate records of outcomes of linear developments in teaching. Reference here is to sequences of learning which might start with the teacher's delivery of a pre-determined teaching and learning experience. This may then be followed by the need for the teacher to respond to student or group clarifications in their construction of meaning. The record of this on paper becomes an add-on, reinforced by the unconformity of text and notes that result with previously acquired notes. The Tablet PC and digital pen allows notes and text to reflect a prepared lesson which has been shaped and added to by a student's construction of meaning.

4.3.10 Aiding student construction of meaning through reflection – Dimension 2

This consideration by the teacher gives rise to an interesting observation related to the skills of a teacher to move beyond the idea of a programmed learning approach and responding to the needs of the learners in question at the time. The teacher expressed the opinion that the Tablet PC and the use of the digital pen and associated software assisted the teacher in an accommodation of both students' thoughts, and where they are at in their construction of meaning and that furthermore that this was not difficult to undertake. In stating as much, however, the teacher acknowledged a certain difficulty for some teachers as the approach to teaching and learning with the Tablet PC implied relinquishing some control of the certainty of the course of the lessons. This was illustrated in the context of the control offered by, for example, creating a lesson resourced solely by a power-point presentation or a printed page. Here there is a safety and certainty of having established a logical, linear progression for the lesson. What has been prepared for the lesson is all that is needed.

Conducting lessons utilising the digital pen can mean that the teacher acknowledges, is ready to respond to and can integrate, what might happen to shape the lesson further. Required is an acceptance that learning needs to be responsive to the needs of the students involved and so the teacher needs to respond to the different possibilities that happen in a lesson. In many instances the teacher is equipped with the Whiteboard and the Whiteboard marker and will respond through that medium. However, as pointed out earlier, this then requires the student to copy notes while at the same time trying to engage with the elaborations.

The key difference with the Tablet PC, digital pen and associated software is that the teacher is also engaged in linking elaborations to their appropriate points in previously communicated notes. In fact, the teacher will lead this process and ensure that the student is adding the elaboration at the correct point of the previous notes. This is the nature of the collaboration that is identified as being assisted by the use of this technology. Previously the teacher elaborates while the student has to

make the connections, copy and reflect upon at the same time. Now the teacher is engaged in that connection process, and providing the notes which appear on the student's Tablet PC while the student can reflect on them. The student's time and energy is thus focused on the task of reflection and constructing meaning that is better likely to result in an outcome of enhanced construction of meaning.

4.4. Results and Analysis of the Student Survey

4.4.1 Use of the Tablet PC: tablet mode or keyboard mode?

The student survey places the student responses to interview questions in a context that clarifies the extent to which answers given in the interviews were common to the group as a whole. The results indicate that the benefits of the Tablet PC, digital pen and supporting software were accessed variably by the students.

A strong indicator of the extent to which students used the digital pen in a manner that reflected the adoption of this form of recording work was the mode that they put the Tablet PC into while they were working. For the purpose of the observation the Tablet mode use of the Tablet PC refers to a situation where the student has the screen in a horizontal position, sitting on top of the keyboard, which, therefore, is unavailable for use. In this mode, students will be writing with the digital pen and using the pen to orientate themselves around software programs. The keyboard mode use of the Tablet PC refers to a situation where the student has the screen in a vertical position and has the keyboard available. This mode of Tablet PC use did not exclude the use of the digital pen, and it was observed on many occasions that students would use the digital pen as well as the keyboard in this mode, with most switching to tablet mode at some point or other.

In this study five students (just over 31%) indicated that at the start of most lessons they began their work with the Tablet PC orientated in the tablet mode with the keyboard unavailable, leaving two-thirds starting in the laptop mode. This would suggest that the students started their computers and accessed the required software using the keyboard. A further five (just over 31)% then moved into the tablet mode as is indicated by the figure of 63% who spent the majority of their lesson time writing using the digital pen. In these Mathematics lessons, six students (37.5%) indicated that they were taking notes throughout the lesson which supports the figure of just over 31% who started their lesson in the tablet mode. An additional eight students (50%) indicated that they were mostly taking notes during a lesson, a figure which would have just over a maximum of fourteen (87.5%) students using the Tablet PC in the tablet mode and two (12.5%) of students moving between the two mediums.

The indicators here suggest that as most students' experience of using a computer prior to the Tablet PC was a desk-top computer used in the desk top mode, the Tablet PC version of which is the keyboard mode, most started their interaction with the Tablet PC in a mode familiar to them. Students, through the survey, suggested that many initially utilised the Tablet PC in the traditional manner and then moved to the less familiar tablet mode as the nature of the task pushed them in that direction.

4.4.2 Use of the digital pen

When using the Tablet PC the student responses indicated that they spent just under 37% of their time on the Tablet PC typing (36.81%) and just over 63% of their time writing (63.19%), so the digital pen was being used for the majority of the time.

Nine (just over 56%) of students indicated that they had their text book in a digital format on their Tablet PC's. In a supplementary question to those responding positively, ten, (just over 83% of the twelve respondents) indicated that they interacted with their digital text using their digital pen. The nature of this interaction appeared to be predominantly highlighting, (seven or 58% of students who responded) and marking in some way (seven or 58%) with annotations (four students or 33%) being the least amount of interaction. The responses indicate that in the area of the digitised text book, the use of the digital pen appeared to be a minor focus for students.

The evidence for constructing meaning through creating new text is more evident in the act of note-making than it is in annotating digital text. All students indicated that they took notes during a lesson at some point (six students or 37.5% always, eight students or 50% mostly, two students or 12.5% sometimes). Asked whether they had a preference with regard to note taking using the digital pen or traditional pen and paper, ten students (62.5% of student responses) indicated a preference for using the digital pen, leaving six students (37.5%) having a preference for traditional pen and paper. In the interviews conducted the reasons for this latter group's preference was explained by two main factors:

a) From the interviews, two respondents reported that writing with the pen on the Tablet PC surface was harder than writing on paper particularly where questions of neatness were a consideration. This may be a reflection of the relative novelty of writing on the Tablet glass surface compared to paper and this point was made by one respondent.

b) The lack of trust in the digital writing being recorded was mentioned. Part of a dislike for writing on the Tablet PC expressed by two students was due to a problem of recorded text disappearing while writing in OneNote. This transpired to be a technical hardware problem which

was eventually confirmed by the hardware manufacturer after questions raised by the school. Subsequently the issue was fixed for 2013. It does point, however, to "technical" issues being a problem for technology.

For students who expressed a preference for using the digital pen the overwhelming reason given was that what they wanted to do was "easier" with the digital pen. The term "easier" was associated with the ability to:

a) erase, select and move notes;
b) changing things easily;
c) write notes neatly and to organise the notes;
d) change colour;
e) highlight;

Student use of the "One Note" software was reported by fifteen students (93.8% of students). Of those users, thirteen students (81.3%) used the digital pen, two students (12.5%) used the digital pen solely and eleven students (68.8%) used both digital pen and keyboard. Only one student (6.3%) used the keyboard exclusively and two students (12.5%) annotated captured text in OneNote.

When asked whether taking notes with the digital pen was better than taking notes on paper ten students (62.5%) indicated a preference for taking digital notes (in OneNote) while four students (25%) expressed a preference for taking notes on paper. Two students (12.5%) felt that there was no difference. Of the reasons given for digital note taking, the combination of the digital pen with the OneNote software was significant as the majority response related to the availability of unlimited paper with an absence of stress associated with trying to save paper or swapping pages when the paper page is full. The availability of unlimited "paper" was a benefit representing three (18%) of responses.

Other majority responses included the ease of erasing digital inking; being able to select and move digital inking - a function of formatting – two responses (12%); changing things easily on the Tablet PC; the versatility of the digital pen in terms of colour options and inking thickness; neatness/organisation of notes, three responses (12%) and having text on panels one response (6%).

Of the four students (24%) who disagreed with the idea that using "one Note" was better than using traditional paper, one (6%) of the responses referred to paper "feeling better" and one (6%) that the screen was hard to write on.

4.4.3 Student views on opportunities available through the use of the digital pen

The students were asked whether there was anything they could do in their work with the use of the digital pen, Tablet PC and associated software, that they could not do previously. This was a question that sought to ascertain student consciousness and attitude towards the use of the Tablet PC and digital inking as a point of difference. Nine students (56%) felt that there was a positive difference. From these nine students the three most often used words in the responses were "Drawing", "Write" and "Easily".

Seven custom categories emerged from this question. Of these categories the highest response was that of writing from four students (40%) – especially complex equations and formulae, followed by the drawing of diagrams or drawing properly from three students (30%). Whilst clearly drawing has always been an option with paper and pen, the ease of editing with the digital pen was a key factor here. Other actions/outcomes identified as differences by individual students were:

- Interaction with software (10%);
- Ability to erase (10%);
- Ability to keep notes neat – including the ability to select notes and/or re-size them (10%);
- Ability to move notes (10%);
- Ability to write complete solutions (10%)

Students were later asked to advise whether there was any work that could be achieved by working with the digital pen which went beyond the work achievable by working with the keyboard. Thirteen students (81.3%) felt that this was the case and this relates strongly to students being able to write expressions associated with the discipline of Mathematics. Eight students or 50% of responses given pointed mainly to the writing of Mathematics equations and symbols. Other generic, i.e. not subject specific, responses given included drawing; selecting text; speed of writing; and can write using touch.

Writing digitally again featured strongly with three students (18%) identifying the type of writing involved as being the ability to digitally write out equations and the working of the solutions to them in that context. These responses went a little further in identifying that a procedural skill could not only be carried out more easily, thus allowing for the erase function, but that it assisted students in the construction of meaning, in this case, of Mathematics skills.

The ability to easily erase mistakes was considered to be a good thing by twelve students (75%). It would seem that students do correct or erase on traditional paper with virtually 100% of the responses in agreement pointing to such actions being quicker, easier and more accurate in the

digital mode. Three students (18%) referred to accidental erasure of parts of work which is easily fixed with the "undo" button. One student responded both positively and negatively indicating that it was quicker and neater to erase but "stuff can go missing".

When asked what function the students used the digital pen for most, the main response was for taking notes (eight students or 50% of responses) followed by writing equations and formulas (seven students or 43%); drawing, including graphs (five students or 30%); selecting text and highlighting (two students or 12%); and underlining, erasing, not much, Maths only and almost everything (one student in each category or 6% each).

4.4.4 The keyboard the only option

When asked if there were some activities or actions that only the keyboard could be used for and which could not be performed with the digital pen, eight students (50%) agreed. This a figure reduced from ten students (62.5%) when the responses were analysed for reasons given beyond the definitional comparison – such as you can't type with a pen as distinct from answers like, typing look better. Most of these responses were allied to personal preferences such as *I'm someone who can't write with a pen very well, so in order to take clear and fast notes I need a keyboard.*

4.4.5 Directives to use the digital pen

In the interview with the teacher, the teacher indicated that stress was placed on the need to use the digital pen at all times in the class. The students in their response to the questionnaire do not seem to have all taken that directive on board. Nine students (56.7%) indicated that they used the digital pen for every lesson; six students (37.8%) did so "often"; just one (6.3%) only "sometimes" used the digital pen.

4.4.6 Summary of student responses to questionnaire

Table 3: Summary of student responses to questionnaire

Question	Response	
Question 1: When you use the Tablet PC what would be your estimation of the percentage of time that you spend typing compared to the time that you spend writing?	Typing: 6 (37.8%)	Writing: 10 (63%)
Question 2: When you open up your Tablet PC do you start in in the "laptop" mode, or in the "tablet" mode?	Tablet mode: 5 (31.5%)	Laptop Mode: 11 (69.3%)
Question 3: How often do you take notes in lessons	Always: 6 (37.5%); Mostly: 8 (50%); Sometimes: 2 (12%)	
Question 4: Do you prefer to take notes on the paper format or the digital format? Explain your answer	Digital: 10 (63%)	Paper: 6 (37.8)%
Question 5: Do you have any of your text books on your Tablet PC in a digital format?	Yes: 9 (56.7%)	No: 7 (44.1%)
Question 6: If yes, do you digitally ink the electronic text?	Yes: 10 (83.3%)	No: 2 (16.7%)
Question 7: If yes, which of the following inking practices do you use?	Highlighting: 7 (58.3%); Annotating: 4 (33.3%); Marking in some way (underline, circle) 7 (58%)	
Question 8: Do you use OneNote?	Yes: 15 (93.8%)	No: 1 (6.3%)
Question 9: If yes, do you:	Type in OneNote only……..… 1 (6.3%) Write in OneNote only: ……2 (12.6%) Type and write in OneNote: ……11 (69.3%) Annotate captured text in OneNote…2 (12.6%) Highlight captured text in OneNote....0	
Question 10: Does the use of the digital pen allow you to do anything that you could not do before?	Yes: 9 (56.3%)	No: 7 (43.8%)
Question 11: If yes, what are these things that you can now do that was not possible before?	Write (complex solutions) 5 (50%); Draw (diagrams) 3 (30%); Move notes 1 (10%)	
Question 12: Do you think the use of inking in OneNote is better than using paper?	Yes: 10 (62.5%); No: 4 (25%); No Difference: 2 (12.5%)	
Question 13: Explain your answer to the above question.	Scrolling unlimited paper 3 (18%); erase/select/move notes 2 (12%); versitility of the digital pen 2 (12%).	
Question 14: When using digital ink on the Tablet PC you can easily erase "mistakes". Do you feel that this ability is a good thing or not?	Yes: 12 (75%)	No: 4 (25%)

Question	Response	
Question 15: Explain your answer to the above question.	Yes: Is quicker/easier and/or neater 8 (50%); No: Easy to erase in error 3 (18%); Difficult to erase 5 (31%)	
Question 16: What do you use the digital pen for?	Equations and formulas 7 (43%); Graphs 2 (12%); Drawing 3 (18%)	
Question 17: Is there work that you can only do with the pen because it cannot be done with the keyboard?	Yes: 13 (81.3%)	No: 3 (18.8%)
Question 18: Explain your answer to the above question.	Writing to solve problems 3 (18%); Maths 8 (50%)	
Question 19: Is there work that you can only do with the keyboard because it cannot be done with the pen?	Yes: 10 (62.5%)	No: 6 (37.5%)
Question 20: Explain your answer to the above question.	Yes: Keyboard faster/easier /better 4 (24%) No: Pen better for writing/everything: 5 (30%)	
Question 21: How often does your teacher direct you to use your Tablet PC digital pen?	Every lesson……9 (56.3%) Often, but not every lesson…….6 (37.5%) Sometimes in some lessons……....1 (6.3%) Rarely, just in odd lessons……...0	

NOTE: numbers refer to numbers of students which is also expressed as a percentage of the total number of students answering that question.

From Table 3 the student responses indicate the use of a combination of keyboard, digital pen and software. There were clear advantages with the pen for "freeform" content creation and the keyboard seems to be defaulted to as custom and practice.

4.5. Results and analysis of teacher survey

The teacher estimation of the amount of time in his lessons that the students spent writing in comparison to typing was 80:20 which differed from the students' estimation of approximately 66:33, but nevertheless confirms that most of the students were writing with the digital pen rather than typing. The teacher confirmed the establishment of guidelines by asking students to put their Tablet PC's into the "tablet" mode, although from the student responses it would appear that the majority did work in the "tablet" mode while a minority drifted between the two modes.

The teacher's preference was for his students to take notes in a digital format because such notes were easier to collect, store for review purposes, feedback on and keep records of. He referred to what the students could do with digital notes, such as erase, re-work solutions and be more visual with colours and symbols, for example. He added that students could share notes with each other more easily, for example after absences. With digital notes the teacher believed that students could

collect notes from a variety of resources and put these together in one place. Notes were easily backed up to keep them safe.

The teacher confirmed that the Mathematics text books are available in a digital format, a fact which 48% of the students chose to take advantage of and as such limited an aspect of the digital options for most (52%) students. He also confirmed that he encouraged students to digitally ink the electronic text. Of the students who had a digital copy of the subject text, 80% did this. The suggested inking activities made by the teacher, such as highlighting, annotating, marking in some way – underline or circle, are mirrored in the student responses.

The teacher encouraged the use of "One Note" software to type, write, annotate captured text and highlight captured text. He also believed that the use of the digital pen allowed the students to do things that they could not do before having Tablet PC's. These things were described as:

> *Annotate or mark clips of text book pages; PowerPoint slides or pages / images from the internet without the need for them to be pre-prepared, photocopied and handed out. Easily use different ink colours, highlighters, shapes and symbols, insert rotate, copy and resize these objects (and written text) with the pen. On paper this would require significant extra equipment (e.g. ruler, protractor, set square, stencils, highlighters, coloured pens). Easily erase work and rewrite or correct it many times if necessary. (The digital pen) allows creation of neater, more visually stimulating notes.*

The teacher felt that the use of inking in "One Note" was better for students than using paper because:

> *Once students adjust to writing on the tablet they can easily rework/correct misspelled words or problems without their page becoming messy with whiteout or cross outs. They can create a set of quality, effective notes in an efficient way.*

The teacher felt that the ability to erase "mistakes" when using digital ink on the Tablet PC was a good thing because:

> *It depends on what we are doing. In a mathematics problem I might like them to shrink their original response down a little smaller and place it next to their corrected response, but if it is reworking notes taken while listening or fixing up notes incorrectly copied from the board then I want*

them to erase the work. I also want them to use erasing when creating study notes in OneNote. If students are digitally inking a handout or drawing a graph making a mistake can mean that a new handout is required and the student may have to start again. Digital ink could just be erased and the student could try again.

When asked what he used the digital pen for, the teacher responded:

Very much the same way as the students. The pen doubles as a computer mouse so I also use it to interact with the various software I use in the classroom, cropping images, or text, from the screen etc. Sometimes I create video demonstrations of written mathematics with the pen that students can watch and listen to multiple times.

The teacher believed that there was some work in Mathematics that could only be undertaken by the students with the use of the digital pen:

For example, in mathematics and science there are a large number of symbols used that are very difficult to get into the workflow using a keyboard. To enter them with the keyboard would require software, add-ons etc. that are slow and not easy to use. The keyboard does not allow for inking texts or images with circles, arrows or annotations etc. in an efficient or effective way. Also there are many diagrams in science and maths. These are usually free drawing processes that cannot be done on a keyboard.

The teacher did not believe that there was any work that the students could only undertake with a keyboard; however there were some activities identified that were better undertaken with the keyboard where it proves to be less time consuming.

There are times when we use the keyboard because it will be a more efficient way to accomplish our goal. This might be in some extended note taking or research, or when typing up report submissions. These could be done with the pen but it would usually be slower for such an extended task. Short phrases can be typed with the pen using the on screen keyboard but this is inefficient and not useful for more extended tasks.

As far as each of the five dimensions of Marzano's "Dimensions of Learning" is concerned, the teacher felt that the use of the digital pen contributed to the student acquisition of each of them.

With regard to Dimension 1 – attitudes and perceptions – the teacher felt that the digital pen enhanced a collaborative feel about teaching and learning between teacher and student and student and student. He described aspects of the Tablet PC:

> *…lending …themselves well to creating a feeling of a 'learning community'. The opportunity and greater scope to rework, improve, share or present work through the use of the digital pen encouraged students…to take greater pride in what they do…*

This alludes to students being able to feel more comfortable putting digital pen to paper knowing they can change what they have done without a wholesale rewrite and with a much clearer product than might have been created previously. This point was raised in the student survey and interview where some students identified the ability to erase easily and to organise notes better as being features of digital inking.

With regard to Dimension 2 – acquiring and integrating knowledge - the teacher referred to the flexibility of the mode of instruction offered by the Tablet PC as a means of acquiring declarative knowledge. Again there was reference to the flexibility of the digital pen which allowed such declarative knowledge to be recorded in a holistic context. The allowance for repositioning of text and creation of space meant that declarative knowledge could be integrated with similar knowledge regardless of the sequence of acquiring such knowledge. The teacher's reference to this point was concerned with a focus on knowledge building:

> *Creating concept maps, diagrams, flow charts and other graphic organisers can be achieved efficiently by using or modifying existing templates. These can act as 'live maps' that can be refined, extended and added to as a unit progresses*.

The greater ease of monitoring student progress in this process was also seen as a benefit:

> *Student acquisition of knowledge through personal practice can be monitored, collected and tracked easily on the tablet PC.*

For Dimension 3 – extending and refining knowledge – according to the teacher the Tablet PC made this easier for both the teacher and student to engage in. The emphasis here seems to be in the assignment of Dimension 3 tasks, described as being "easier" to do. A contrast made with more

"traditional methods" suggests that moving into Dimension 3 tasks from a Dimension 2 focus may not be well associated whereas the use of Tablet PC*:*

> *…means these tasks can be allowed to evolve during a lesson or lesson sequence in a more natural (even spontaneous) way…*

The teacher did not clarify what it was exactly that was wanting in the transition from one phase of learning, (Dimension 2), to the next, (Dimension 3), without the Tablet PC, that is deliverable with use of the Tablet PC. Reference was simply made to "evolving" tasks. The teacher made reference to objectives, which in this case were differentiation and a refinement or extension Dimension 3 task, being achieved *'by the process'*, more easily with the Tablet PC.

The teacher also felt that Dimension 4 focused tasks – applying knowledge meaningfully – in Mathematics:

> *…usually takes the form of worded (sic) problems or problem solving questions based on real scenarios. The work that students undertook with this focus…is similar to that done by students in traditional classrooms on pen and paper.*

The teacher then extrapolated on how such work might progress with the use of the Tablet PC:

> *I could see that students working collaboratively to develop a response to a complex meaningful scenario or problem, might find the Tablet PCs let them collaborate and bring their work together more easily although these tasks are currently fairly uncommon in mathematics.*

Dimension 5 aspects – habits of mind – the teacher considered to be: …*generally accomplished through the curriculum, classroom management etc. regardless of equipment used.* Again, the teacher extrapolates:

> *…that aspects of the tablet PC discussed in this survey will lend themselves to the development of some of these more specifically than others. These might be: persisting, striving for accuracy, communicating with clarity and precision, creating and innovating.*

4.6. Results of Observations

4.6.1 Levels of observation

From the observations of lessons it was possible to see how the Tablet PC was utilised during the course of teaching and learning from two main perspectives. The first of these perspectives was an "external" one related to the visual, general observation of how the teacher and his class engaged with the Tablet PC – the interaction of students with their teacher and the interactions of both student and teacher.

The second of these perspectives was a more "internal" viewpoint – less superficial and more "intrusive" in the sense that this perspective was of the evidence of construction of meaning. As that evidence was being developed by the students and modelled by the teacher, the process was recorded through the software being used. Like a "close-circuit" network of cameras, multiple views of individual students at work were observable. Every student's work was also being recorded so offering the opportunity to revisit visual observations and view those not observed in this way. This meant that every student's learning artefact was captured and was replayable. The observation perspective here was a much more personal and individualised one. This is considered to be a significant point in terms of insights offered and is elaborated upon in the discussion chapter. Procedural activities such as student's work products following teacher modelling could be observed in real time. Added to this was the capture of teacher processes in structuring the learning and checking for understanding.

4.6.2 Observations of the procedural use of the Tablet PC

From the first perspective the observations suggested that the use of the Tablet PC either duplicated the employment of a notebook/laptop PC or the use of pen and paper but with the advantage of allowing for the freehand creation of text in a digital format which represents an extension of the capabilities of both the notebook/laptop computer and pen and paper. So students were observed to write with the pen where the activity they were asked to undertake lent itself more to that approach. For example in the first lesson observed the structure of the session was a pre-test, which was then marked, followed by reflections and further practice to go over errors. At this point only one boy was in Tablet PC mode (using his pen) to set out a problem and solve it. The teacher then provided students with a summary of their achievement. This served to identify the weaknesses of the group and the focus for the next stage of the lesson which was practice on the weaknesses. Of the seven areas pre-tested no-one had mastered all of them. From this point three more boys were in Tablet PC mode using One-Note with digital graph paper, joined after another five minutes by another

student in Tablet PC mode. The use of the Tablet PC mode reflected the stage of the process the student was in. If he could achieve an activity in "keyboard" mode he did. If the task required the use of the pen, he went into the Tablet PC mode.

Examples of the use of the Tablet PC mode here included the writing of formulae and the drawing of graphical representation of formulae as shown in Figures 5 and 6:

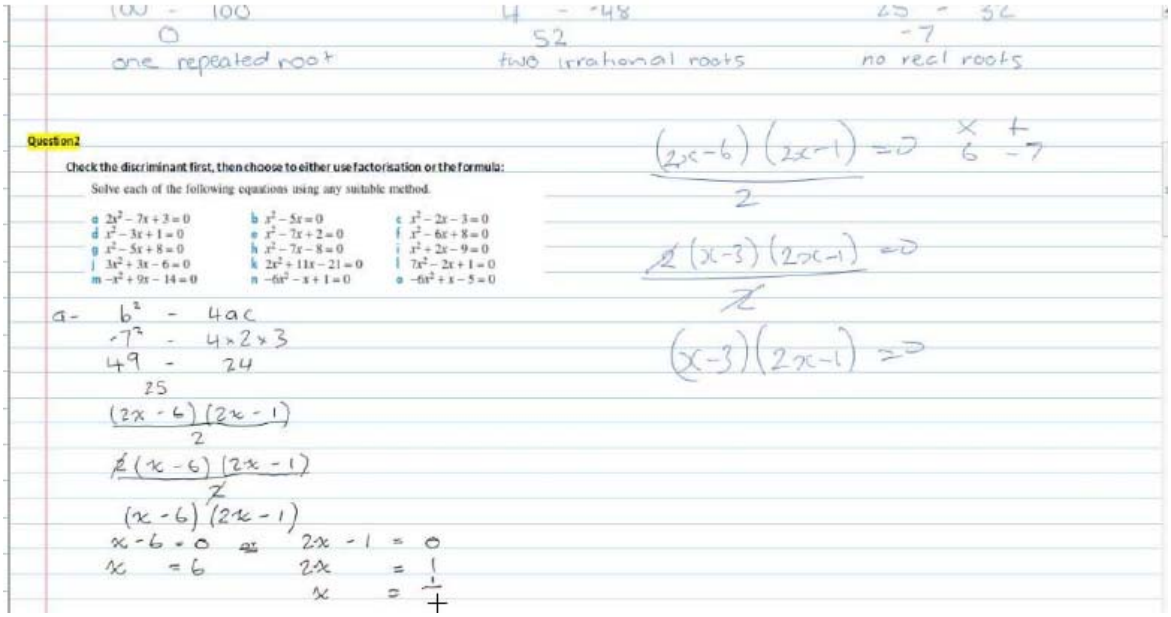

Figure 5: Example of the use of inking to write formula

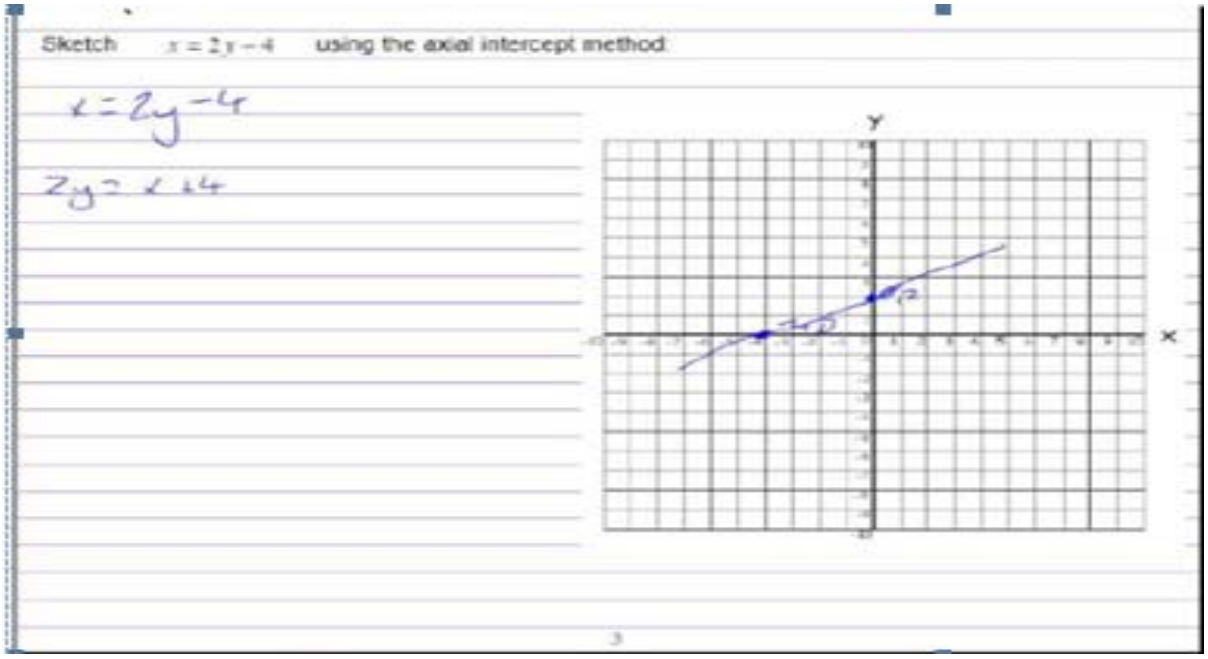

Figure 6: Example of the use of digital inking to draw a line graph

It was noted that in Figure 7 below all students were in the Tablet PC mode, engaged in plotting the graph and calculating the answer.

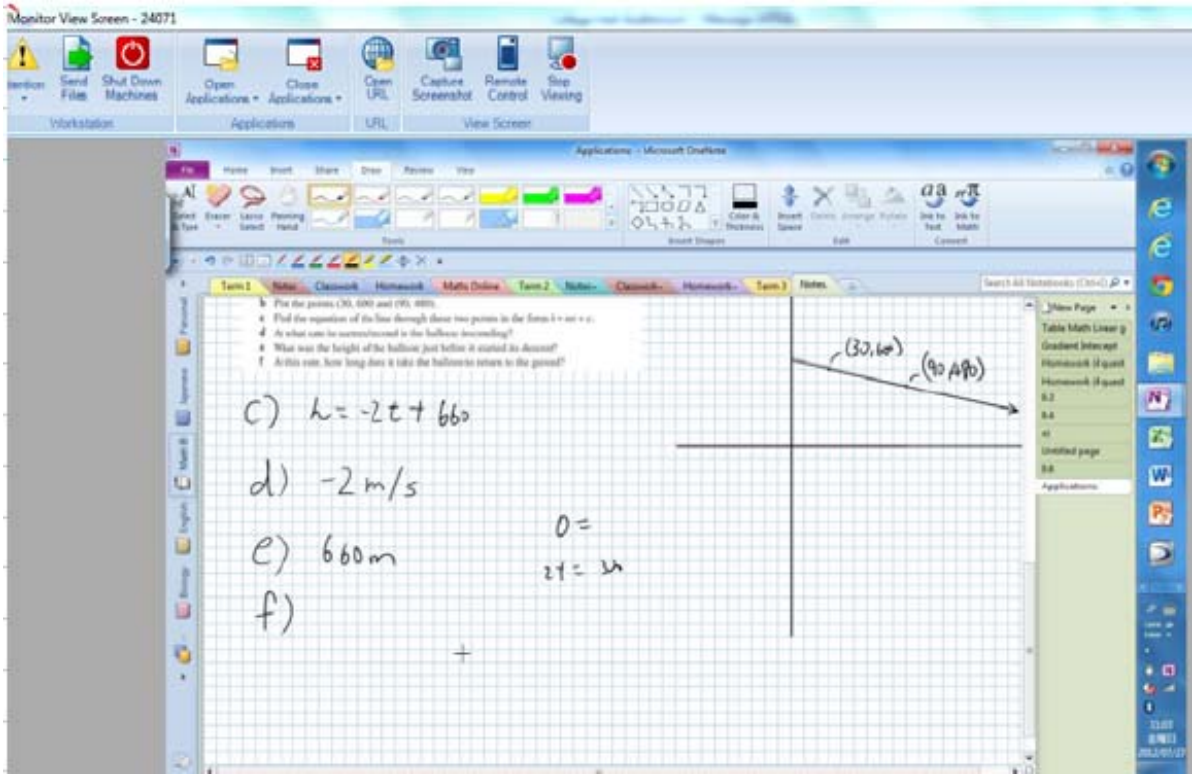

Figure 7: Example of student engagement in responding to steps involved in creating a graphical representation.

The teacher was also observed to be using the pen on his Tablet PC, the image of which was projected onto a screen. In Figure 7 above, the teacher was writing on his Tablet PC what a teacher might ordinarily write on a Whiteboard. In the first instance of this occurring it was noted that by using OneNote to do this the students were able to get a copy of the teacher's analysis as the OneNote was a shared Notebook. An example of this is shown in Figure 8.

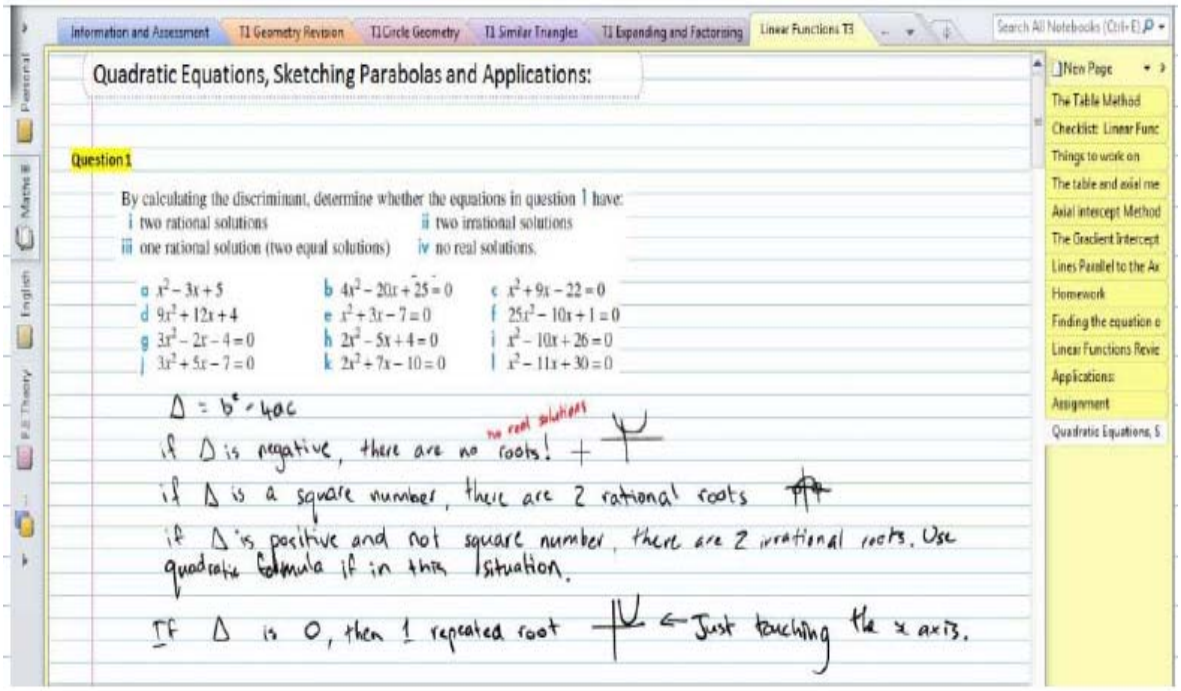

Figure 8: Example of "board work" created by the teacher inking, captured on student Tablet PC.

The first level of observations described above as general observation of how the teacher and his class engaged with the Tablet PC, provided data on how the teacher used the Tablet PC to achieve a number of teaching objectives. These included content delivery and the engagement of the students in practising the mathematical model demonstrated to them. Other objectives included collaboration objectives and how they were facilitated; and facilitating individualised learning opportunities. The observations of the whole class and teacher activity provided some general procedural results reflecting the development of the organisation of the learning dynamic as it unfolded.

Varieties of instances of the use of the digital pen were observed. These instances included the provision of Mathematics tasks which the students were asked to work through on the panel provided. The students undertook their working using the digital pen, and as the problems in many instances required them to draw a line representing the equation given, the digital pen was also used.

4.6.3 Observations of the use of the Tablet PC to assist learning

The second level of observed activities represented the extended opportunities which arose from the digitisation of writing, such as collecting copies of the artefacts of the construction of meaning in a timely manner to be able to respond to errors within the context of the same lesson. Clearly where the errors were seen by the teacher to be widespread this was the signal to the teacher that the concept needed to be revisited for most of the class. Where the errors were detected with a few

students then there was the opportunity for the teacher to feedback to the students concerned in the time frame of the lesson as suggested above.

An example of the feedback is shown in Figure 9 below where the task of simplifying surds was modelled and then students were asked to apply the model to another example and the teacher then followed up with the correct answer.

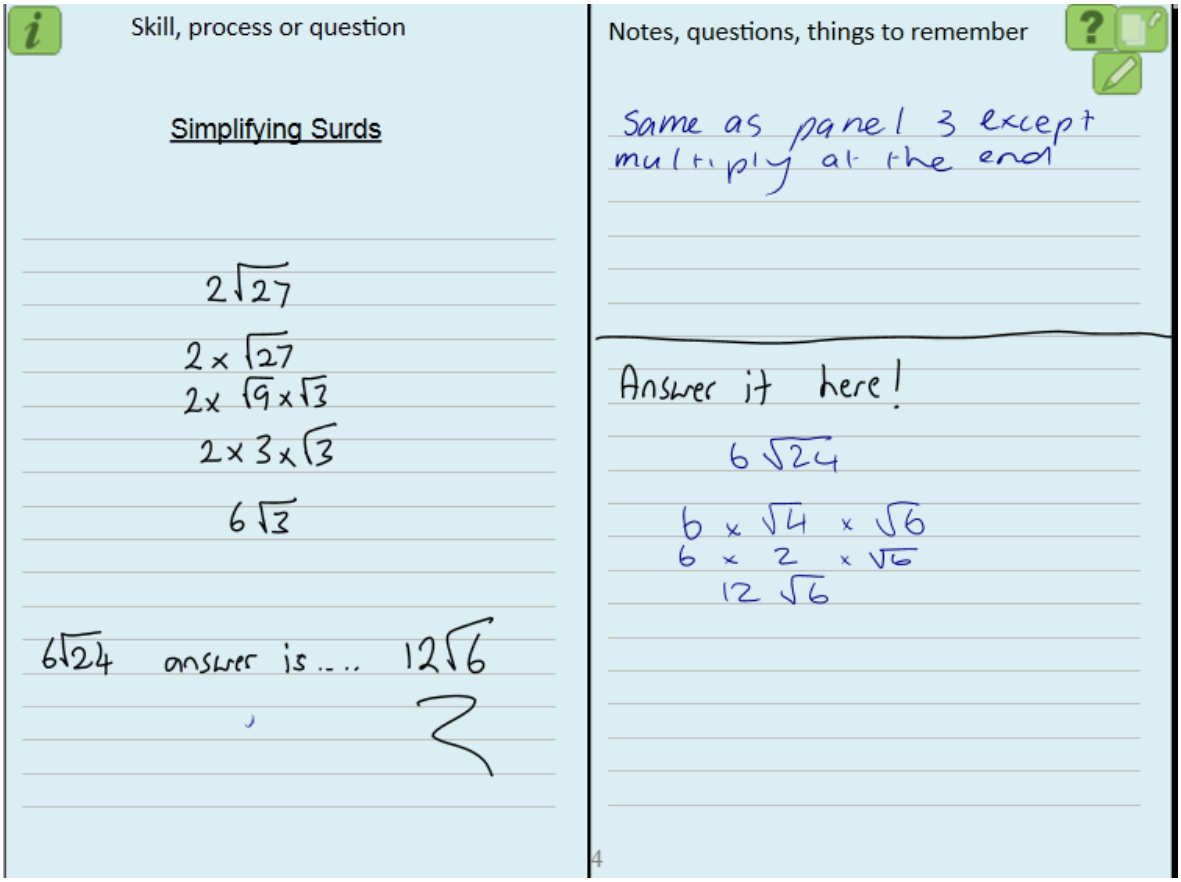

Figure 9: Example of student solving a problem, followed by teacher's answer, followed by student reflection.

From the perspective of the observation of the individual student's work, the record of this provided by the capture of the student panel (the final product) was supplemented by the recording of how the student's final product came to be constructed, how quickly it was constructed and any alterations made in the creation of the final product. This record was then available for "playback" to the observer. It was possible to capture all students' work in this way and offered the option of reviewing all individual students' products, and the stages in the production of that product, of the lesson.

4.7 Analysis of Observations

Analysis of the first of the two observation perspectives referred to earlier relates to the visual, general observation of how the teacher and his class engaged with the Tablet PC.

What was observed in lessons initially was a default preference by the students to using the keyboard mode of the Tablet PC as opposed to the Tablet mode. This view was supported by the student questionnaire where 69% of students indicated that they opened up their Tablet PC in the laptop mode rather than the Tablet mode. The suggestion here is that that this tendency is associated with each student's prior familiarity with the use of computer technology, either in the form of the desk-top computer or the Notebook computer where, of course, the Tablet mode was not an option. Where activities required the student to apply the Tablet mode usage, the Tablet PC's were easily and quickly placed into that mode. The skills and training needed to make this change were minimal, students simply reconfigured their Tablet PC's to bring the screen into a flat, surface mode, take pen in hand and select the function from the tool bar and begin inking. From this observation it was apparent that the Tablet PC fitted in as a supportive resource and was not the focus of the learning activities. The point being made here is that the Tablet PC was not driving the activity but supporting it and offering opportunities for insights and practices by both the teacher and the students which were previously not available to either.

The second level of observations, described previously as the observation of the use of the Tablet PC as a means of checking for understanding, could be interpreted as a variation on the strategies that may be employed in the course of applying assessment for learning (Black & Wiliam, 1998). For example, student feedback to the teacher was observed with the use of a "traffic light" signalling mechanism incorporated into the software which allowed students to signal to the teacher that they had either completed tasks set (green) or were having problems (red). The teacher was able to respond in a timely manner to check for understanding and assist the student or allow him to move on in his work. Also, the teacher used a built in chat facility which allowed the students to flag concerns with him confidentially to which the teacher would respond either via a return chat message or by attending to the student personally. This served the function of allowing a student to flag a concern with his teacher without alerting the rest of the class to his problems.

Teacher awareness of the level of understanding of work undertaken was also observed. Here the teacher collected "panels" which represented "pages" of the Notebooks constituting the lessons activities. He was able to do this virtually, so that students were able to carry on working on their Tablet PC's with no inconvenience associated with handing in work to be checked on paper.

Students continued to work through set tasks while the teacher scanned the collected "panels" for errors. As he encountered them he spoke to the relevant students in turn to correct their errors.

The teacher had the option of replaying a student's construction of their solution to the problem while the lesson continued without taking the student's work away from him. This allowed the teacher to approach the student with an understanding of where in the process the student had gone wrong, in the context of the lesson that the student had demonstrated his error. The identification of the error in itself is no significant advance on a teacher collecting work from students and identifying the same error in the finished product. The difference here is that the teacher and the student in question did not have to wait until the next lesson for this to be pointed out, and so what was observed was that feedback was timely and targeted.

4.8 Conclusion

The Tablet PC provided students with opportunities to do what they had previously done with pen and paper but in a digital format. This then gave rise to perceptions of digital inking being faster, easier and quicker. The digital pen clearly needs to be linked with software that facilitates its use and provides "value added" elements such as flexibility, when compared to pen and paper. The student voice here very much reflects the Oviatt view of pen interfaces and flexible expression of multiple representations (Oviatt, 2013, p. 118).

The teacher expresses an awareness of the engaging and collaborative nature of the digital pen. This gives rise to a stronger co-construction of meaning, giving an emphasis to the practice of learning by doing, or an active construction of meaning. This all aligns with a constructivist view of learning and the Dimensions of Learning Framework which derives from such a view.

Chapter 5. Discussion

5.1 Introduction

The purpose of this research was, through a case study methodology, to investigate the utilisation of a combination of software technology, designed to facilitate recordable collaborative learning experiences, with Tablet Personal Computer technology, equipped with digital inking capacity in the high school (secondary) mathematics classroom where the teaching and learning was focussed on the framework of Dimensions of Learning (Marzano, 1992). The research was constructed with a view to explore the question whether, as a result of the use of the Tablet PC, there were consequent new opportunities identified which contributed to student learning, as perceived by both student and teacher.

Essentially the question posed is whether such a resource "package" offers learning opportunities to both teachers and students. In order to explore this question, a class of Year 10 mathematics students and their teacher at an all-boys independent high school were, over a period of fourteen lessons, observed in class. These observations were then supplemented by individual interviews of students; student responses to an online questionnaire shortly after the observations; an interview held with the teacher; and an online questionnaire completed by the teacher. These five sources generated data designed to give some insight into the research questions posed. The results from these data sources indicated that for both students and teacher, there were both identifiable opportunities and disadvantages which manifested at both a functional level in terms of digitising "freeform' representations of student work and at feedback levels of learning. The nature and form of these functional and feedback levels of learning identified is the subject of the following discussion.

The discussion is organised around the three main research questions and as such the discussion centres firstly around the question of whether the extension of the digitisation of student work from the products of laptop/notebook and pen and paper technologies to the added products of Tablet PC technology, give rise to new learning opportunities. This first question draws from the data which related to the opportunities afforded by the use of the Tablet PC and concern the implications of digitising "free form" representations of student work. Whilst these "functional opportunities" may seem to be inconsequential to student learning, it is suggested that they are responsible for extending opportunities in the teaching and learning dynamic and opportunities for students to represent, shape and work through their thinking strategies. These opportunities may also be interpreted as the students better personalising their learning with differentiation driven by the student through the individualisation of formatting and notations.

Deriving from the first question is whether the use of laptop/notebook computer technology in education is somewhat limiting thinking in students and the feedback to students as a consequence of what cannot be achieved compared with Tablet PC technology. These first two questions are discussed in section 5.2.

A final question also emerges from the outcomes of the first and this concerns teacher access to the creation as well as to the product of student "freeform" representations. Prior to the development of Tablet PC technology, representations of student work were confined to the two technologies of computer and pen and paper. As such the questions arises as to whether the power to combine both these products of notebook/laptop technology and pen and paper technology in one mode with exposure to the technologies of digitisation and recording, offer more insightful opportunities for teachers to influence learning.

This question is discussed in section 5.3 where the possible implications and opportunities for both students and teachers in terms of affective and cognitive possibilities feature. One such possibility to emerge in this discussion is that, particularly from the students' perspective, and conversely for teachers, student engagement with this particular technology combination gives rise to the prospect of them receiving informed and specific timely and targeted feedback in the manner associated with "assessment for learning" approaches. More specifically the prospect is raised of insights available to the teacher on student learning that have not been extended to the pen and paper "freeform" representations of student thinking previously. The discussion here points to the student and the teacher realising an opportunity to engage in more informed and insightful ways in the manner of the objectives of "assessment for learning" (Black et al. 2002, 2011; Black & Wiliam 1998, 2009, Wiliam 2011).

This discussion then gives rise to particular reflections emerging from the study. One concerns the need to raise both teacher and student awareness of these opportunities. This reflection relates to the need for both teachers and students to be aware of, and to consciously employ, the opportunities offered by the Tablet PC to avoid the Tablet PC's use being no more of a resource than a Notebook computer.

A further reflection considers the prospect of increased learning outcomes generated from positive attitudes and perceptions (Dimension 1) which are the product of conscious instructional decisions by teachers and conscious student learning strategies designed to enhance learning. These generate positive attitudes and perceptions towards the learning experience where successful.

The study centres on the idea that the utilisation of the Tablet PC by students and teachers in the classroom provided opportunities for students and teachers to consolidate the actions of teaching

and learning in such a way that the two actions could become more symbiotic. For the activity of teaching to be successful, it is necessary that the recipient of the teaching (the student) is able to construct meaning in the process, and as such is developing new understandings. At one level there is the need for the student to feel comfortable and empowered in the process of learning. On the other hand there is the need for the teacher to pause every so often in the process of teaching and check that students are in fact constructing meaning and understand what they have been taught. This study throws some light on the opportunities offered by the use of the digital inking capabilities of the Tablet PC and associated software, through three main points of discussion which emerge from the study.

5.2. The "functional" opportunities

In this section the question for consideration concerns what functional aspects of their work the students and teachers could do with the Tablet PC that they could not do before. Further, consideration is given to the implications of the extension of the digitisation of student work from the products of laptop/notebook and pen and paper technologies to the added products of Tablet PC technology and whether this gives rise to new learning opportunities. This then prompts consideration of whether the use of laptop/notebook computer technology in education is somewhat limiting both the thinking of students and the feedback to students from teachers as a consequence of what cannot be achieved compared with Tablet PC technology.

From the data gathered (observations, student and teacher interviews and student and teacher questionnaires) there is evidence to suggest that the Tablet PC combination gives rise to a number of possibilities that become newly achievable as a consequence. These possibilities were not previously an option for teachers or students because the medium of creating artefacts of student learning was confined either to pen and paper at one level, or pen and paper and Notebook computer technology at another level. Additionally, where computer technology replaces pen and paper, the data suggests that the benefits of using pen and paper, lost when Notebook/Laptop technology is employed, can be restored in a digital format which not only replicates the advantages of pen and paper but makes the advantages of digital formatting available. These perceptions of outcomes made possible by the utilisation of the Tablet PC are the product of both teacher and students' comparisons of achieving the same objectives with the alternative resources of the Notebook computer and pen/pencil and paper.

In essence the research question here for both students and teachers was concerned with what it was that could be done with the digital pen in the process of teaching and learning, that could not

otherwise have been done with only pen/pencil and/or paper and a Notebook computer. In responding to this question an aspect of the study aimed to distinguish between the attributes of a Tablet PC and a computer notebook. The emphasis at this "superficial" level is on procedural attributes. Such attributes may be seen as representative of the concept of technology per se in that the Tablet PC enables the teacher and student to achieve what they always did but now far easier. Additionally the Tablet PC allows them both to achieve a few more objectives that represent extensions of those outcomes. Such points that emerged from the study and from all data points are discussed below.

5.2.1 The recording of student work

A reflection on the outcome of the recording of student work in the pen and paper context is that only one copy of the work is created. The Notebook computer and the Tablet PC both offer more in this context than does pen and paper in this category. Also the two technology options are generally offering equally extended options. Where there is a difference between the Notebook/Laptop record of student work and the Tablet PC record of student work is that with the Tablet PC approach, the recording and replaying of work is extended to written and "freeform" work, a format not available with the Notebook/Laptop.

5.2.2 The nature/format of the work collected

In terms of the nature of the work created and collectable with pen and paper all work that is of a freehand nature (including handwriting and drawing) is facilitated by pen and paper. However, typed text is not available through pen and paper, neither are pre-formatted shapes, objects, background paper formats, although these can be freehand drawn. It is not possible to import objects, shapes, background paper, images in the pen and paper mode and colours may be employed if the student is equipped with a variety of pen/pencil colours and highlighters.

In the Notebook\laptop mode all work of a freehand nature, (including handwriting and drawing), cannot be created and collected. Typed text does become available, as can the import of objects, shapes, background paper and images. Colours may be applied to text or lines or as in-fills. All colour tools are included in the Notebook\laptop which negates the need for students to be equipped with a variety of pen/pencil colours and highlighters.

In the Tablet PC mode all work that is of a freehand nature (including handwriting and drawing) can be created and collected and the option of typing text allows two options for "writing". Objects, shapes, background paper and images can similarly be imported and colours may be applied to text

or lines, as in-fills and over text or drawings created. Colour can be applied in a variety of contexts and all colour tools are included in the Tablet PC.

From the perspective of the nature or format of work that can be created and collected, the Tablet PC has the flexibility of pen and paper in terms of free form writing or drawing; it has capability for the more formalised typed text and importation of standardised shapes or objects. The Tablet PC thus combines outcomes available in both pen and paper modes and Notebook computer modes. DyKnow panels collected during observation and reproduced in the Results chapter, show all three modes of work (written, typed and drawn) having been created with the Tablet PC.

5.2.3 Editing work

With the editing of work, in the pen and paper model the altering of text, if written in pencil, makes editing possible. If written in ink with a pen, alterations generally require a re-write; the alternative in this situation is that the student must get the work correct the first time. The formatting of text; moving of text; or re-sizing of text in both cases requires the erasure of the original work. In the Notebook mode, alteration of text is possible, although the formatting of text and moving of text around or re-sizing it is possible only with the products created through the keyboard. Products created through the Tablet PC are obtained through both a keyboard entry and the digital pen (equated to the pencil or ink pen in the "pen and paper mode). As such the altering of text is possible for work which has been either typed or handwritten. So here the Tablet PC offers the flexibility of editing written or freehand drawings and text or inserts generated through a keyboard. In the study, students describe altering written text as being "easier" to do. For example, students felt that the erasure of "mistakes" was far easier and that was a good thing because "mistakes are bad". The ability to "erase text/writing easily and to keep to a certain level of neatness" was valued and reflected a feeling students had that they could be more efficient in the control of their notes with the Tablet PC. The experience is similar to that of the student writing in pencil where changes can readily be made to the text created without major re-writes. This capability links with other capabilities in this area of editing work.

While the point about the students feeling that they must get the work correct the first time may seem somewhat trivial, it was clear from student responses to the questionnaire that they liked to have neat work as a product of their learning and this thought impacted on their commitment to starting to write. As is noted in the "Results and Analysis" chapter (4.1.4), students reported that they engaged in writing sooner because they could edit efficiently and they could better achieve the desire for neatness and clarity in their work. The ability to create a neater, clearer written product was seen as important because such a product could be better read and understood. This expressed

reflection on the use of digital inking suggests an outcome for learning. In particular, for those students whose writing is not good in terms of legibility, the experience of writing in a permanent mode (ink pen on paper) did not result in a product which is legible even for them. The constraints to clarity of written communication were possible to overcome with digital inking.

DyKnow panels captured and replayed showed students editing their work as they were constructing it. With the question of the editing of student work the Tablet PC appeared to provide enhanced options and mitigated any ideas that Mathematics did not involve good written communication.

5.2.4 The recording of mathematical symbols

The recording of mathematical symbols was an easy function with pen and paper. It was harder to achieve with the Notebook/laptop computer as additional software was required. Such software was not evident in the case study. As with pen and paper, this function was not an issue with the Tablet PC. Here the Tablet PC offered more opportunities but this could quickly be equalised with the inclusion of mathematical symbol producing software. DyKnow panels captured in the process of observation showed the students using digital inking to record mathematical symbols.

5.2.5 The viewing of student work by the teacher

In the pen and paper context the teacher had access to original work only. Once the teacher had this work, either complete or incomplete, the student did not have access to it for the duration of teacher viewing.

In the Notebook/Laptop mode the teacher could collect a copy of work being created by a student at any time in the lesson if the work was being created in Dyknow panels. Here only typed (not written) work could be obtained and its development recorded. The student continued to have access to the typed work while the teacher has a copy.

In the Tablet PC mode, the creation of written and or drawn as well as typed work could be obtained by the teacher, in a format that can be replayed. The student had access to the typed and/or written work while the teacher had a copy. So in this respect the Tablet PC covered both written and typed artefacts in contrast to the context of the Notebook/Laptop of a typed product only. The software utilised allowed the teacher to collect work electronically, providing the student with uninterrupted access to their work. From a teaching-outcome perspective, the teacher was able to engage in reviewing a student's work, whilst the student was in the process of continuing to develop it. The software offered the opportunity for more immediate feedback on elements of work produced, both written and typed, and the opportunity to intervene in the direction a student was

developing if necessary. From a learning perspective, the teacher, through such an intervention, was able to correct misconceptions earlier. Again, the Tablet PC offered such an intervention in all formats of work creation: typed, written and freehand and extended the reach of such an intervention.

5.2.6 The utilisation of software programmes

In this study, the software that were observed being used centred on the Microsoft Office suite, particularly OneNote, and on the DyKnow software. Clearly software cannot be utilised with pen and paper, rather software can be used in conjunction with pen and paper where students are able access a "computer laboratory" for this purpose. With the Notebook/Laptop option, clearly software can be utilised but here the relationship is a "linear" one, meaning that the work product is conditional on the functions of the keyboard and only the keyboard as there are no other input interfaces available. With the Tablet PC, the utilisation of software is not limited to the functionality of the keyboard as the functionality of the pen is now involved. Some software has been designed to leverage this additional functionality and they would not function as well on the Notebook/Laptop computers.

From a learning perspective the impact of the software was the facilitation of digital inking. Digital inking then allowed the student to utilise a learning tool (the pen) in a freeform, unrestrained digital format. The software facilitated the ability to record thinking digitally thus "cross fertilising" the attributes of pen and paper with the attributes of a computer as a technological tool. The students in the study referred often to the ability to draw and create diagrams, such as graphing, as being easier in the sense that they could draw digitally in the first place and that such drawings were easily editable. This gave rise to an earlier commencement of expressions of thinking as students realised that first attempts could easily be edited.

5.2.7 Observation of student work

In "real-time" and in the pen and paper mode, teacher observation of students who were in the process of constructing meaning and providing subsequent feedback to the teacher, was possible where the teacher moved around the class. However, the teacher could only be in one place at a time and such observation was limited to one student at a time. In the Notebook/Laptop mode the teacher's range of observation could be extended through the "real-time" recording of all student work. This, when replayed, gives the effect of observing any student's work albeit at a later point, in the recorded format, additional to the "live" observation of some of those students in the class. For the teacher, the opportunities to view all student work is likely to be limited as a great deal of

data would now be available and this would be overwhelming. Notwithstanding, selective replaying of data, based on the objective of feeding back to certain students, is possible and "archived" data can be referred to in times of concern with any student's progress.

In the Notebook format, the work observed was limited to the product of the keyboard. In the Tablet PC format the DyKnow notebooks that were retrieved by the teacher during the lesson evidenced a wider feedback opportunity.

5.2.8 Teacher feedback to students

With regard to teacher feedback to students in the pen and paper mode, generally the teacher needed to collect written work to give the student feedback. This work was then not available to the student to continue on with. In the Notebook/Laptop mode teachers could feedback to students at any time in the learning process. This could be as they were working through solutions to problems, or after completing this task. It could also be before the end of the lesson, or after the lesson by collecting panels and marking them and returning later. The difference here with paper was that it was a copy of student work that was collected - the student kept the original and could work further on it. The difference with the Tablet PC was that the teacher was not confined to either viewing typed work or to giving just typed feedback. Feedback could be written, or markings of any type, (ticks, crosses, highlighting, underlining, and other symbols) could be made. Whilst the opportunity to do this existed, it did rely upon the teacher to give this timely feedback.

5.2.9 The broadening of digital capture of student thinking

In some regards the creation of a digital record and the subsequent ease of the editing and reproduction of this record, reflected computer technology's edge over pen/pencil and paper. Digital inking goes that one step further in its capacity to digitise writing, and thus capture that free form of organised creation, but also in the recordable, easily edited and reproducible manner of the Tablet PC. So the benefits of the freehand creation of work with pen/pencil and paper and the digital benefits of the Notebook computer have been combined in the Tablet PC. The edge that the Tablet PC therefore has over the Notebook computer is its affordance in recording a wider range of student products, not only text but also freehand constructed creations.

From the perspective of impacting on student learning, the digitisation of freeform content creation (writing and drawing), brings into the domain of computer technology the full range of different spatial representations of learning and capacities for learning. That is the freeform examples of writing and drawing (but particularly drawing) can now be included in the range of student products in the process and demonstration of, learning. This point is elaborated upon by Oviatt (2013) who

advances the idea that "interfaces capable of supporting more expressively rich communication also stimulate the mental effort required to generate ideas and solve problems" (p. 117).

The consequence of the extension of the type of product that could be created and recorded through the Tablet PC then give rise to opportunities that did not exist before in terms of what the student and the teacher could now do that they could not before.

Now that the freeform products could be captured in a digital format, they too could be added to the digital products of the Notebook computer which could be edited, formatted, re-sized, and re-positioned. In this study, and of particular significance in terms of digitising freeform products, was the digitisation of mathematical symbols without the need to incorporate additional software options to achieve the same. This serves as another example of the benefits of pen/pencil and paper which are often lost in the use of keyboard stroke inputs, being revived through the inking capacity of the Tablet PC.

On the other hand there are examples of the benefits of the software applications which are associated with keyboard stroke entry, now being extended to the freeform products associated with pen/pencil and paper. In this study it was noted that the use of Microsoft software such as Word and OneNote alongside other software such as DyKnow allowed the affordances of digital capabilities such as search and linking functions, to be extended to freeform products.

Both the above analysis and the Literature Review offer evidence to suggest that the Tablet PC shares many features of the more traditional notebook/laptop PC. These relate to the functions that the Tablet PC duplicates such as a keyboard, internet connectivity, use of software and many more functions. Other functions of the Tablet PC are not shared by the Notebook computer, predominantly the inking function. As such, and as posited earlier, the influences of computer technology (notebook/laptop) on student learning per se apply to situations where Tablet PCs are used. The critical difference of the Tablet PC to the notebook/laptop technology is more evident in observations of student and teacher practices. This case study has suggested that the Tablet PC does enable extensions to student communication in contrast with the notebook/laptop PC.

In Figure 3 of this study the speculation that the Tablet PC offered opportunities to both student and teacher beyond those offered by the utilisation of the Notebook/laptop computer was represented by an outer yellow shaded area, outside the opportunities offered by the Notebook/laptop. This first phase of the discussion of such opportunities involving the digital capture of freeform expression suggests that the yellow outer area of Figure 4 can be identified as being defined by these "functional opportunities". Below, Figure 4 has been edited to Figure 10 to reflect this. The inner circle continues to represent technology that was in use in the classroom prior to the advent of the

desktop computer. The educational benefits are then extended with the arrival of computer technology in the form of desktops and later notebook/laptop computers, represented by a second, inner circle. The third circle from the centre is representative of the first group of extended educational opportunities in terms of communication and development of ideas and artefacts of learning available with the use of Tablet PCs.

A fourth circle in Figure 10 highlights speculation around the broadening of digital capture and the subsequent broadening of insight into student thinking, or those artefacts of learning which cannot be created in a Notebook computer. The fourth circle derives from the third.

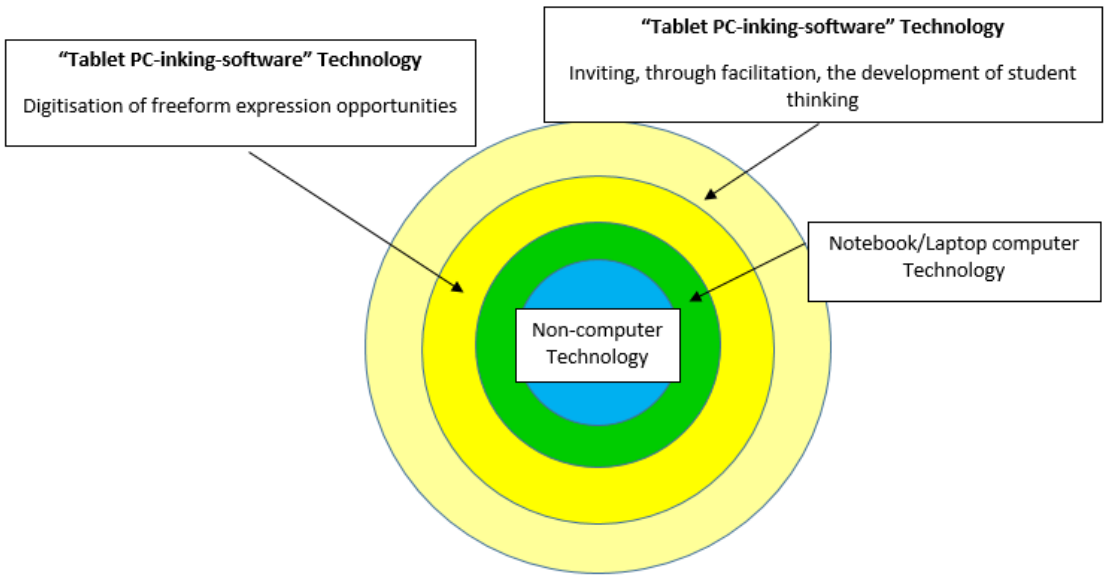

Figure 10: Growing learning opportunities from computer technology 2

5.2.10 Summary

The discussion to this point centres on the perspective of the additional functional opportunities provided by the use of the Tablet PC, with its digital inking capacity. The study identifies aspects of the realisation of the Tablet PC's role in facilitating and capturing both non-linear created student work, such as drawing, sketching, hand writing, and linear created student work, typed text and insertion of objects.

From the perspective of student thinking and learning there needs to be a flexibility in the way that students are able to conduct the process of constructing meaning and communicating this. The replacement of pen and paper technology with laptop/notebook technology removes the flexibility

of expression that students are capable of accessing. The Tablet PC restores such flexibility of expression whilst also maintaining the linear nature of expression possible with the laptop/notebook technology. For example with the Tablet PC, students were able to flexibly construct meaning through their acquisition and integration of knowledge. In comparison to the Notebook PC they were flexibly able to extend and refine that knowledge and apply it meaningfully.

The study has not sought to evaluate or measure the extent to which student thinking and learning is enhanced through the additional functional opportunities of the use of the Tablet PC. Rather the study provides some confirmation of these additional functional opportunities. In one sense it would be necessary to evaluate the idea that the laptop/notebook imposes limits to student thinking and the work of Oviatt (2013) provides evidence to support this view. From there derives an evaluation of the extent to which the laptop/notebook computer limits students' thinking and learning and the extent to which the Tablet PC overcomes these limitations.

Further to these reflections, it should also be noted that whilst the study has offered some confirmation of the additional functional opportunities of computer technology, the extent to which they are realised by both student and teacher are a crucial factor in any impact on student learning outcomes that the use of the Tablet PC may have.

5.3 Further opportunities offered by the use of the Tablet PC in the teaching and learning dynamic

This section of the discussion considers whether the combination of the products of notebook/laptop technology and pen and paper technology, allied with the technologies of digitisation of freeform expression and its recording, may offer more insightful opportunities for teachers to influence learning. Such insightful opportunities concern the digital capture of freeform artefacts of learning not possible with the Notebook PC. From the perspective of constructing meaning, one of the study's research questions centres on whether there is any evidence that the use of the Tablet PC and its digital inking capacity assist students to successfully achieve the construction of personal meaning from new information to create new knowledge. This question is a constant theme shaping this section of the discussion.

Specific aspects of the attributes of the Tablet PC arguably facilitated further opportunities for students to construct meaning. In the context of the teaching and learning framework, Dimensions of Learning, the term "constructing meaning" refers to the use of strategies that help students understand new information through association with information retained in long term memory. Marzano (2006) defines the term as a:

> *perspective of learning….based on a highly interactive process of constructing personal meaning from the information available in a learning situation and then integrating that information with what we already know to create new knowledge.* (p. 5)

With the Tablet PC the digitisation of writing means that all forms of content creation (typed, inserted or inked) can be captured and recorded as distinct from the limited content creation through computer Notebooks. Similarly content creation through pen/pencil and paper is limited to freeform content creation, which is not recorded. What then are the potential benefits to a student's construction of meaning of capturing all forms of content creation and through digital records, being able to replay that again and again?

5.3.1 Opportunities for further insights around teaching for learning?

5.3.1.1 Student Feedback to the teacher

One of the insights suggested by the study concerns the Tablet PC as a potential resource which supports the teacher's ability to obtain feedback on the objective to deliver teaching which assists students in their construction of meaning. This was evident in the case study through the data and observations concerning an individualised feedback loop which the Tablet PC opened up to the teacher.

In the absence of Tablet PC technology, student feedback is generally accessed by a teacher through a variety of strategies. One of these strategies is that of direct individual questioning in class. In the course of this strategy one student responds and provides feedback to the teacher on their construction of meaning whilst other students take the role of onlookers or listeners, or they are disengaged. Questioning strategies which put all students on alert that they will be asked to demonstrate their construction of meaning, overcome the drawbacks to single student questioning and, whilst time consuming, at least include all students. To overcome this issue of time, other strategies of eliciting feedback are possible. They include peer to peer discussion and small group feedback, whereby a group's construction of meaning may be ascertained. In this situation, however, the individual contribution to that construct, and thus the feedback to the teacher from all students, is likely to be clouded. In effect the scenario created is a miniature of the one-student response approach. Other strategies such as "traffic light" indicators, which are also available in collaborative software, are subject to questions around the sincerity of understanding that the student has. So while they might indicate understanding, through registering a "green" response, their understanding may in fact be a misconstruction which they do not realise.

The opportunity for individualised feedback to the teacher through the Tablet PC occurs as a result of the potential offered to the teacher to capture all artefacts of learning digitally. This then offers the potential for the teacher to subject digitally recorded work, which represents a wider set of data, to scrutiny and review not possible with student work or feedback in conventional pen and paper or indeed Notebook computer formats. The differential here between the Tablet PC in comparison with Notebook computers, is, again, the capacity of the Tablet PC to capture all non-typed artefacts. The study suggests that the utilisation of the Tablet PC and associated software, such as DyKnow, theoretically gives rise to the opportunity of contributing to the goal of impacting positively on student learning. The emphasis here is on "theoretically", as there is a further stage to be completed and that is the actual viewing and scrutiny of the record of student work.

Specifically the contribution indicated in this study concerns the contention that previously unavailable insights into student construction of meaning can now become available through the benefits offered through the Tablet PC package. The objective for the teacher in the teaching and learning paradigm is to teach, and the students to learn, new declarative and procedural knowledge. This needs to take place in such a way that students are able to connect this new knowledge to their prior learning and in doing so understand the new knowledge and extend their construction of meaning. Student understanding of new declarative and procedural knowledge can then be demonstrated through tasks that require them to demonstrate the ability to extend and refine their knowledge and to apply it meaningfully. Ultimately, students are required to demonstrate their understanding through a summative assessment task.

It is in the formative stage of this construction of meaning, that feedback from students to teacher and teacher to students enhances the chance that the new knowledge will eventually be correctly understood and internalised. This new knowledge can then be readily linked to further new declarative and procedural knowledge objectives. One of the strategies for facilitating such feedback is formative assessment and one of the reflections from this study of the utilisation of the Tablet PC and the use of software such as DyKnow is the potential contribution that digital inking might make towards a realisation of this strategy.

In the study, suggestions of this possibility were provided mainly from the teacher interview. When reflecting upon the dynamic in aspects of lessons involving discussion and verbal feedback from students the teacher noted that the Tablet PC and DyKnow software allowed him to check how student construction of meaning was developing:

> *…there's time for them to develop a synthesis of what they need to be able to do. There's more leeway for them to then develop consequential things – diagrams, or flow charts or whatever from that* ***- that I can review by collecting and having a look at how that is developing.*** [My emphasis].

Digital inking with the Tablet PC enabled students to create and construct meaning with computer technology. The same technology has captured this construction of meaning and provided the teacher with the opportunity to review it for accuracy while the student still possesses it.

5.3.1.2. The link between digital inking and strategies associated with assessment for learning principles.

The focus of the discussion here is to consider the confluence of the strategies associated with assessment for learning and feedback, with the potential contribution of the Tablet PC to this objective.

The concept of "assessment for learning" (Black & Wiliam, 1998; Black et al. 2002; Wiliam, 2009; and Black et al. 2011) and the propositions around the effects of "feedback" on student learning outcomes (Petty, 2009(a); Petty, 2009(b); Hattie, 2009; 2012; 2014) place an emphasis on pedagogy where teachers actively include within their pedagogy, strategies designed to provide measures or indicators of the extent of student understanding and construction of meaning**.** Just where in this pedagogical process the Tablet PC sits, parallels the question asked by Black & Wiliam (2009) of where in the pedagogical process formative interaction sits. In their response to this question Black and Wiliam acknowledged that formative assessment needed to be viewed in the context of broader theories of pedagogy. Reference is made (attributed to Perrenoud 1998) that formative assessment in the form of feedback is not the central issue but rather an element of theoretical models of learning. This insight resonates with the outcomes identified in the results and analysis of data from observations, interviews and questionnaires from this study on the potential of the use of the Tablet PC in the classroom. The Tablet PC when utilised in the context of formative assessment, is considered here through a theoretical model of learning, namely Dimensions of Learning and constructivist theories. Perrenoud's (1998) analogy in his commentary on the Black & Wiliam's 1998 paper was that *…the feedback given to pupils in class is like so many bottles thrown into the sea. No one can be sure that the message they contain will one day find a receiver"*, (p. 87).

In considering where in the context of formative assessment the Tablet PC could serve as a resource, some insight is offered by Black & Wiliam (2009). Here a rationale of formative assessment is established through the development of a framework which serves to identify and relate formative practices.

They draw upon the work of Ramaprasad (1983) who outlines three key processes in learning and teaching. Those three processes refer to establishing where the learner is going; where the learner is in their learning; and what needs to be done to get the learner to the learning destination. In cross referencing these three key processes with what are described as the "agents" involved with these processes (teacher, learner and learner peers) the framework referred to above is developed. Table 4 illustrates the unifying basis for the diverse formative practices, and is reproduced below.

Table 4: Aspects of formative assessment (Black & Wiliam 2009)

<table>
<tr><th></th><th>Where the learner is going</th><th>Where the learner is right now</th><th>How to get there</th></tr>
<tr><td>Teacher</td><td rowspan="3">1 Clarifying learning intentions and criteria for success.

Understanding and sharing learning intentions and criteria for success.

Understanding learning intentions and criteria for success.</td><td>2 Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding.</td><td>3 Providing feedback that moves learners forward.</td></tr>
<tr><td>Peer</td><td colspan="2">4 Activating students as instructional resources for one another.</td></tr>
<tr><td>Learner</td><td colspan="2">5 Activating students as the owners of their own learning.</td></tr>
</table>

From this framework five key strategies of formative assessment are identified:

1. clarifying and sharing learning intentions and criteria for success;
2. engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding;
3. providing feedback that moves learners forward;
4. activating students as instructional resources for one another;
5. activating students as the owners of their learning.

This study focused, as it is, on the potential benefits of the utilisation of the Tablet PC, offers evidence to support the view that the second emphasis, "engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding" is the area in which the use of the Tablet PC can be particularly useful and thereby assist to facilitate the subsequent aspects of emphasis.

In further defining formative assessment Black and Wiliam state that "…it is clear that formative assessment is concerned with the creation of, and capitalisation upon, 'moments of contingency' in instruction for the purpose of the regulation of learning processes", (Black & Wiliam, 2009, p. 8). These 'moments of contingency' are described as being either synchronous (real-time adjustments

during teaching or whole class discussion); or asynchronous, (teacher feedback through grading practices, homework or student summaries). This study suggests that the availability of such opportunities is extended by the use of the Tablet PC to 'moments of contingency' which occur while students are forming their construction of meaning, that is while they are expressing their understanding in response to tasks in a freeform context, writing or drawing or creating graphic organisers, for example. Such a response can be synchronous where a teacher is observing a student's response through the monitor function of the DyKnow software, or it can be asynchronous where the teacher replays the recording of the student's construction of meaning. It is suggested in this study that the 'moment of contingency' offers the teacher greater insight into the student's construction of meaning. This is because the teacher can observe the creation of the written record and so have additional information on how the student came to construct their meaning.

Black et al. (2011) contend that improved academic standards can be achieved by implementing formative assessment in the classroom for the purpose of providing feedback to both students and teachers on the effectiveness of teaching and learning experiences. Such feedback to students is identified by Hattie (2009, 2012) as having amongst the highest impacts on student learning outcomes. Studies highlighted by Black (1998) showed that improved formative assessment helps low attainers the most and reduces the variation in levels of attainment whilst raising it overall.

The work of Black & Wiliam (1998) in particular identifies characteristics of a teaching and learning paradigm that need to be evident for assessment for learning principles to be effective. Their work on assessment for learning highlights that, (p. 14):

- Learning is driven by what teachers and students do in classrooms.
- The prime focus for raising standards is the classroom.
- Standards can only be raised if teachers can tackle the task of raising standards more effectively.
- The over-arching priority has to be to promote and support change within the classroom that results in raising standards.

At this point in the discussion, and at a superficial level, the utilisation of the Tablet PC within the classroom resonates with these broad and very general teaching and learning characteristics. Certainly the Tablet PC has a classroom focus, with a view to enhancing the construction of meaning and thus "raising standards". The effectiveness of the Tablet PC in this respect, however, does rely on teacher effectiveness and consciousness of the use of the Tablet PC and meeting the need to support teachers in this respect. This is a point outlined further on.

The data collected from the observations, interviews and questionnaires provides some evidence of the Tablet PC being instrumental in assisting in the development of new modes of pedagogy. Such

pedagogy, Black (1998) implies, is the means by which teachers can improve academic standards. That teachers approach teaching with a view that all students can learn and assessment for learning strategies assist in the realisation of such a view. Specifically this involves developing new ways to enhance feedback between those taught and the teacher. The evidence of student panels being collected by the teacher in order to review student understanding of mathematical concepts; the traffic light signalling facility; the use of "student to teacher" and "teacher to student" chat; and the opportunity to replay student construction of their artefact of learning are all examples of such evidence. This evidence is referred to in the "Results and Analysis" chapter.

These possibilities seem to reflect Black's new modes of pedagogy and significant changes in classroom practice. This approach implies an awareness of the assumptions about what makes for effective learning and in particular in this regard that students have to be actively involved. It also implies that tasks are justified in terms of the learning aims that they serve. These implications are not the preserve of the use of Tablet PC's, however, Black does point out that such implications can only work well if opportunities for pupils to communicate their evolving understanding are built into the planning of tasks and the Tablet PC seems to facilitate opportunities to achieve this beyond classroom dialogue.

The evidence suggests that the Tablet PC has a role to play in establishing another opportunity for a formative assessment process where the results of assessment are used to adjust teaching and learning. Black indicates that a significant aspect of any programme will be the ways in which teachers do this and the use of the Tablet PC has the potential to be one of those ways, providing that they use it in this way.

Black claims that many educational innovations have developed self and peer-assessment by students as ways of enhancing formative assessment. This, it is stated, requires students having a sufficiently clear picture of the teaching targets that their learning is meant to attain. This is a feature which does not require the use of a Tablet PC. Where this is established, it is suggested that students then become more committed and more effective as learners as their own assessments become an object of discussion with their teachers and with one another. It was observed in this study that the teaching targets were communicated to students through the Tablet PC, thus ensuring that they had an accurate record of what they were. In the process of engaging in the solution of mathematical problems, the students were able to reflect back on the teaching targets as they were elaborated. In other words, the construction of the problem solving strategy could be replayed by the students so that they could not only see the objective but that they could also see how that objective was achieved and its undertaking constructed in a step by step, practical way. Thus, in this

way a student's reflection on their own ideas contributes to what is regarded as being essential to good learning.

For teachers applying assessment for learning principles, Black contends the question they need to ask is whether they know enough about the understandings of their students to be able to help each of them. The evidence of the insights that the Tablet PC can give to teachers is referred to in the Results and Analysis chapter as the recording and capturing of the full range of student artefacts of learning. This evidence suggests that the Tablet PC can make a contribution to this objective. In this case study the observed and captured evidence of the ability of the teacher to replay the student manifestation of their thinking and solution solving processes, pen stroke by pen stroke, gives the teacher a unique insight, contributing to the clarity of their perception of the level of understanding of a student. The teacher can identify any prevarications involved in the creation of solutions through the gaps in time of recorded pen strokes. Additionally the teacher can see when uncertainties arise, when the students are thinking about solutions, or where adjustments are made, where responses are altered and edited; and finally the teacher can see how the finished solution was constructed and identify exact points of error.

Documented in the Results and Analysis chapter was the evidence provided through observation and also the capture of student panels of situations where the student, set a task to solve, was able to see the teacher's solution to the problem unfolding on his Tablet PC as a result of its transmission from the teacher's Tablet PC. The teacher's solution to the problem was revealed to students sometime after they had started working through their understanding of how to solve the problem themselves. This allowed students to see how the solution was constructed and self-diagnose, if they had gone wrong, where they had gone wrong. Conversely students who had the correct solution were given immediate feedback confirming this. These examples exemplified the concept of "timely and targeted feedback" for students. So the facilitation of an insightful diagnosis by both the teacher and the student into error identification was evidenced in the case of this study.

A further characteristic of a teaching and learning paradigm that needs to be evident for assessment for learning principles to be effective, according to Black and Wiliam, concerns the characteristic of teaching through formative student and teacher interaction. This characteristic is seen as necessary in order to develop each student's power to incorporate new facts and ideas into their understanding. Teaching through formative interaction in the classroom is intended to develop a classroom culture of questioning and deep thinking in which pupils learn from shared discussions with the teacher and from their peers. This feedback is distinguished from that related to the marking of student work which is usually conscientious but is missing the insights of classroom discussion. One of the issues, however, of the classroom formative interaction is the problem

associated with the teacher's intended meaning during the discussion and the meaning interpreted by the student which can then give rise to a misconstruction of that meaning. The evidence provided by the teacher in the Results and Analysis chapter suggests that the Tablet PC offers the potential to mitigate this issue. The teacher referred in the study to the way in which the use of the Tablet PC allowed him to create a structure for students to construct meaning. The Tablet PC then also facilitated the monitoring of the resulting work of the students either synchronously or asynchronously. As the teacher put it, he could monitor how a student's construction of meaning was developing.

The study of the use of Tablet PC's in the classroom offers a means by which many of the necessary characteristics of the teaching and learning paradigm giving rise to improved academic standards can be realised. The opportunities offered by the Tablet PC in the classroom that were evident in this study and which assist in the potential realisation of aspects of this required paradigm described in the literature on improving academic outcomes, are discussed in the next section.

5.3.2 How does the Tablet PC contribute to effective student and teacher feedback in the teaching and learning paradigm?

The study suggests that the Tablet PC offers evidence of further feedback opportunities from the perspective of both students and teachers. From the teacher perspective there are insights into the students' construction of meaning through the viewing of the recording of the creation of all student work, in all formats. From the student perspective there is the opportunity to receive teacher feedback whilst retaining work which is still being developed.

What the study offered in this context were examples of what the teacher and student did do. What was also apparent, and is addressed in this discussion, are the possible opportunities based on what was done and evidenced. Thus included in the discussion, are potential extensions of what was evidenced through the study. It is suggested that these extensions could be the focus of further study into the relationship between assessment for learning approaches embedded in a teaching and learning framework and the use of the Tablet PC in the classroom.

With regard to teacher insights on student construction of meaning, this objective of the teacher seems simple yet it is not often readily achievable because of the limitations of insight available to the teacher. Through the construction of digital freeform content, students provide evidence of their construction of meaning which surpasses that previously available to teachers because this digital evidence is recordable and thus can be replayed. In such a mode the teacher is able to provide feedback on the manner of construction of the artefact of learning. The artefact of learning can be viewed in a temporal manner, that is, the teacher can view the actual sequences of student

construction of the artefact of learning and thus gain some insights into their development of their work. The emphasis here is on the insights gained from the physical evidence of that construction which includes edits and corrections, erasures and discarded work leading to the finished product. This attribute of the Tablet PC serves as an example of a technologically assisted way to enhance feedback between student and teacher through new modes of pedagogy in which students are actively involved.

The study suggests that additional teacher insights of students' construction of meaning take the form of additional signals or clues available for the teacher to interpret. In the context of the pen/pencil and paper paradigm, the teacher is in the position of needing to move around the class to get a sense of how well students are constructing meaning. They can only view one student at work at a time and would rarely get to see every student. Where the teacher seeks to view as many students as possible in this situation, the observation is necessarily relatively cursory and certainly not sustained for the period of student demonstration of understanding.

In the context of the notebook computer, the teacher can also employ the technology which records student products. The difference, however, is that written or creative work is not possible to generate through the linear nature of keyboard stroke inputs. In that situation only typed or imported shapes/objects can be captured in the recording. Student references, in the interviews and responses to the questionnaire in the study, to their capacity to annotate and edit readily with digital inking suggest that without the digital option, students tend to prefer working through solutions in pen and paper. As noted, work captured by pen and paper is a process whose construction cannot be captured and readily observed in its entirety as it is constructed.

This study illustrated that with the use, in this case, of DyKnow software all student work could be captured simultaneously, including erasures. This serves to give teachers insights into, potentially if not realistically in the case of all students, the work products of each and any student while they were in the process of solving solutions. More realistically, those insights are into the work product of any one or more students with the choice of student or students being unrestricted. For the teacher this represents the type of feedback suggested in the literature on assessment for learning outlined by Black & Wiliam (2009), necessary for improving student outcomes. Such insight assists teachers to know whether students are operating with taught declarative and procedural knowledge in a manner which shows that they have an understanding of the concepts, generalisations or principles involved. Clearly the teacher is not in a position to review each and every student's recorded products, but having a record of every student's work means that they can target any particular student whose previous academic outcomes data shows them to be relatively weak on understanding.

The additional flexibility of the appropriate software use is that this feedback to teachers can occur at any time in the student's practice in their construction of meaning. Further this feedback to teachers can occur in such a way that the student is not disrupted in their work with the work being collected electronically without any action required of the student and without removing it from his possession. As such the student can carry on with what they are doing and always have their work with them. At the same time the teacher can have access to that work and review it and feedback on it at any time without the pressure of having to review work quickly in order to minimise the hold-up for the students. The result is that the students are not kept from the products of their learning for any period of time.

The keyboard entry format of student products may equally be captured in the same manner as digital inking. The difference in this situation for the teacher is that the feedback that they are able to give would have to be the same as the format received - that is the format of keyboard strokes. Just as the digital pen offers students more options to create their work, so the digital pen offers the teacher more options in providing feedback. There is no restriction on the format of the feedback that teachers can give with the digital pen. Indeed the digital pen lends itself to a practice that many teachers will be familiar and more comfortable with – the freehand written comment, underlining, and highlighting, editing and general marking. Just as the teacher might have written on submitted student scripts, where these scripts were in the paper format and the teacher marking was with a pen, so, with the digital pen, they can mark just as freely on a digital copy of work submitted.

The practicalities of following through on the possibility of ongoing feedback, as distinct from marking summative work, are limited to a few students in reality. The teacher will be overwhelmed with artefacts of student work and it would be an impossibility to provide feedback with regard to all students, given the current contact loads teachers have with students. In this case study the teacher had a reduced teaching load due to added responsibilities allocated to the teacher. Contact with five classes of around 25 students over five - 45 minute lessons, offers the prospect of 625 artefacts produced each week! Teachers are, however, able to target students they feel need such insightful intervention in situ or during the next lesson and they may also respond more insightfully to student or parent inquiry around the question of how they might progress in their construction of meaning of the subject discipline. Such a response, in situ, was observed in this study when the teacher collected a copy of the work from students electronically who were subsequently able to continue with ongoing work. The teacher, upon reviewing responses collected, then went to the students at their desk who he had noted had applied incorrect solutions. (See section 4.2.7 Feedback)

One of the areas of potential development here, which was not observed in the study, is the equipping of students with the metacognitive skills to "self-diagnose" in a manner similar to that observed where the teacher provided the solution digitally while students were working through it. Certainly students would know where they went wrong, the important point here, however, would be their need to understand where they went wrong. The work of Black and Wiliam once again offers some solutions and strategies to this question of feedback to all students which can be adapted for students working in the context of the Tablet PC.

Black & Wiliam (1998) refer to an assessment for learning strategy where students peer review each other's approaches to problem solving. At one level digital inking offers a greater opportunity of exposure of student responses to another student, supplementing what the teacher can reasonably do. It was observed in the study that the software used enables the teacher to group students virtually and anonymously. The teacher is in a position to review the top-five students' work. Such a determination of these students would be derived from previous academic data. In this process it would be possible to confirm that the prior data is predictive of successful further construction of meaning. When the required number of "experts" has been determined they can be utilised as "team leaders" for the peer review. All students can now be engaged in blind peer reviews with a group leader who has successfully understood the task.

Continuing with the parallel being established here with the work of Black and Wiliam, carefully grouped "successful" students will be able to identify errors in their partners' thinking processes through comparison with their own thinking. The process of explaining to peers where they have gone wrong and why they have gone wrong also helps the successful students themselves. This is because they have to reflect on the depth of their own understanding and communicate this. This process reinforces the procedural skill of practicing and internalising understanding for themselves. This strategy does, however, require an accurate identification of the successful students and a certainty about how they came to the correct solution as they serve effectively as agents for the teacher.

The DyKnow software and the capacity to digitally ink facilitate this strategy through grouping students virtually. The group leader is able to use digital inking to annotate the panels being reviewed in the same manner that the teacher might. The annotated panels can be saved by all members of the group. This allows an active, small group, review of understanding.

The study suggests that from the perspective of feedback, this is available to both the students and the teacher because work generated in a digital format is recordable. As such all work can be reflected upon and feedback given in the context of how it was created as well as feedback on the

final product, with the former building to the latter. This functional aspect of the Tablet PC lends itself well to assessment for learning strategies designed to enhance learning. Of significance here, however, is the capacity of both the teacher and the student to capitalise on the suggested opportunities to employ assessment for learning strategies with the Tablet PC.

5.4 The importance of student and teacher leverage of the digital inking capacity

One of the considerations that this study highlights is the importance of both the attitude and perception of the teacher and the students towards the utilisation and value of the act of creating digital content with the Tablet PC. In this study the teacher in question was a risk taker in terms of being prepared to explore the opportunities offered by the combination of the Tablet PCs and as such the ideas that he articulated and the utilisation of the Tablet PC observed need to be qualified by this point. It is a point that is significant when consideration is given to the possibilities of what was observed as being achievable by other teachers. What is suggested here is that the opportunities raised in this study of the use of the Tablet PC are only realised when students or teachers, or preferably both, utilise the digital pen and software and record the creation of content. If the digital pen is not utilised by the student then the content which can be captured is limited to typing and insertions, with freeform content creation recorded on paper. Additionally, if the digital pen and software is not utilised by the teacher then the opportunities to capture the creation of content which occurs spontaneously and often recorded on the Whiteboard is not available to replay and re-live the teaching moment. In such a context the Tablet PC is effectively a Notebook computer with inking capabilities which are not used, and where paper notebooks still abound. This issue was noticeable in the observation of lessons. Consideration, therefore, needs to be given to why teacher or student or both might not employ the digital inking tool.

5.4.1 The factors driving or inhibiting the use of the digital inking aspect of the Tablet PC

Students' use of the Tablet mode of the Tablet PC and thus their access to the digital inking capacity of the technology was shown in the study to be influenced by three factors: default responses to the use of the Tablet PC; perceptions around the neatness of digitally created written work; and the imperative to use the digital pen.

The first of these factors concerns the students' default actions when bringing the Tablet PC into use. The questionnaire revealed that when students opened up their Tablet PC's, 69% started work in the Laptop mode. This tendency was supported in class observations. Where the student could type, rather than write, at the onset of working, this seemed to be their preference. This preference may be derived from the student's familiarity with the use of computer technology, either in the form of the desk-top or the Notebook where, of course, the Tablet mode was not an option. Such a

suggestion was not evident from the student interviews or questionnaires and is a point which would need further testing to be confident of its influence.

Evident from the student responses was a second factor which was likely to have been an influence on the nature of the initial student engagement with the Tablet PC. This second factor concerned student perspectives on the standard of their own handwriting. It was a perspective that was associated with their experience of a difficulty in writing neatly on the glass surface of the Tablet PC as compared to writing on paper. Reference was also made to the neater and faster product of typed work. A preference for writing on paper rather than the glass surface of the Tablet PC; the idea that typing looked better; that all could be done on the keyboard; and that typing was a faster activity than writing were points expressed in 24% of responses to the question around why the use of the keyboard was preferable to the digital pen.

From the observations of the students in the class, however, the shift from this default Laptop mode to a Tablet mode occurred naturally, in terms of there being no directive from the teacher to do so, rather the student made this move when he realised that this was a necessity. This realisation, the third factor influencing the choice of mode of use of the Tablet PC, was a consequence of the imperatives of the work and is supported by the student responses to the questionnaire. For example there was an 81% response to the question asking if there was any work that could only be completed with the digital pen and not with the keyboard.

The imperatives to use the digital pen, or conversely the failure of keyboard entries to achieve what the students needed to achieve, were varied. From the questionnaire, such identified imperatives were: the need to highlight (58% of the group); marking in the form of underlining, circling (58%) and annotating (33%). Where students had their text book in a digital format (56%), 83% of them used digital ink on the digital text. So here, where an action could not be performed through the input of a keyboard, the student moved immediately into the Tablet mode and began to engage the digital inking aspect of the Tablet PC.

From the study then, it is suggested that student use of the Tablet PC in the Tablet mode is influenced by their familiarity with computer technology. Prior to the Tablet PC, students were familiar with desktop computer technology and pen and paper technology. The Tablet PC presented a new modality and students were still adapting to this unfamiliar modality. When students are being encouraged to apply new processes in their learning, this is only successful where the teacher models the new process. Teacher modelling of the new processes involved in the use of the Tablet PC is therefore necessary to fully realise its potential to impact on learning.

5.4.2 Teacher impact on the engagement of students with the Tablet PC

The question of effective teaching with technology is the subject of the work of Mishra & Koehler (2006, 2008). Here some of the essential qualities of teacher knowledge required for technology integration in teaching (2006, p. 1) are identified. The authors' acknowledge the role of subject discipline content knowledge and pedagogical knowledge and the combination of both based on Shulman's idea of subject discipline described as pedagogical content knowledge (Schulman, 1986). Their contribution is to associate technology knowledge with content knowledge and pedagogical knowledge to identify what they call technological pedagogical content knowledge (TPCK), described as truly meaningful and deeply skilled teaching with technology (2008, p. 17). Their work emphasises the need for teachers to consider how technology, in this case the Tablet PC and associated software, can help both them and their students understand the subject discipline better than they could before. This perspective goes beyond the goal of utilising technology to enable themselves and students to do what they have always done, albeit in a more efficient and effective manner.

The teacher concerned in this case study has previously been described as a risk taker in terms of utilising the Tablet PC in his lessons, although he was by no means a teacher coming from the perspective of technology as a new overwhelming dimension to his pedagogy. It was evident, however, that the teacher has taken the time to familiarise himself with the Tablet PC and had sought to question how the technology might assist him in his teaching and learning goals. Thus there was clearly, as evidenced in the teacher interview for example, a comfort with the Tablet PC and clarity around how it would assist him and his students in the intention of achieving intended learning outcomes.

In his interview the teacher pointed out that it was very important to establish strict or formal guidelines along with the necessary processes being in place. He confirmed the point referred to in the previous section that the unfamiliar nature of the technology was the cause of this need. He identified the Tablet PC as a new technology requiring a new pedagogy. It also required the establishment of a new base line of skills. With the digital pen was needed an understanding around how it will be used at different moments in the learning process. As the teacher modelled the use of the Tablet PC he felt that its application had an impact on student learning. He noted that once the procedural skill was in place and once the expectations of the use of the digital pen were understood by the students, a collaborative way of teaching with the students was established. This was met by some appreciation by the students, according to the teacher, as the teacher proceeded to feedback to his students. As they made mistakes he was able to correct them in a timely manner. The integration of assessment for learning was a feature here.

Teacher direction with regard to how the Tablet PC should be used by students and the modelling of this, establishes for the students a sense of comfort with using the technology. In the context of the teaching and learning framework, Dimensions of Learning, this need reflects the strategies outlined in Dimension 2 with reference to embedding procedural knowledge with students. Of particular note here, though, is the need for the teacher to have an awareness of what it exactly is that the Tablet PC can enable, that was not available before. What the observations and interviews revealed, as previously mentioned, was the potential to obtain a greater insight as to where students are in their learning journey and greater insights into any misconceptions that exist. However, teacher awareness of this capability needs to be raised so that the teacher engages the students with the Tablet PC with this intent in mind**.** For the Tablet PC to have this influence it is vital that the teacher plan to use it in this way, amongst the other possible uses. It is also important for the Tablet PC to play a role in learning that it integrates well as a technological tool with the teaching and learning framework that learning is organised around.

5.5 Analysis from a 'Dimensions of Learning' perspective

From a teaching and learning framework perspective and, in the case of this study, the teaching and learning framework, Dimensions of Learning, the study offers evidence of varied levels of contributions made possible through the use of the Tablet PC. These contributions are discussed through the criteria of each Dimension considered in terms of the extent to which the data suggests they assist the teacher to achieve the intended outcomes which are the focus of each Dimension. The question here was whether the use of the digital pen gives rise to additional opportunities to successfully realise strategies associated with the framework. These strategies are designed to focus student and teacher practices on constructing meaning and lead on to deeper, higher order thinking.

5.5.1 Dimension 1:

Dimension 1 has the stated focus of helping students develop positive attitudes and perceptions about the classroom climate, through acceptance by teachers and peers and through experiencing a sense of comfort and order with classroom tasks. There are then two distinct aspects to Dimension 1. With the first aspect, classroom climate, feeling accepted by teachers and peers is very much associated with affective behaviour. The strategies identified in the Dimensions of Learning Teachers Manual, (Marzano et al., 1997) for establishing classroom climate objectives are elaborated in some sixty-two examples. What is clear here is that the digital pen serves a purpose in the same way as pen and paper would. It offers flexibility in the creation and illustration of student thoughts which have been elicited which is a common activity amongst the sixty-two strategies. The facilitation of freeform responses with the digital pen and the opportunities associated with

digitising such responses are all achievable in this Dimension. In the study, however, the use of these strategies was not so apparent and consequently the use of the digital pen for the purpose of achieving classroom climate objectives were not so apparent. To a degree this may have been due to the stage of student learning that the students were at with their course. Collection of data from the very first lessons that the students had with their teacher would likely have provided more opportunities to evidence the teaching and learning of these strategies with the use of the digital pen.

Helping students develop positive attitudes and perceptions about classroom tasks, the second aspect of Dimension 1, is achieved through students perceiving tasks as valuable and interesting; students believing that they have the ability and resources to complete tasks; and students understanding of and being clear about tasks. The second area, students believing that they have the ability and resources to complete tasks, is one the Tablet PC has an additional contribution to make. The strategy of providing targeted feedback in order to assist in the student's construction of meaning is evident in the study. It is the proposition of the study that the feedback is enhanced with the capture of freeform artefacts of learning which in themselves represent more comprehensive evidence of student thinking than that evident from Notebook computers. Being better informed of student thinking gives the teacher a greater opportunity to develop a student's belief in their ability to complete tasks.

5.5.1.1. Other issues Impacting on Dimension 1

Issues in this category relate to what could be referred to as transitory issues as they represent particular instances of events or perceptions associated with getting used to an action. An example of such an issue was the feeling expressed by some students in their interview who indicated difficulty with writing with the stylus on glass. Students indicated in their interview that this was a new experience and some found it uncomfortable. Another transitory issue concerned a psychological mistrust of the Tablet PC technology to keep a student's work. Some students had experienced loss of work, for reasons associated with failing to adhere to practices that need to be followed when working with computer technology, such as backing up work. Such issues could be associated with learning in that they tended to work against the sense of comfort and security necessary for students to engage freely in their learning experiences. Where dwelt upon they tended to work against the Dimension 1 focus.

5.5.1.2 Engagement on task

There were a number of generic issues that were observed in the study or that emerged from the interviews. From the observations it was evident that the Tablet PC offered students the opportunity

to access web sites to which they were not directed or which were not related to the subject at all. Only one instance of this was observed through monitoring student Tablet PC's remotely. This is a function of the DyKnow software which allows a supervisor to observe what students are doing on their Tablet PC by giving thumb-nail images of their computer screens. This possibility is only an issue where the teacher does not apply a viewing plan for the students' Tablet PC. It is possible to control exactly what the student can access by denying them access to software or internet other than that software which is to be used, or web-sites that students will be asked to visit. In the observations undertaken there was no evidence of viewing plans being implemented. Whilst one example of being off task was identified, it is likely that there were other instances, however, the general observations and panels captured indicated that a great number of students were on task. The point here, however, is that without there being an engaging or demanding learning episode, or without the restraint of a viewing plan the temptation to be elsewhere in thought is readily achievable. The Tablet PC, in this instance, could be seen to be the equivalent of gazing out of the window. However, this point is one which applies to all computer technology with web site access and not just the Tablet PC. Issues associated with controlling student use of computer technology arise because of the alternative opportunities, such as online games, available to students.

5.5.2 Dimension 2

Dimension 2 has the stated focus of students acquiring and integrating knowledge. Such knowledge is defined as being either declarative, which is achieved through the phases of constructing meaning with information, organising information and storing information; or procedural, which is achieved through the processes of constructing procedural models, shaping those models and internalizing the processes such that they become automated.

For students to be successful at acquiring and integrating knowledge the acquisition of both types of knowledge is necessary, otherwise the use of newly acquired knowledge is limited. Procedural knowledge requires learners to perform the steps of a specific process. Declarative knowledge requires recall, but for that recall to be appropriately applied it is necessary for the students to understand as well as know. Successful acquisition of declarative knowledge enables the student to know how and when to use successfully acquired procedural knowledge.

In the observations, both declarative knowledge and procedural knowledge was observed to be delivered to the students through the medium of the Tablet PC. For example, in one observation the declarative knowledge concerned calculating the distance between two points. The declarative knowledge here involved knowledge of Pythagoras' Theorem, whilst the procedural knowledge concerned how this Theorem could be used.

The role played by the Tablet PC here was to automate the recording of the teacher's elaboration of both the declarative and procedural aspects of the knowledge being acquired. This served to provide two functions. The first was to remove the necessity for the student to copy such an elaboration from what would ordinarily have been an elaboration on the Whiteboard. Such a process focuses the student on the mechanics of copying the elaboration and in some cases being frustrated in this process, as was indicated in one student interview, rather than offering the student the opportunity to follow the logic of the elaboration. The second function offered was that of the opportunity to replay the process of elaboration at a later time. This second function was never observed in the context of a lesson, the only arena of observation, but is referred to in the student and teacher interviews.

From the point of view of assessment for learning, the strategy of requiring students to practise the application of particular declarative knowledge to a particular procedure which is designed to solve a question, the Tablet PC offered the teacher opportunities to view student progress. In some instances this opportunity occurred during the lesson, and in others, this opportunity occurred between lessons as a consequence of the recording function of the software.

The observations also confirmed that the technology of the digital pen was purposely used in this process of applying declarative and procedural knowledge to solving questions. For example from observations, students were seen to organise information by creating freehand diagrams such as drawing parabolas and graphs, which were easily editable.

The student ability to replay the experience of content created by the teacher as many times as they want has the potential implication that the student can "practice" the experiences of processes modelled. If this is indeed carried out by the student, the consequent implication here is that the student will better internalise the process, as a result of repetitive exposure to the procedure. Where successful the student has the opportunity to shape the acquired procedure as they commit the process to long term memory.

5.5.3 Dimensions 3 and 4

As a generalisation, Dimension 3, extending and refining knowledge and Dimension 4, using knowledge meaningfully; were not observed and as such the opportunities offered by the Tablet PC cannot be commented upon. What was observed was an emphasis on Dimension 2 on practising the procedural aspect of the process. On occasion it was observed that scenarios were created as mediums for the application of declarative and procedural knowledge. For example:

> *If the length of a paddock is 2 metres more than its width and the area is 48m squared, find the length and width of the paddock.*

So no analysis of the declarative or procedural knowledge with a view to making new connections, discover new meanings, gain new insights or clarify misconceptions was attempted. Similarly the declarative and procedural knowledge was not applied meaningfully in the sense of decision making; problem solving of constraints or limiting conditions; invention; experimental inquiry; investigation of an issue; or a systems analysis. A longer study of a unit of work where these Dimensions are consciously delivered to the students would be necessary to consider what the Tablet PC has to offer there.

5.5.4 Dimension 5

Dimension 5, which concerns productive mental habits, was observable in the context of the teaching and learning of declarative and procedural knowledge. Dimension 5 is concerned with the mental habits of critical thinking. These habits focus on three groups of behaviour. The first group is concerned with being accurate and seeking accuracy; being clear and seeking clarity; maintaining an open mind; restraining impulsivity; taking a position when warranted; responding appropriately to others' feelings and level of knowledge. The second group is entitled creative thinking and covers the habits of persevering; pushing to the limits of knowledge and abilities; generating, trust, and maintaining personal standards of evaluation; and generating new ways of viewing a situation that are outside the boundaries of standard conventions. The third group relates to self-regulated thinking and includes monitoring thinking; planning appropriately; identifying and using necessary resources; responding appropriately to feedback; and evaluating the effectiveness of actions.

Of these mental habits, being accurate and seeking accuracy was observed both in the context of seeking to get the correct answer and in the clarity of work. The Tablet PC helped with the second objective, with the students able to edit fairly easily any written or drawn work. However, it was mainly in the area of self-regulated thinking that the Tablet PC was observed to offer opportunities in the aspect of Dimension 5. The use by the teacher of sections of the working panels for providing correct solutions allowed the student to monitor their own thinking and to correct this where a discrepancy was noted. The question of whether this was just a mechanical response to the teacher's solution, and whether the student understood why their attempt was incorrect, was evidenced by the requirement of students to complete a reflection section after the solution had been provided. This offers the teacher, upon replay, the opportunity to not only observe the student's first attempt at a solution and their subsequent correction but also whether they understood why they went wrong in the first place.

5.6 Conclusions

During the case study it emerged that the anticipated opportunities offered to both teachers and students with the utilisation of the Tablet PC in the classroom were in fact very much a factor of technology being able to facilitate previous practices in a digital format. This then gave rise to the reflection that what the Tablet PC actually did, from this perspective, was to facilitate a return to writing and drawing as a major generator of learning artefacts as distinct from that artefact being generated by the keyboard. In the previous context of keyboard digital creation there was obviously a need for pen and paper to fill the gaps in recording learning artefacts that the linear keyboard could not generate. What was evidently clear in the observations and in the capture of student work was the ongoing use of the computer technology during classwork. At times students would start to employ the Tablet PC in its laptop mode while it was possible to use the keyboard as the method of responding to tasks. As soon as there was a need for the more free form response, or more importantly, a response that was not deliverable by the keyboard, the students went into tablet mode. Teacher insistence that such responses were made in the DyKnow panels forced the choice of the Tablet PC as the medium here, rather than the student note paper. The students could understand that the teacher wished to capture their work digitally and did not want the pen and paper hard copy.

Thus one of the conclusions of this study is that the Tablet PC offers students the opportunity to digitise all writing and drawing and as such access all the opportunities that digitisation offers. At the same time students can still use the keyboard entry to provide neatly typed text.

What also emerged as this study progressed, particularly evidenced in the observations and the capture of DyKnow notebooks and panels, was the opportunity offered by the use of the Tablet PC to contribute to any intention to apply assessment for learning principles to the teaching and learning dynamic. Use of the Tablet PC offers an opportunity to capture student work and replay this with a view to identifying whether students have understood something. This then offers the opportunity to shape the focus of the next lesson, where the captured panels cannot be replayed in lesson time. The proviso here though is teacher awareness of this opportunity and the will to utilise it, otherwise the opportunity does not exist for them.

5.6.1 Implications of the Study

For teachers this study suggests that the Tablet PC with its digital inking and associated software can assist the teacher's insight into student construction of meaning. In doing so the teacher is likely to have a greater insight into student errors in their construction of meaning. With this knowledge teachers can be more accurate and focussed in the corrective feedback that they offer to their students and as such their feedback should be timely, targeted and effective. The outcome should

then be that learning intentions are realised. A clear limitation, however, is the extent to which such feedback can be given. It is likely that time constraints will prevent the teacher from being able to review all students' recorded work and give feedback, at least in the conventional mode of marking. Were teachers to be more targeted in their feedback to students, such as seeking evidence of extension and refinement of declarative and procedural knowledge or meaningful application of such knowledge, the marking of student work would be associated more closely to the understanding of concepts and meaning. If, as Wiliams (2009) asserts, assessment for learning is an effective strategy for improving student learning outcomes, the Tablet PC may be a useful resource to this end.

As such the diagrammatic representation of the original perception of the opportunities offered by the utilisation of the Tablet PC in the classroom has been extended, (and identified), once more from the original:

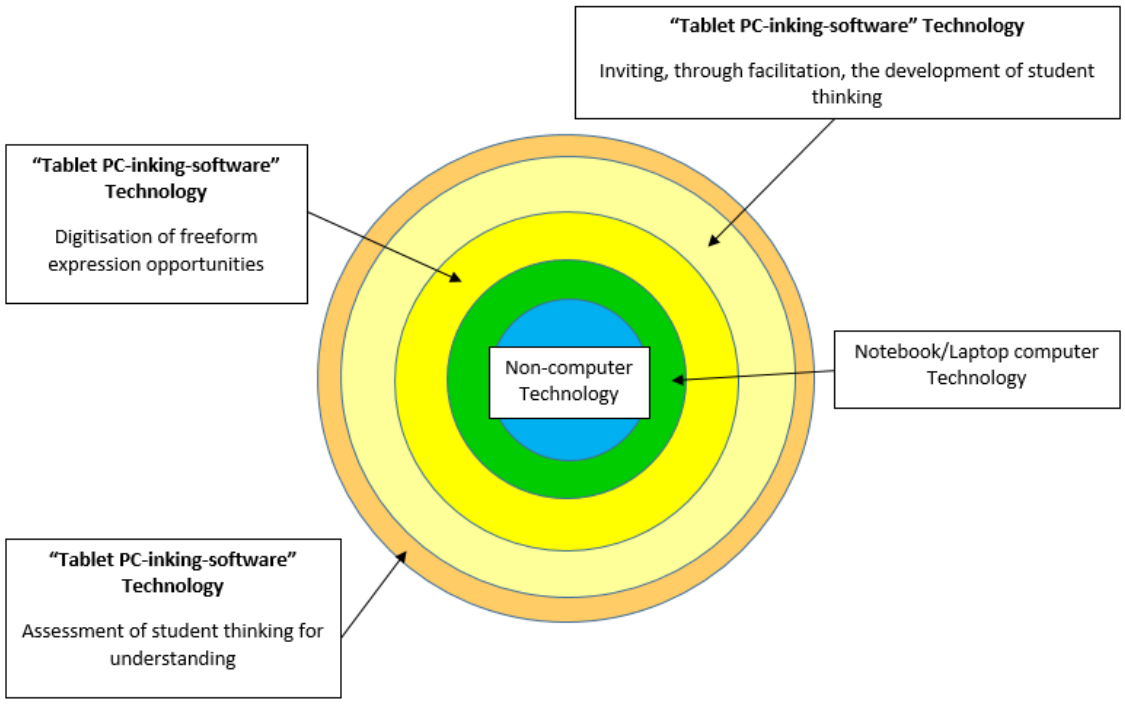

Figure 11: Growing learning opportunities with computer technology 3

For researchers the study suggests that the opportunities offered by the utilisation of the technology of the Tablet PC and associated software go beyond the usually hoped for opportunity of more efficiently being able to do what has always been done before, without computer technology. Student learning based on pen and paper operates within a context of accessing content that is printed and whose accessibility is restricted in some ways. With computer technology the access to content is far broader and the student product can take an equitable printed format. With Tablet PC

technology the attributes of writing and drawing with pen and paper and the attributes of computer technology are now combined. The options for students are far greater than they were before because the differences between them are incorporated in the Tablet PC technology. The digitisation of writing and drawing is a differential which then gives rise to the question, at one level, of whether writing is an advantage to typing, or at another level whether writing and drawing and typing is an advantage over the former option. That writing enables the student to utilise such options in a more individualised and freeform way than typing, was illustrated by one response that made reference to increasing or shrinking the size of writing and drawings/tables and to be able to create room or emphasise something, as being easier with the pen.

This general idea is illustrated below:

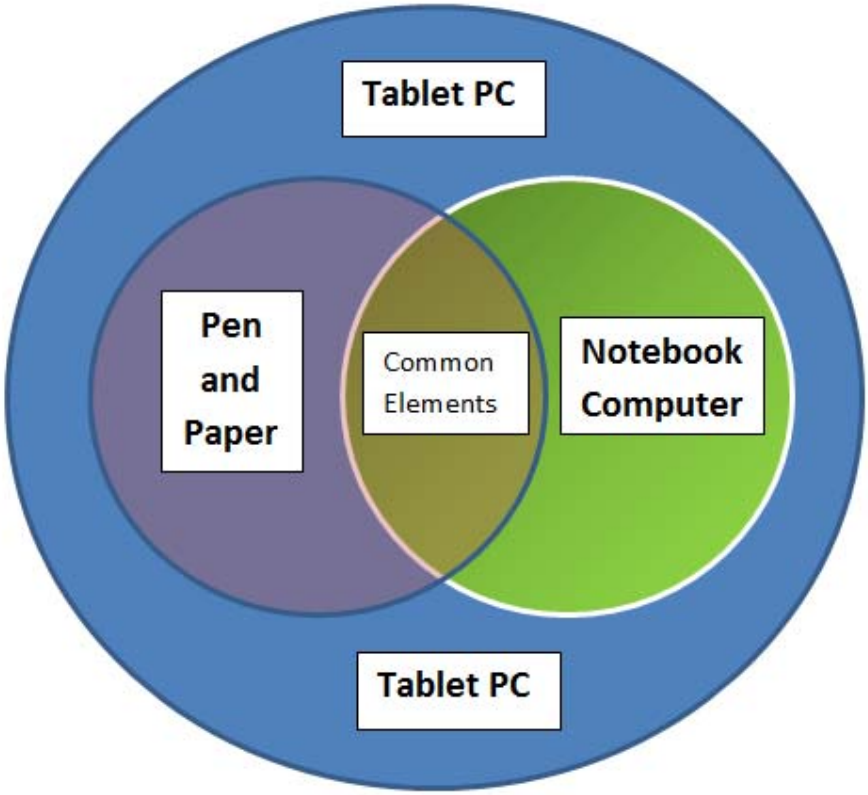

Figure 12: The relative opportunities for learning offered by Pen and Paper, Notebook and Tablet PC technologies

Another element that has interesting implications for research is the opportunity provided by the software component of the Tablet PC and its digital inking capacity, is the ability to record and replay student typed and written and drawn work. This enables the teacher to watch how the students constructed meaning in the context of the work product. As the record of work created has a time dimension to it, the speed at which work is created is observable and this allows for

observations of hesitation; alteration; erasure and replacement, all of which add additional insights into the student's creation of work. These insights are in addition to a record of how the work was constructed. Whether such insights give indications of confidence, hesitancy, certainty and uncertainty, are points that could be explored through further research into the use of this technology.

In the discussion it is suggested that the Tablet PC could well be a useful resource in the context of assessment for learning and that its utilisation might provide more insightful data for this purpose. Knowing that students are constructing knowledge as a consequence of the planned learning intentions is the aim of assessment for learning. Knowing with greater insight how students are constructing their knowledge and the errors which lead to an erroneous construction of this meaning is taking this insight to a higher level.

The following questions emerge from this study:

1. Does Tablet PC technology offer a means, a how, to identify, or be made aware of, such obstructions to a successful construction of meaning which, once discovered/identified in this way, can then be acted upon?
2. Does the ability to track student thinking processes as expressed in the context of capturing their own written record of their formulation of a construction of meaning, inform teachers better on the errors of thinking that students are making in their construction of meaning? Does such insight accessed in this way provide teachers with more insightful evidence upon which to correct errors in the construction of meaning?
3. Does the Tablet PC provide teachers with evidence of student learning in a format which was not available previously to them, and if so, does such evidence enable teachers to give feedback more effectively, efficiently and expediently to students?
4. Might such interventions by teachers with students have previously been limited by the lack of evidence of this nature and the means to communicate and consequently feedback to students more expediently?

Further research in the area of comparing data that the Tablet PC can capture with the data captured by assessment for learning strategies based on the criteria of providing new insights into student acquisition of learning intentions would provide most of the answers to these questions.

5.6.2 Limitations of the Study

One of the limitations of this case study is the short term nature of the study and as such is subject to the observation referred to earlier (Mehlinger, 1996) that evaluation research needs to go beyond the short-term period and look at the longer term sustainability of teaching and learning outcomes that may be initially evident in the short term. The focus outcome of this case study, the posited opportunity for the Tablet PC with appropriate software and utilisation of digital inking contributing as a resource complementing the numerous other strategies that may be employed in "assessment for learning" approaches, would need to be tested against the same criteria as purported by Black & Wiliams (1998) that assessment for learning is a means of raising student learning outcomes. This study does not look at student learning data but as suggested earlier further research into the contribution that the Tablet PC plays in the process of assessment for learning would need to incorporate student learning outcomes data as an aspect that will confirm or refute the contribution of the Tablet PC (given the establishment of control groups).

5.6.3 Final Words

This study started out as an investigation into whether the application of Tablet PC technology in a teaching and learning environment could potentially contribute more to both teacher and student learning intentions than the alternative of notebook computer technology or indeed no computer technology at all. The interpretative framework for this investigation was constructivism and in the context of this study that constructivist learning framework takes the form of the Dimensions of Learning. The context of the investigation concerned developments, discussions and breakthroughs in the field of technology in education concerning the use of tablet technologies whether in the personal computer or iPad formats. Through the observations in the course of the study, which were enhanced with the computer software, and the interviews conducted, particularly that with the teacher concerned, it became evident that there was another dimension to the use of the Tablet PC that was not considered at the start. This dimension concerned the role that the Tablet PC might play in the assessment for learning context of determining whether learning intentions were being realised in a timely context.
The findings of the study were that:

1. The Tablet PC and associated software provided a number of enhancements which students used as these enhancements allowed them a more efficient or combined way of performing actions that they had always done, actions such as note-taking and annotating

delivered content. Other perceived benefits were associated with the package that the digital inking offered such as multi-coloured inks.

2. Greater opportunities for collaborative worked were identified where teacher and students shared the same DyKnow panels and this collaborative work could be captured and replayed for later revision.

3. The recording aspect of the software was seen to be another important point as it allowed students the opportunity to replay demonstrated processes.

4. The Tablet PC allowed for the digitisation of freeform content, such as writing and as such brought this content into the context of being recorded and subject to all the consequences of such a format, such as the ability to make copies easily and to easily change content format.

5. The most significant of the findings concerned the possibility of the Tablet PC serving as an example of a technologically assisted way to enhance feedback between student and teacher through new modes of pedagogy in which students are actively involved. This is only possible with the level of technology of the Tablet PC and associated software, and it gets to a serious issue of how to really understand the learning problems students are encountering.

The study indicates that there is some importance associated with the need to clearly illustrate to teachers that aspect of the use of Tablet PC technology which enhances feedback between teacher and student. Here the use of the Tablet PC is seen to be in the hands of teachers, under their control, for a distinctly educational purpose which is central to their need to obtain feedback on the success of their pedagogy on student learning outcomes. By identifying such a means, the Tablet PC supported by collaborative software which captures the record of such collaboration, the Tablet PC serves to contribute to the facilitation of the quest of improving teacher quality through assessment for learning strategies.

In the same way as Black & Wiliam (2009) described formative assessment as being potentially…

> *…peculiarly effective, in part because the quality of interactive feedback is a critical feature in determining the quality of learning activity…*

…so, it is suggested here, the use of digital inking, the Tablet PC and associated software, may also be peculiarly effective for the same reason, namely as an element of formative assessment.

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Appendices

1. Student Questionnaire

1. When you use the Tablet Pc what would be your estimation of the percentage of time that you spend typing compared to the time that you spend writing?

Percentage typing

Percentage writing

2. When you open up your Tablet Pc do you start in in the “laptop” mode, or in the “tablet” mode?

Tablet Mode

Laptop Mode

3. How often do you take notes in lessons

Always

Mostly

Sometimes

Rarely

Never

4. Do you prefer to take notes on the paper format or the digital format? Explain your answer

Digital

Paper Explanation

5. Do you have any of your text books on your Tablet in a digital format?

Yes

No

6. If yes, do you digitally ink the electronic text?

7. If yes, which of the following inking practices do you use?

Highlighting

Annotating

Marking in some any (underline, circle)

8. Do you use OneNote?

Yes

No

9. If yes, do you:

Write in OneNote only

Type and write in OneNote

Annotate captured text in OneNote

Highlight captured text in OneNote

10. Does the use of the digital pen allow you to do anything that you could not do before?

Yes

No

11. If yes, what are these things that you can now do that was not possible before?

12. Do you think the use of inking in OneNote is better than using paper?

Yes

No

No difference

13. Explain your answer to the above question.

14. When using digital ink on the Tablet Pc you can easily erase “mistakes”. Do you feel that this ability is a good thing or not?

Yes

No

15. Explain your answer to the above question.

16. What do you use the digital pen for?

17. Is there work that you can only do with the pen because it cannot be done with the keyboard?

Yes

No

18. Explain your answer to the above question.

19. Is there work that you can only do with the keyboard because it cannot be done with the pen?

Yes

No

20. Explain your answer to the above question.

21. How often does your teacher direct you to use your Tablet Pc digital pen?

Every lesson

Often, but not every lesson

Sometimes in some lessons

2. Teacher Questionnaire

1. When you use the Tablet Pc what would be your estimation of the percentage of time that your students spend typing compared to the time that they spend writing?

   Percentage typing

   Percentage writing

2. When you ask students to open up their Tablet Pcs do you request this to in the "laptop" mode, or in the "tablet" mode?

   ( ) Tablet mode

   ( ) Laptop mode

   ( ) Do not request any particular mode

3. How often do you expect your students to take notes in lessons?

   ( ) Always

   ( ) Mostly

   ( ) Sometimes

   ( ) Rarely

   ( ) Never

4. Do you prefer your students to take notes on the paper format or the digital format? Explain your answer.

   ( ) Digital

   ( ) Paper

   Explain your answer

5. Are any of your subject text books available in a digital format?

   ( ) Yes

   ( ) No

6. If yes, do you ask the students to digitally ink the electronic text?

   ( ) Yes

   ( ) No

7. If yes, which of the following inking practices do you suggest they use?

Highlighting

Annotating

Marking in some way (underline, circle)

Other (please specify)

8. Do you ask your students to use OneNote?

Yes

No

9. If yes, do you encourage students to:

Type on OneNote only

Write in OneNote only

Type and Write in OneNote

Annotate captured text in OneNote

Highlight captured text in OneNote

I do not stipulate how they use OneNote

10. Do you think that the use of the digital pen allows students to do things that they could not do before?

Yes

No

11. If yes, what are these things that they can now do that was not possible before?

12. Do you think the use of inking in OneNote is better for students than using paper?

Yes

No

No difference

13. Explain your answer to the question above.

14. Do you find the fact that when students are using digital ink on the Tablet PC they can easily erase “mistakes” a good thing or not?

Yes

No

15. Explain your answer to the question above.

16. What do you as the teacher use the digital pen for?

17. Is there work that the students can only do with the pen because it cannot be done with the keyboard

Yes

No

18. Explain your answer to the above question.

19. Is there work that the students can only do with the keyboard because it cannot be done with the pen?

Yes

No

20. Explain your answer to the above question.

21. How often do you direct students to use their Tablet Pc digital pen?

Every lesson

Often, but not every lesson

Sometimes in some lessons

Rarely, just in odd lesson

22. From the list of teaching intentions below, please indicate if you feel that the Tablet PC enables you to achieve them?

Convey attitudes and perceptions to students that enable them to learn

Acquire and integrate knowledge

Extend and refine knowledge

Apply knowledge meaningfully

Develop Habits of Mind

23. If you said no to “convey attitudes and perceptions to students that enable them to learn” suggest why this was the case

24. If you said no to “acquire and integrate knowledge” suggest why this was the case.

25. If you said no to “extend and refine knowledge” suggest why this was the case.

26. If you said no to “apply knowledge meaningfully” suggest why this was the case.

27. If you said no to “develop Habits of Mind” suggest why this was the case.

28. If you said yes to “convey attitudes and perceptions to students that enable them to learn” suggest why this was the case.

29. If you said yes to “acquire and integrate knowledge” suggest why this was the case

30. If you said yes to “extend and refine knowledge” suggest why this was the case.

31. If you said no to “apply knowledge meaningfully” suggest why this was the case.

32. If you said yes to “develop Habits of Mind” suggest why this was the case.

3. Student Interview Questions

1. In the Maths lessons that I observed where you used OneNote and/or DyKnow, was the option of the digital pen of value to you? If so, when and why?

2. Were there some things that you did in your Maths lesson that you could not have done without the digital pen?

3. Was there anything that you did with your handwritten notes, diagrams that you could not have done if you had written the same notes/diagrams on paper?

4. Did you find any noticeable differences between writing on paper in ink and writing on the Tablet in digital ink?

5. Do you feel more confident starting writing in digital ink than writing in ink on paper? Explain your reasons for your answer.

6. Were there any new or novel things that you found you could do with the digital pen when studying Maths that you were unable to do when you didn't have the Tablet PCs?

7. Do you think that there was any benefit to your study of Maths through using the digital pen?

8. Did you use the colour functions/highlighter functions/other functions for the digital pen? If so, how?

9. The digital pen is no better than writing on paper? Do you agree?

4. Teacher Interview Questions

1. Did you feel that the use of digital ink enabled students to undertake work with their Tablets that they otherwise would not have done?

2. Was there anything specifically mathematical that they could do with the pen which they couldn't do previously?

3. Were there any learning outcomes that you think were possible to set with the pen that otherwise might not be possible to set?

4. So was that using DyKnow software to create those little video libraries

5. Do they use the digital pen in that process?

6. There were a couple of occasions I noticed where you got the students to, using their pen, to reflect on the objectives of particular series of lessons you had a panel on DyKnow for example where they actually wrote down what the objectives were. Is that something that they could have done by typing it in?

7. When planning your lessons, did you consciously think about the students using the digital pen? Was that a conscious thought on your part?

8. Did you find that obviously for yourself as a teacher in a spontaneous way, responding to the needs of students in a particular lesson the way the discussion was going and the responses were going did you find that the students similarly, through their annotations, were creating knowledge as they, according to their needs? Did you see evidence of that in terms of what they were writing on their panels?

9. Do you think your work with the students could have been as easily achieved without the digital pen, as with?