ANY TOOL WORKS IF YOU ARE USING THE LANGUAGE

The Role of Knowledge in ICT integration in a Johannesburg private school

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A research report submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements of the degree of Master of Education by combination of coursework and research.

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Declaration

I declare that this research report is my own work and has been completed unaided. It is being submitted to the degree of Master of Education to the University of the Witwatersrand, and has not been submitted for degree purposes to any other institution.

Signed

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Dorian Aden Sean Love

_____________ day of __________________ year ________________

Abstract

Increasingly teachers are expected to integrate ICTs into their teaching practice. Recent studies have focused on the role played by teachers' technological pedagogical content knowledge in explaining how they exploit the affordances offered by the new digital technologies, and yet the pace of integration has been far slower than expected.

Education is founded on the business of knowledge, and yet there is a knowledge blindness in educational research. This study tries to discern what effect subject specialization and knowledge has on teacher's adoption of ICTs into their pedagogical practice, using the framework of Legitimation Code Theory, in particular semantic waves. Seeing ICT practices as affording both knower and knowledge practices, and as affording gravitation or levitation allows us to start to unpack further how the forms knowledge takes influences decisions around ICT adoption.

Keywords: Educational technology, Technology adoption, Technological pedagogical Content Knowledge, Legitimation Code Theory, Semantic Waves,

Dedication

I dedicate this to my wife, Lisabetta, who is my muse and inspiration. Without her insistence I would never have undertaken this study, and without her cajoling I would never have continued.

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Firstly I would like to thank my Supervisor, Tom Waspe, for his patience and advice, which was always precise and timely and helped to crystallize my ideas. Tom, your hands-off approach was just what I needed during a difficult year of research, when my full-time job almost precluded any regular commitment and I was plagued by health problems. You must have despaired of me.

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A Glossary of Terms & Acronyms

Aruba	A powerful, but expensive Wi-Fi network
Autograph	Mathematics software which allows a user to input parameters and graph functions
BYOD	Bring Your Own Device
Flipped Classroom	A pedagogical model in which students are expected to access readings or view lectures at home and do activities in the classroom with the help of the teacher. In essence this reverses the roles of homework and instruction
GeoGebra	An alternative Maths program to Autograph which is free to use. https://web.geogebra.org/
Google Docs	Google's Online word processing package which allows users to compose, edit and share documents online
ICTs	Information and Communication Technologies
ID	Instructional Design
IWB	Interactive White Board
LCT	Legitimation Code Theory
My Maths	An online program (http://www.mymaths.co.uk/) to which students can subscribe providing practice and instruction in Mathematics
PC	Personal computer
PCK	Pedagogical Content Knowledge
SAMR	Is a model for ICT integration in the classroom made popular by Dr Ruben Puentedura, which seeks to help teachers understand how to infuse technology into their lessons. It stands for Substitution – Augmentation – Modification – Redefinition.
TM	Technology Mapping
TPACK or TPCK	Technological Pedagogical Content Knowledge
Turnitin	A popular online plagiarism checker (http://turnitin.com/)
Wi-Fi	Wireless network

1. Introduction and Background to the Research

1.1 The Problem Statement

As ICTs are becoming increasingly integrated into our economic and social lives, the argument that they will also transform educational practice becomes increasingly strident (Carmona & Marin, 2013). This argument is framed not just in terms of increased efficiency, but also in terms of facilitating a movement towards more student-centred, constructivist pedagogical practice (Karagiorgi & Symeou, 2005; Duffy & Cunningham, 1984; Tam, 2000). Computers and other ICTs are conceptualised as cognitive technologies (Dror & Harnad, 2008) which can promote critical thinking and knowledge construction (Jonassen, 1995) and enhance students' capacity to meet the challenges of the globalised information economy. Technology is often seen as something of a magic bullet, something which will fix all the perceived problems in education with a single intervention.

However, while ICTs have entered the classroom at an ever-increasing rate, expected pedagogical transformation has been sluggish, and largely based on merely substituting older technologies such as blackboards with newer ones, such as smart boards, without significantly transforming pedagogical practice (Cuban, Kirkpatrick, & Peck, 2001). ICTs appear to be following other waves of technological innovation over the last hundred years or so, all heralding great promise, which have come and gone, and largely left the classroom unchanged (Cuban, 1990; Cuban, 1993).

In South Africa, despite the stated intent of government policy (Department of Education, 2007) to use Information and Communication Technologies (ICTs) in teaching to foster higher order thinking skills, as Ndlovu & Lawrence (2012) point out, mere access to ICTs does not imply that they are being used in pedagogically meaningful ways to promote critical thinking skills. Access to technologies alone does not always equate with the perceived affordances for transformation (Tondeur, Sinnaeve, van Houtte, & van Braak, 2010). The PanAf survey of ten South African schools (Karsenti, Collin, S, & Harper-Merrett, 2012) indicates severe weaknesses in integrating ICTs into teaching practice, and highlights both a lack of resources and training as substantial stumbling blocks. Furthermore, Blignaut, Howie, & Draper (2008), analysing the SITES 2006 survey into ICT adoption in South African schools, describe a very low level of usage of ICTs.

Clearly, in South Africa the gap between rhetoric and implementation represents something of a chasm. Even in well-resourced private schools, Sackstein (2014) found that the response of teachers to mounting pressure to integrate tablets into their classrooms was patchy. The most common use of tablets in the classroom is for Internet access and productivity enhancement, with collaborative learning being less well represented in classroom practice. Where ICTs are being adopted, they are not necessarily altering pedagogical practice, nor are they achieving the hoped for advances in critical thinking.

The problem of explaining this lack of enthusiasm for ICT integration has traditionally rested on isolating factors which affect use. Innumerable studies have attempted to focus on various factors such as age, gender, culture, or willingness to take risks, and clearly each of these factors plays an important part in particular contexts. Factors affecting ICT integration have further been classified as **first order barriers**, extrinsic to the teacher, such the lack of resources, training or technical support, or as **second order barriers**, intrinsic to teachers, teacher attitudes and beliefs (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012; Ertmer, 1999). This is helpful in shaping our thinking about possible inhibitors to the integration of ICTs, but the two are often linked, or co-existent, and sometimes conflated. As Sherman & Howard (2012) argue, in the South African context, the enormity of first order barriers serves to mask very real second order inhibitors. Internationally, indeed, as more and more classrooms become equipped with ICTs, there is a growing trend towards stressing the importance of second order barriers in explaining the non-adoption of ICTs in the classroom.

Although teachers' attitudes and beliefs are clearly important, how these are enacted in the classroom is unclear. Although beliefs clearly influence actions, a more sophisticated model is needed. Some researchers have turned to the role played by teacher's Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). TPACK, an extension of Shulman's (1987) Pedagogical Content Knowledge (PCK), defines the competencies and skills needed by teachers to integrate ICTs in their classrooms, or how they teach particular content using technology. While useful for conceptualising ICT integration, TPACK does not, however, explain how and why ICT integration in enacted in the classroom in particular contexts. What it does begin to foreground, however, is the importance of content knowledge and subject specialisation and their pedagogical practices, in shaping teacher's decisions around ICT integration rather than a narrow focus on their technological competency alone.

The first problem is thus how to explain the gap between rhetoric and implementation of ICT integration within a South African context, and to come to a clearer understanding of how teachers go about making decisions around the use of ICTs in their lessons. This necessarily begs the question of why teachers ought to be integrating ICTs into their lessons in the first place. I will not attempt to address this question directly, but I believe that addressing the first problem goes a long way towards critiquing many of the assumptions made about the inflated effects of ICTs in the classroom. Once stripped of false expectations, we can begin to see ICTs as effective pedagogical technologies rather than one stop solutions to all educational problems.

The second problem revolves around a gap in the research. The core business of education is the transmission of knowledge (Moore, Young, & Maton, 2010), and yet the forms that knowledge takes and its effect on educational practice has not been sufficiently studied. While knowledge has been seen as the defining characteristic of our age, and we talk glibly of the information economy, and the information age, our focus in the social sciences has been on the knower, rather than on knowledge (Maton, 2014b). This has been brought about by a philosophical turn towards a subjectivist epistemology which, I will argue, conflates a belief that knowers construct knowledge of the world with a denial of ontological realism. In rejecting a crude positivist stance towards epistemology, knowledge has come to be seen as something which resides entirely within the minds of the knower, and what has been lost is the referent to the object of knowing, knowledge itself (Maton, 2014b; Maxwell, 2012b).

Thus there is a knowledge blindness in educational research (Freebody, Maton, & Martin, 2014; Howard & Maton, 2011) which obscures the role knowledge plays in teaching. Howard, Chan, & Caputi (2014) have identified considerable correlation between particular subject areas and attitudes towards, and level of integration of ICTs in classroom teaching. Howard & Maton (2011), analysing the data from a one to one laptop programme in New South Wales, have suggested that English and Science teachers found a better fit for technology use in their subjects than Mathematics teachers, and explain this in terms of subject specialisation. The ways in which different subject teachers teach with technology reveals that different technologies are being deployed within different subject specialisations.

Legitimation Code Theory (LCT), which draws a distinction between knowledge practices which draw legitimacy from epistemic relations, based on hierarchically structured knowledge systems, and those which draw legitimacy from social relations, based on the gaze of the knower, is used to explain code matches and clashes with ICTs. Mathematics was found to be a subject specialisation strongly associated with strong epistemic relations, a knowledge code. The fact that Mathematics teachers did not find as many uses for technology in their classes is explained not in terms of belief. Teachers, on the contrary, had a positive orientation towards technology. But Howard & Maton (2011) described a code clash between the subject of Mathematics and its pedagogical practices, and those normally associated with ICTs, which is seen as a knower code. Where Mathematics teachers did use ICTs, it was for uses which did find a match with the greater knowledge code practices of Mathematics, for example, drill and practice and visualization.

English teachers, on the other hand, were found to use ICTs more frequently in their lessons. Howard & Maton (2011) explain this in terms of a code match between the subject specialisation, with its emphasis on social relations as a basis for knowledge, a knower code and the knower code orientation of ICTs. However, not all knowledge practices within the subject specialisation of English are seen as knower code. Some aspects, such as formal grammar are based on hierarchical knowledge structures and represent a knowledge code. When teaching these aspects of the syllabus, English teachers saw less of a match with ICTs, and used ICTs less frequently, or used them with similar drill and practice software as is found in many maths classrooms.

This research is suggestive that the forms that knowledge takes has considerable bearing on how it is taught, and consequently on how it is taught using technology, and yet this factor has been under-researched. The notion that ICT integration, or lack of it, could be explained in terms of code matches and clashes between subject specialisation codes and the predominant mode of ICT use needs further research, and offers a way of moving beyond a focus on teachers' attitudes and beliefs, and perhaps, a fruitful way of unpacking TPACK.

1.2 The Purpose Statement & Research Questions

The vexed question of the integration of ICTs into the classroom has become politically and morally charged, with teachers who do not use technology, or who use it in certain ways, often being seen as failing to deliver in their duty. As a practising teacher in a private school in Johannesburg which was in the midst of the implementation of an IT Strategy which involved the rollout of a one to one BYOD programme, a member of the IT Strategy Team, the computer skills teacher, and a champion of ICT integration, I found myself in the middle of a period of change in the institution, and uniquely positioned and challenged to research teacher's approaches to the integration process.

The teachers at the school being researched, Girl's High, had access to adequate resources, with an IT Department dedicated to providing technical support and some training. While there were certainly some first order barriers remaining in place, in general these were of an order that they could largely be subsumed within second order barriers in the sense that they could easily have been addressed by anyone with the motivation to do so. I felt that the school offered an opportunity to be able to research teacher's approaches towards ICT integration, and to try to explain how teachers made decisions around ICT integration and to what extent these decisions were influenced by their subject specialisation, and the content they were teaching.

The purpose of this study was thus to investigate the role of subject area specialisation in influencing teachers' decisions around the integration of ICTs into their pedagogical practice in trying to unpack how Technological Pedagogical Content Knowledge is being deployed within the classroom. It is hoped that this will contribute to our understanding of how teacher's TPACK influences the decisions they make over whether, or how to integrate ICTs into their lessons.

As will be discussed, TPACK remains a rather vague concept, useful in focusing on the need to consider technological, pedagogical and content knowledge practices, skills and competencies, but weak in terms of conceptualising how this articulates and plays out in the classroom. The purpose of this study was thus to try and unpack TPACK. I was particularly interested in seeing how the forms knowledge takes influences their use of ICTs. While specialisation codes taken from LCT clearly offer a fruitful avenue of exploration, it seemed to me that to understand how teachers are taking decisions around ICT integration we need to look at how the confluence of technological, pedagogical and content knowledge plays out in the classroom. It seemed to me that another concept taken from LCT, that of semantic gravity and semantic density might be useful in explaining the role of ICTs in how knowledge is being deconstructed and reconstructed in the classroom through the creation of semantic waves (Maton, 2014a) to build knowledge.

Rather than seeing ICT in broad strokes as offering a code match or code clash with different subject specialisations, a more nuanced view of how ICTs articulate with pedagogical and subject knowledge in the classroom is needed. The idea of semantic waves sees knowledge building as involving two complementary processes. The first being the unpacking of abstract concepts and ideas so that students can concretise and apply the ideas to their own experience in order to understand it. The second, less frequent (Maton, 2014d), involves scaffolding student's attempts to take their own understandings and frame them in the more abstract, more academic language of the discipline.

I would argue that the first process lends itself rather better to more traditional, instructivist, teacher-centred conceptions of teaching, while the second is more commonly associated with constructivist pedagogies because it is necessarily more student centred. Both processes, however, are vital for knowledge building.

If we assume that this explanation of knowledge building correctly describes what it is that teachers are doing in the classroom, and we need to take this as a working hypothesis, we can only really assess the efficacy of ICTs in terms of whether ICTs are able to assist teachers in helping students unpack abstract concepts and understand ideas in terms of their own experience, or use their own experiences to reframe and reconstruct more abstract, academic knowledge. This perspective of what it is that teachers do stands somewhat at odds with the dominant constructivist paradigm, but resonates with a view that both teaching and learning are dialogically linked.

As Sfard (1998) has observed, there are two overarching metaphors guiding our thinking about the nature of learning and teaching, the metaphor of acquisition and that of participation, and that both offer insights and explanatory power. While the metaphor of acquisition suggests that education is about transmission and transfer of knowledge, participation suggests that education is about meaning making. Bakhtin's (1981) notion of the centripetal and centrifugal forces of language that are brought to bear at the same time, allows us to see how the dialogic voice of knowers, and the monologic voice of knowledge are able to define the point at which these metaphors of learning intersect and correlate. There is no real contradiction between the monologic voice of the teacher, teacher-centred instruction, and the dialogic voice of learners' own experiences and utterances. Anyone who has ever stood in a classroom will appreciate that it is a teacher's job to scaffold students' understandings of received knowledge, and that this intimately and inextricably involves both instruction and the scaffolding of student's construction of knowledge, and finding their own voice.

Legitimation Code Theory offers an explanatory framework for researching knower and knowledge structures. But I was not aware of any study which used the concept of semantic waves to help explain how the affordances of ICTs might help explain teacher's decisions to use, or not use the technologies in their lessons, so I was also anxious to see whether these concepts, derived from Legitimation Code Theory held explanatory power and might be helpful in addressing the knowledge blindness in educational research (2011) discussed above.

1.2.1 The Main Question

The central question that I sought to address was thus in what ways ICTs are being used in particular subject disciplines. I wanted to find out how teachers who are using ICTs in the classroom see it as helping to teach their subject, and how the affordances of the technology are being translated into integration of the technology within their particular pedagogical practices, and to what extent it alters or changes their practice. This forms an over-arching concern for the research, and was addressed largely through a series of in-depth interviews with particular teachers.

1.2.2 The Secondary Question

The secondary question was to seek to find out whether Legitimation Code Theory offered explanatory power when looking at how ICTs are used in particular lessons. In particular, whether the semantic wave model (Maton, 2014c) offered ways of explaining why ICTs are perceived as being useful or not useful in particular subject teaching practices within a high school context.

My intuitive hypothesis was that teacher's Pedagogical Content Knowledge practices, designed to teach particular content, would need to articulate with the particular affordances (Gibson, 2014; Norman, 1998) of specific technologies and find a match before a teacher would consistently use any technology on a routine basis. This hypothesis is very close to the Instructional Design model of Technology Mapping developed by Angeli & Valanides (2013) which will be discussed in detail in the next chapter. Essentially Angeli & Valanides argued that what teachers do is to map concepts that they are trying to teach to technologies which carry affordances which enhance the teaching of this content. I was keen to find out if the semantic wave model, with its view of knowledge building activities in the classroom, offered a way of explaining technology integration, by extending the TM model to focus more sharply on the effects of knowledge.

There were thus, essentially, two subsidiary questions around the question of how the affordances of ICTs articulate with the semantic wave model. Firstly, are teachers finding any fit with these technologies when they seek to help students unpack concepts? And secondly, are teachers finding any fit with the technology when they seek to help students re-frame and re-conceptualise knowledge?

These sub-questions were addressed through two lesson observations, and a detailed semantic analysis of the transcripts.

1.3 Personal Perspectives

In this section I set out a brief discussion of my own personal history. In Chapter 3 I will set out the contours of a debate over the nature of reflexivity in research, which carries with it implications about how the subjectivity of the researcher is viewed within a Social Realist research paradigm. If I have followed this debate accurately, it is ultimately to recognise that the knowledge claims made in this research are not purely reflexive if they are carefully situated within the context of a pursuit of knowledge that is socially and historically based (Bourdieu, 1992), and within the context of the knowledge claims that are made (Maton, 2003).

In short, I need to situate my own stand point as knower, both in relation to the object of study, and how knowledge claims resulting from this research are to be legitimated. In other words, it is important to give some sense of why the question is important at the current time in educational research, and how the question has unfolded. This is covered in the first section of the next chapter. Against this will be set the claims for knowledge which emerge out of this research, and how they relate to cumulative knowledge building. This discussion is set out in successive sections in the next chapter. In the chapter on the Research Methodology I will tackle questions of epistemic relations directly in terms of the framework for research and how it aligns with the methodological approaches adopted. This speaks directly to the extent to which my own subjectivity is implicated in the research.

What follows below may therefore be seen as something of a coda to the problem being researched. It speaks to what led me to the research questions and why they are important to me.

I qualified as a teacher of English and History, and taught for many years in inner city state schools previously under the Department of Education and Training. As someone who had an interest in computing and programming as a hobby, around twenty years ago I started teaching computer literacy in grades 8 and 9, and Computer Application Technology in grades 10, 11 and 12. Between 1994 and 2008, I thus had experience of introducing computers into two schools which were under-resourced, but intended to use computers to transform educational practice. Computing resources were limited to a networked computer room, to which classes could be brought. Lack of adequate air-conditioning, technical support, reliable power supply and Internet access severely constrained computer use. For example, if I wanted a class to research a topic using the Internet, I had to download complete websites and load them on a local server, providing access via a home-made portal. My experience here was shaped by my role as a computer literacy and applications teacher. While I taught some programming, using JavaScript, my main function was to teach computer literacy and Computer

Applications Technology as a subject to matric level and to assist other teachers wanting to use the computer room, mainly for research or digital authoring purposes.

In 2008 I started working at Girl's High, a suburban private school for girls, as an ICT and English teacher. This school was blessed with superb resources, which were extended year on year. My interest in ICTs led me to champion their use in the classroom, something which I was slowly integrating into my own practice as an English teacher. I became an enthusiastic blogger, documenting my own attempts to find value in ICTs, and then started studying towards a Masters in Education, for which this research forms part requirement, in order to better understand the foundations of my efforts.

At this time Girl's High started to frame ICT integration as one of the planks in its strategic initiative to meet changing educational needs, along with a greater emphasis on Mathematics and Science, and on embedding Thinking Skills in the curriculum. For the better part of a year a small team, of which I was a member, met and hammered out a proposed IT Strategy based on foundations laid in 2010 when similar discussions had been held. The previous initiative had stalled when the Board member carrying the IT portfolio had to resign due to work commitments. This new IT Strategy was adopted late in 2014, and implemented in 2015, involving the provision of a device, either tablet or laptop, to every teacher, a teacher training programme in the first term, followed by the expectation that all grade 9s, and then all grade 8s would bring their own devices to class in the second and third terms respectively. The roll-out of this programme coincided with my research into how teachers in different subject areas were implementing ICTs in their lessons.

As the IT Strategy was implemented in the school, it became increasing obvious to me that there was a dissonance between the expectations of the IT Strategy team that had drawn up the policy and teachers' attitudes towards the use of ICTs. During IT Strategy team meetings the headmistress of the school had expressed the feeling that many of the school's IT resources were being under-utilized, that "sometimes the only one who touches the smartboard is the cleaner". In large part the IT Strategy initiative was designed to address this. While many teachers had been using ICTs successfully for a period of time, this moment in time represented a point at which ICT resources had been introduced into the school, and at which teachers were faced with an imperative to use them.

The mission statement adopted by the IT Strategy team carried the aspiration that the school would become “a leading school in the use of ICTs for teaching and learning”. The SAMR model of ICT integration (Puentedura, 2014) was adopted, with its hope that ICTs would act as agents of transformation in the classroom. In this model, ICT integration is described on a continuum from enhancement to transformation. ICTs can be used merely to substitute existing technologies, with no functional change, or with some enhancement. Or they may allow for learning activities to be substantially redesigned , or redefined, as shown in **Figure 1.1** (Puentedura, 2014, p. 8) below:

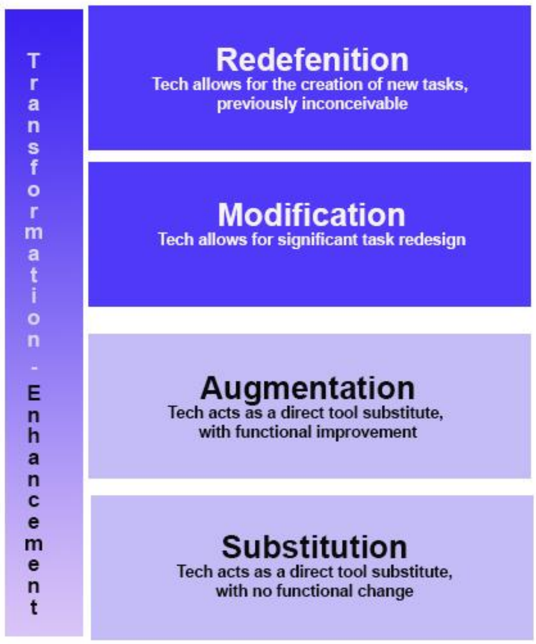

Figure 1.1 The SAMR Model

There was clearly a gap between expectations and the current reality, very much in line with the broader educational experience discussed above. Some of this was due to poor technical skills on the part of staff. During training sessions I attended, a number of teachers were unable to access the training resources because they had forgotten passwords, some were unable to operate their devices properly, and others expressed reservations about how much they could accomplish. The full expectation of the IT Strategy team was that after training and provision of a device, all teachers would be empowered, and contractually obliged to integrate ICTs in their lessons, and that they would be fully supported in doing so by the IT Department and any internal and external one-on-one training that might be necessary. The IT Strategy team, in other words envisioned that they needed to remove all first order barriers, and sought to provide training to overcome second order barriers. And yet the SAMR model adopted privileges a certain view of the pedagogical purpose of ICT integration, setting it very much within a student-centred, constructivist paradigm.

This paradigm, which as Maton (2013) notes, carries with it a moral weight, has become somewhat hegemonic within educational debate. For any teacher with reservations about this, the use of the SAMR model carries with it not just a contractual imperative to use ICTs, but also an injunction to use them in a certain way. This is problematic, not simply because it threatens professional autonomy, but also because, as we shall see, the grounds for privileging any particular paradigm is shaky.

I have painted a somewhat bleak picture of the staff's ability to implement the IT policy. The flip side, however, is that a majority of teachers were able to use devices in their personal capacity, many teachers were already using computers, or other devices in their lessons, but were being held back by the lack of an official BYOD policy or adequate technical support in terms of Wi-Fi. Unofficially the IT Department had been enabling devices owned by staff and students for years, but the ability to use them outside of the computer room (35 networked computers) or media centre (60 networked computers) was severely constrained by limited Wi-Fi capacity. Many classrooms did have Interactive Whiteboards which were being utilized effectively, and over time more were being added. With the rollout of the IT Strategy in 2015, the Wi-Fi was also upgraded to an expensive, but powerful Aruba system at the beginning of 2016 to meet the vastly increased demand for bandwidth as more students and staff made daily demands on the infrastructure.

As I conducted the Literature Review for this research, it became clear to me that the expectations of the IT Strategy team were largely shaped by a global discourse over the position of ICTs within education and their role in transforming education and pedagogy. The school was anxious to exploit the perceived affordances of ICTs to motivate for wide ranging change, which it was felt would support the school's efforts to become a Thinking school, accredited by the University of Exeter, and move towards encouraging enhanced critical thinking skills in the student body. Staff were integrating cognitive strategies such as Habits of Mind, de Bono's Thinking Hats, David Hyerle's Thinking Maps, or the Harvard Visible Thinking strategies into their teaching, and some teachers were exploring ways in which ICTs could be used to enhance this drive towards empowering independent critical thinking in their students.

For example, some staff began exploring concepts such as the Flipped Classroom, and a series of monthly meetings of a core group of teachers were held in which best practice was shared. These efforts represented something of an argument for change in which the integration of ICTs was seen as an essential component. Some staff were being sent on workshops and to conferences at which this linkage of ICTs and critical thinking skills was foregrounded, as will be discussed in the next section.

It is my fervent hope that this research into the role of knowledge in shaping teacher's attitudes to ICT integration will help remove some of the anxiety many teachers face when being called upon to change their practice, by shifting explanation away from the opprobrium of blame towards a more objective understanding of how ICT integration plays out in the classroom in different subject areas.

2. The Literature Review & Theoretical Framework

Google Scholar was used to cull recently published, and most cited papers using search term keywords “ICT Integration”, and “TPACK”. Google Alerts was used to extend this search. I added the keywords “Legitimation Code Theory” as my theoretical focus sharpened. The bibliographies of key papers were then used to search for further sources using ERIC and other academic databases.

2.1 General Background & Preliminary Literature Review

In this section I hope to give a sense of why the questions posed in this research are important at the current time, and how they fit in with different ways of seeing the issues.

There is a widespread belief that the integration of ICTs in schools will provide opportunities for addressing educational and social imperatives, and indeed a raft of research indicates that the use of ICTs does indeed benefit educational practice (Higgins, 2003; Condie & Munro, 2007; Balanskat, Blamire, & Kefala, 2006) or produces at the very least modest gains in educational outcomes (Higgins, 2009). In general, while research has not established a clear improvement in students' achievement as a result of the impact of technology (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011), there is some evidence that when technology is used in conjunction with thought out pedagogical approaches, benefits can be clearly shown (Hennessy, Ruthven, & Brindley, 2005).

As Selwyn (2015) has pointed out, because there is an underlying faith in those who practise and research educational technology that it is, or will ultimately prove, beneficial, this narrative often goes unquestioned. Since the careers of many teachers and educational technologists are invested in promoting the idea that ICTs will transform education for the better, there is often a very natural tendency to shy away from critique. Hence there is an absolute imperative for research into educational technology to adopt a critical approach as a counterbalance to the sometimes messianic triumphalism present in much of the popular and professional discourse around ICT integration in the classroom. This zeal follows from the grand narrative which sees Information Technologies as the essential path to entering the globalised information economy (Selwyn, 2004), and the introduction of computers and ICTs generally as a means to this end. This argument informs so much of the popular debate around education and establishes an unquestioned imperative for ICT integration.

This argument is essentially technologically reductive. How ICTs are used is not seen as problematic, and yet the how appears to be the key differential between little or no benefits being experienced, and marked benefits being recorded. A review of literature on ICT and student attainment appears to indicate that how ICTs are used is vital in fostering achievement (Abbott, Webb, Blakeley, Beauchamp, & Rhodes, 2004). Clearly what teachers do, and the way that they do it is crucial. Nevertheless, the magic bullet claim represents a narrative of considerable power, which needs to be carefully examined, and not just taken at face value. According to this narrative, the introduction of technology into the classroom will solve many, if not all educational ills, but is being hindered by barriers to its adoption. These barriers include extrinsic factors such as lack of resources, training or support, but also intrinsic factors such as teacher attitudes and beliefs (Ertmer, 2005). As more and more resources have been deployed in schools, the focus has shifted, often with opprobrium, to reasons why many teachers appear to be resisting ICT integration (Sandholtz, Ringstaff, & Dwyer, 1997). This approach does teachers no favours, and indeed may alienate many educators, as it positions teachers as obstacles to progress and places enormous social pressure on teachers to conform to what is perceived as necessary change (Frank, Zhao, & Borman, 2004). This would be all very well if it could be shown that ICTs were producing more than the mixed, or the modest gains suggested, but, while these benefits may well be possible, possibility lives in the realm of polemic. Research needs to focus on what is happening inside actual classrooms.

A second trend in the literature is to associate the integration of ICTs with particular pedagogies, and to see their use as heralding a move in education away from teacher-centred to learner-centred pedagogies (Becker & Ravitz, 1999; Jaffer, 2010). This move is seen as a necessary prerequisite to transforming educational practice to meet the challenges of the twenty first century. This attempt to move educational practice from teacher-centred to student-centred approaches, or from instructivist to constructivist pedagogies is not new, as Cuban (1990) has argued. For many, the new digital technologies may appear as a vehicle for finally prevailing in this endeavour.

Again, while there may be nothing essentially wrong with this move, its claims cannot merely be accepted at face value. We need to be very clear that any perceived superiority of one pedagogical orientation above another does not carry any weight when looking at how teachers approach the integration of technology in their classrooms since these views may simply not be shared by the teachers concerned. The classroom appears peculiarly resistant to change (Cuban, 1990; 1993) and as Kuhn (2007) argues, the efficacy of the method is largely determined by the context: who is being taught, and what is being taught. Teaching is a complex activity (Hegarty, 2000), and cannot be reduced to simple one-dimensional models. We cannot be pedagogically reductive, in other words. As Harris (2005) argues, teachers need to be afforded academic freedom to choose both technologies and pedagogies that match their purposes.

Indeed there may be very real reasons for rejecting the notion that ICTs favour any particular pedagogy. As Dron (2012) has noted, pedagogies are themselves educational technologies in the sense that they are ways of organising beliefs about how people learn, to the purpose of learning. These form part of an assembly of broader technologies and organisational means that teachers deploy to bring about learning. Dron argues that pedagogies are more “malleable and flexible” (Dron, 2012, p.28) than other technologies, and hence tend to be more amenable to change. He uses the example of the lecture theatre. If that is your teaching space, allocated institutionally, then any predisposition to small-group discussion as a pedagogy is militated against: not impossible, but less likely than whole class pedagogies since it is easier to change pedagogies than it is to change buildings. Those aspects which are less open to change tend to determine with greater force how resources and technologies are marshalled in the classroom. This view of how pedagogies and technologies articulate emphasises the role played by the teacher in making decisions within the classroom, and speaks to the relative impact of factors that shape classroom practice, and might help to explain why more student-centred pedagogies have not gained the kind of traction many have hoped for.

Anderson & Dron (2011) argue, in the context of distance education, that the emergence of different learning theories and pedagogies has been largely shaped by the affordances of available technologies. Using the metaphor of a dance, Anderson (2009), argues for a path between both technological and pedagogical determinism, that the two weave a complex dance which is constantly changing as the affordances of new technologies disrupt the flow of the dance, and the dance has to change.

As I read around the issue of ICT integration, I became increasingly filled with a sense that trying to isolate particular factors was indeed like watching a dance in which the rhythm constantly changed and all certainty became elusive. It seemed to me that models of integration were either too simplistic, too reductionist or too relativist. There were simply too many factors to isolate, and given the complexity of the business of teaching, no clear way of assessing one claim above another. The teachers I spoke to, my colleagues, were grappling with how to use new technologies not in isolation, but in the lessons they taught daily, to teach a particular curriculum. During training, if they were shown how to make videos on an iPad, their concern was not first and foremost about how this might transform their pedagogy in the grand sense; it was how they might possibly use it in their subject area to teach particular aspects of the curriculum.

It has long been recognised that ICTs have been used in different ways in different subject areas in the secondary school, with subject specific pedagogies tending to shape

ICT use rather than the other way round (Goodson & Mangan, 1995). Goodson (1988) sees subject sub-cultures as ways of legitimating what knowledge is valued, taught and assessed. These subject cultures are formed by the collective experiences of teachers and academics and shaped by institutional practice (John & La Velle, 2004). They form a relatively un-malleable set of practices within which ICT integration is mediated, and renders any transformative effects of ICTs highly resistant to change.

This is not to say that the introduction of computers into a classroom has no effect. Goodson and Mangan (1995) noted a marked shift towards small group activity, and away from teacher initiated activity with the introduction of computers, although this may reflect moves towards more student-centred approaches before the introduction of the computers. According to Goodson and Mangan

> "In most cases teachers perceive their pedagogical styles as a limited arena of personal choice, in which they have the freedom and power to make minor variations in curriculum and pedagogy. These variations are constrained by both the fundamental culture of teaching and the subject sub-culture." (1995, p.112-113)

This perspective helps explain how different practices appear to have emerged historically in different subject areas within the curriculum. Maths teachers have used software to help students visualise mathematical functions in the form of graphs (Ruthven, Deaney, & Hennessy, 2008) and for repetitive drill and practice (Williams, 2000). Science teachers have used simulations to help explore Scientific concepts (Sahin, 2006). English teachers have used authoring software and the affordances of online publishing to enable student creativity (Warschauer & Healey, 1998). While this list is not exhaustive, it is indicative of the ways in which the shape of knowledge itself appears to influence how ICTs are deployed in the classroom. What is clear is that there is not a universal blanket approach to ICT integration across the curriculum. Indeed, if we are to understand how ICTs can be used to teach particular content or skills we need to be able to explain why this is the case.

This requires some way of understanding the contours of knowledge and how knowledge articulates with particular technologies and pedagogies.

2.2 Conceptual Models of ICT Integration

From the preliminary literature review it was clear that any attempt to research how teachers in different subject areas are using ICTs in their classrooms needed a conceptual framework that could take curriculum, pedagogy, technology and a wide range of contextual factors into account, and avoid a crude techno-determinist, or pedagogically-determinist position. In this first section I will discuss various options in the literature, and unpack the model which appeared to offer the best fit in this regard.

Researchers have, for a long time, sought to explain why many teachers appear to resist the integration of ICTs into their lessons. A large number of research studies have isolated a range of diverse factors such as age (Guo, Dobson, & Petrina, 2007), gender (Tondeur, Valcke, & Van Braak, 2008; Umar & Yusoff, 2014), length of teacher experience with ICTs, culture (Wang, 2009) and the culture of the school (Demetriadis et al., 2003). Institutional factors such as scheduling and types of school leadership have also been put forward as having an effect on teachers' use of computers (Cuban et al., 2001). The characteristics of the individual teacher, including willingness and ability to use technology as well as pedagogical styles (Becker & Riel, 2000) and willingness to take risks (Howard, 2013) are all cited as factors.

Sherman & Howard (2012) argue that in the South African context, notions of "face" affect ICT integration: that teachers do not want to expose themselves by using ICTs in situations where their lack of knowledge will become evident to students, that there is a perceived need to be seen to be in authority. Cultural perceptions and world views are clearly important in establishing any teacher's willingness to adopt ICTs, but it may not be very useful to conceptualise of teachers as simply being influenced by the range of factors which are brought to bear.

It is common practice to explain the lack of adoption of ICTs in terms of first and second order barriers (Ertmer, 1999). First order barriers are described as being factors external to the teacher such as lack of resources, training or support, while second order barriers are intrinsic to the teacher - beliefs, particularly pedagogical beliefs and attitudes. While Ertmer's characterization of first and second order barriers to integration provides a clear framework for categorizing factors at play in inhibiting the integration of ICTs in the classroom, this may be too simplistic a model to offer sufficient explanatory power, and clearly needs teasing out.

While access to hardware, software and support (Collins 1996; Cuban 1999; Loveless 1996; Zhao, Pugh, Sheldon, and Byers 2002; Umar & Jalil, 2012) is clearly important, many of the first order barriers have been removed over the last decade or so. This process is uneven, however, and in many places teachers are still reporting lack of computers, and lack of in-service training and support as primary barriers to the integration of ICTs in their classrooms (Goktas, Education, & Technology, 2009). While this makes obvious sense - you cannot teach using ICTs if you have no ICTs to teach with, the fact that some teachers have been able to design situations in such a way as to maximise the use of what little was available, and others do not do so even when they have the resources at their disposal, suggests that what is at play is ultimately teachers' ability and/or willingness to use these resources. Lack of resources undoubtedly remains a stumbling block in many schools, but lack of adoption even in well-resourced schools (Ertmer, 2005) would indicate that this, while a factor, does not carry sufficient explanatory weight.

Increasingly nuanced models, such as the Conceptual Framework used in the SITES 2006 study, shown in **Figure 2.1** below (Carstens et al., 2006, p. 13) have been employed to try and explain the complex range of factors influencing teachers' decisions, but essentially these models do not go beyond highlighting particular factors in different contexts. The model does, however, situate ICT integrated pedagogies within the overall pedagogical practices of a teacher. How teachers use ICTs, "the reasons why and the ways in which they use ICT in the classroom are underpinned by their overall pedagogical vision and competence" (Carstens et al., 2006, p.12).

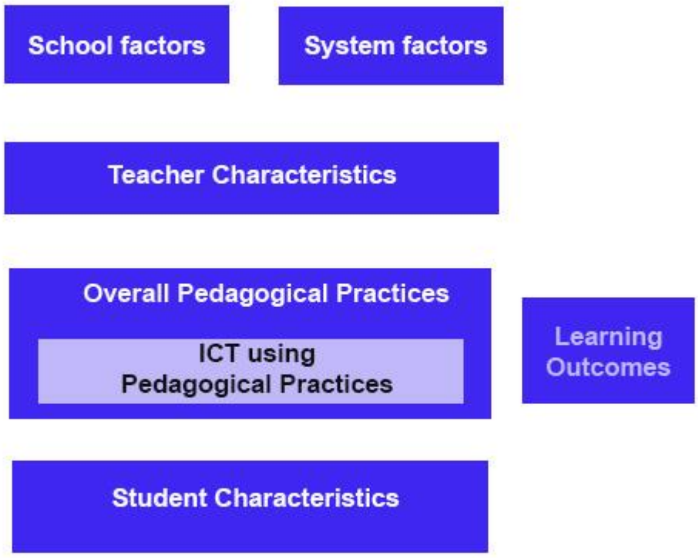

Figure 2.1 The Conceptual Framework for SITES 2006

While the various factors such as competency with technology are subsumed under teacher characteristics in this model, there is a recognition that student characteristics have an effect on pedagogical practices and so too do learning outcomes. What is conspicuously absent from this framework is the curriculum itself and the effects of subject specialisation in driving pedagogical decision-making. Learning outcomes are seen as being the result of other factors, and as was discussed in the previous section, learning outcomes are experienced by teachers as the least malleable features. Whatever else one can say about teachers, it is clear that teacher's decisions are largely driven by the need to complete a curriculum over which they have very little control, and in systems which rely heavily on assessment, even on teaching to the test (Higgins, Miller, & Wegmann, 2006).

Increasingly, thus, the focus has turned to looking at the interface between Technological Knowledge, Pedagogical Knowledge and Content Knowledge (Mishra & Koehler, 2006; Harris, Mishra, & Koehler, 2008; (Koehler, Mishra, & Cain, 2013); Schmidt et al., 2009 ; Koehler et al., 2014) to help understand teachers' integration of ICTs in their classrooms. This perspective offers a key advantage over isolating individual factors at play as it offers a framework for understanding how teachers teach (pedagogy) a subject (content knowledge) with technology (Niess, 2005; Polly, McGee, & Sullivan, 2010; Angeli & Valanides, 2013). This framework, with its overlapping concerns, see **Figure 2.2** (Koehler et al., 2014, p. 15) below, highlights a range of competencies required by any teacher, but does not address how these are enacted in any teacher's practice. The whole, in other words, is not simply the sum of its parts. As Angeli & Valanides (2009) point out, growth of each of the constituent competencies has not been shown to have an effect without a focus on developing TPACK itself. In other words, teachers need to be specifically taught how to teach with ICTs, increased technological knowledge alone is not sufficient.

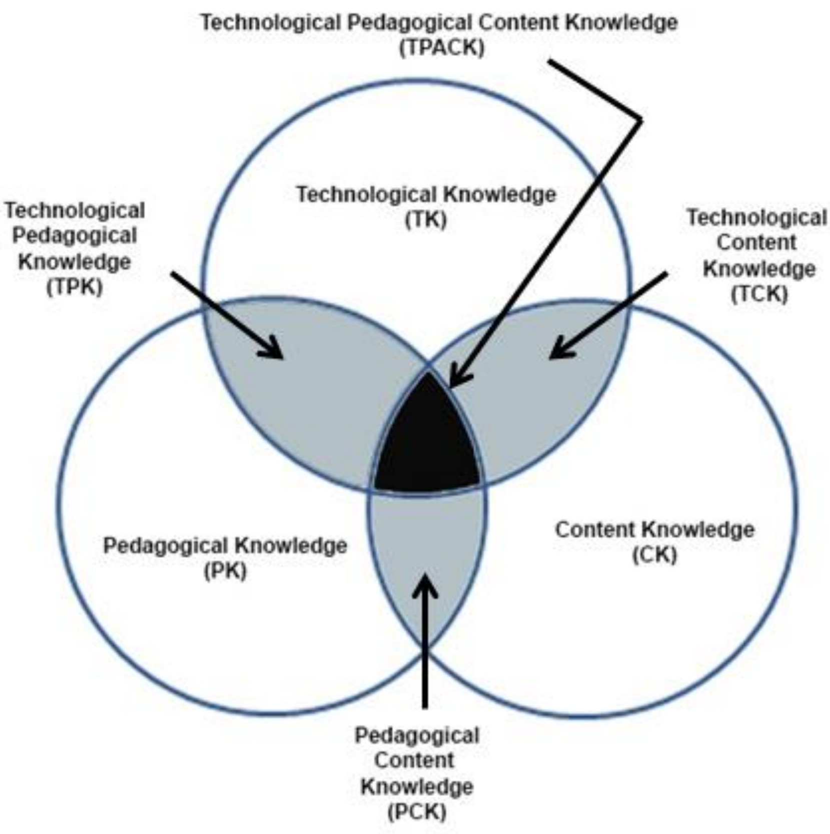

Figure 2.2 The TPACK Framework

The framework is nevertheless extremely useful in directing the gaze of the researcher towards key concerns. By drawing attention to the differences between Technological Pedagogical Knowledge (TPK), for example, and Technological Content Knowledge (TCK), one can begin to interrogate particular uses of technology which are common in all subjects, and have to do with how to teach (TPK) and technological uses which are singular to particular subject areas (TCK) and are not necessarily about teaching at all. How teachers use an Interactive Whiteboard, is not necessarily subject-specific at all, while musical notation software, such as Sibelius, represents specific content related technologies, which may, or may not have particular pedagogical impact.

These distinctions are useful in allowing the researcher to characterise and discuss how technology is used to teach particular content in the classroom, even if they do not offer specific guidance around how, or why a teacher might make one decision rather than another. Angeli & Valanides (2009) have proposed a transformative model of TPACK with ICTs, which conceptualises five distinct knowledge bases, namely content knowledge, pedagogical knowledge, ICT knowledge, along with knowledge of learners and contextual knowledge. It is considered a transformative knowledge because the resultant knowledge goes beyond the integration of constituent knowledges to produce something new, as shown below in **Figure 2.3** (Angeli & Valanides, 2013, p. 205), in essence "knowledge about how to transform content and pedagogy with Information and Communication Technology (ICT) for specific learners in specific contexts and in ways that signify the added value of ICT" (Angeli, 2015, p. 13).

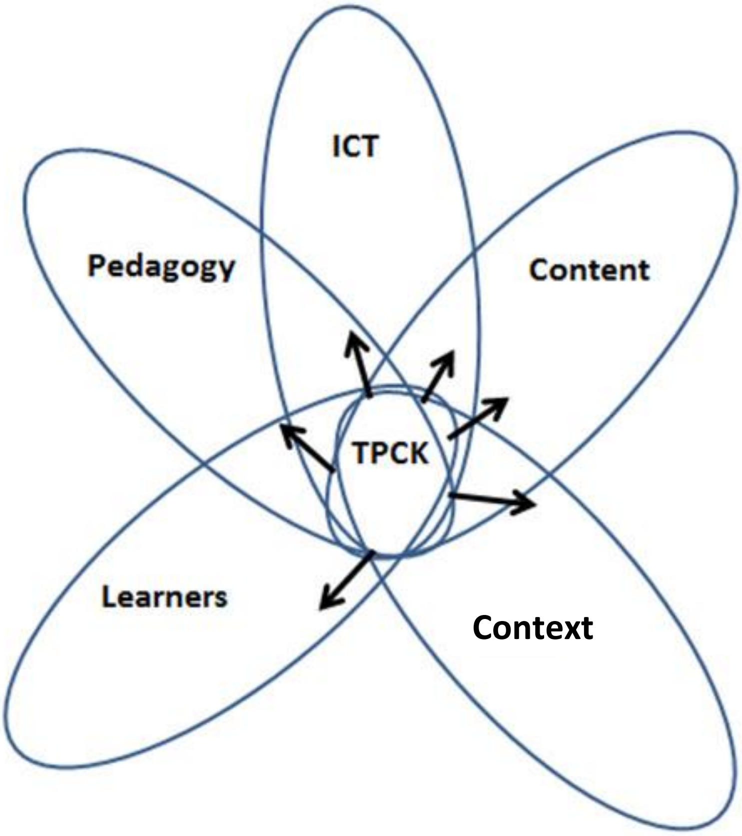

Figure 2.3 The Transformative Model of TPACK

The Transformative model of TCPK thus offers another way of viewing the SAMR model, discussed above, but without the same sense of valorisation because the sense is that unless ICTs can transform practice, there is no sense in using them. This is a subtle distinction, but an important one. The SAMR model, by contrast, argues that substituting newer technologies for older ones (eg. IWB for blackboard) is a necessary first step, even if the use of an IWB offers nothing new. In the Transformative model of TCPK, the added value deriving from ICTs can only come from affordances which go beyond what traditional technologies can offer and hence allow teachers to teach particular content in ways they would not otherwise have been able to do. An example might be the key affordances offered by Google docs for collaborative writing.

Since there has been very little meaningful integration historically, very few teachers will have been exposed to teaching with ICTs as students themselves. Both pre-service and in-service teachers therefore need to learn how to do this. Angeli & Valanides (2013) suggest a model for understanding how teachers may transform their practice by mapping the particular content of any lesson to the particular affordances of technologies within the context, with particular learners in mind, as shown in **Figure 2.4** (Angeli & Valanides, 2013, p. 205) below. The process they describe begins to highlight ways in which we can model teacher decisions around ICT integration.

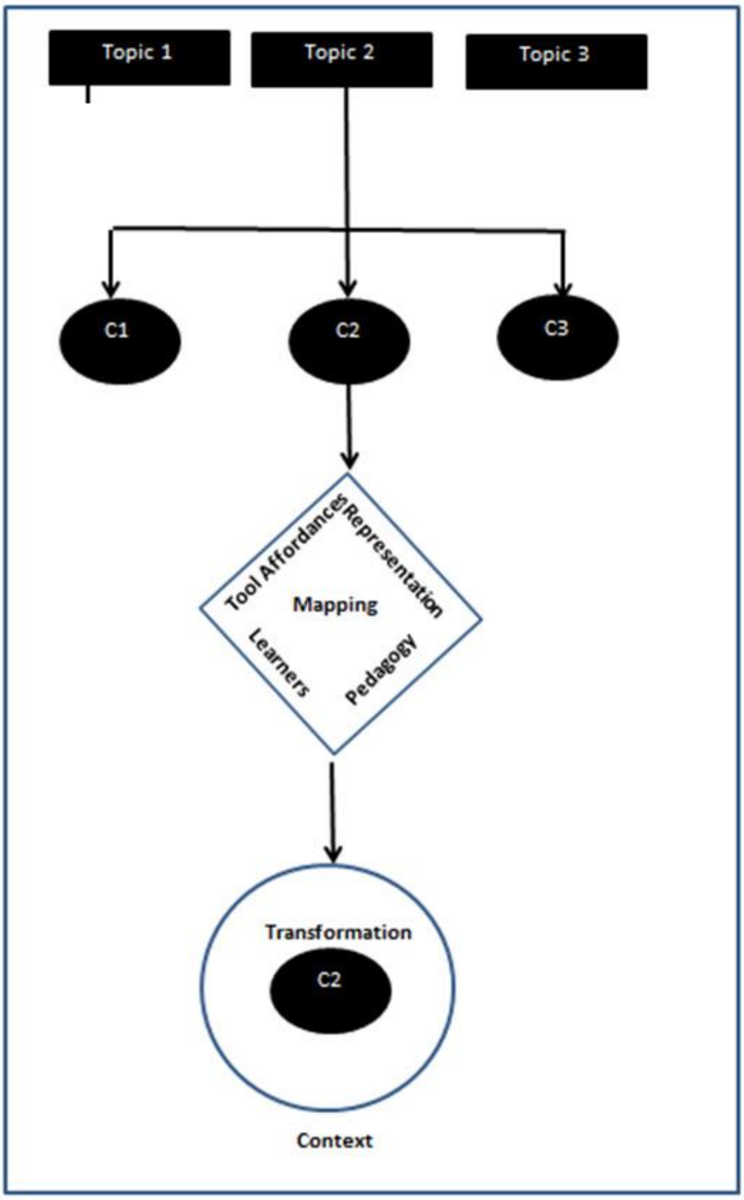

Figure 2.4 The Technology Mapping Instructional Design

This Technology Mapping (TM) model describes an Instructional Design methodology developed by Angeli and Valanides in a series of design-based research studies to assist the teacher to think about how to use ICTs to transform their teaching practice. Angeli and Valanides argue that the TM model differs from other Instructional Design models in that it seeks to situate the model within the context of classrooms and teaching, better to understand teacher's thinking. How are we to assess this claim?

In brief, the process illustrated in Figure **2.4** is one in which all context related factors can be taken into consideration in determining teacher's decisions around how the affordances of particular technologies, specifically ICT technologies in his instance, map to the content being taught, altering thereby the ways in which knowledge is represented in particular pedagogical contexts with particular learners. This is a transformative process, in that "(c)omputer tools with appropriate affordances can transform the content into powerful representations that can actually foster or augment students' conceptual understanding" (Angeli & Valanides, 2009, p. 161).

The strength of the model is that it shifts the focus onto teacher's decision making from a rather vague convergence of Technological, Pedagogical and Content Knowledge in the TPACK model to the point at which decisions are made by the teacher about how particular content is to be taught in any particular context. Crucially, this occurs between decisions about curriculum, and together with the choice of pedagogy. Curricular decisions about which content is to be taught precede any ICT integration in the design model, and are not usually affected by the choice of ICTs to be used. A possible exception to this is Wolfram's (2010) suggestion that the affordances of computer devices may well enable a re-sequencing of the Mathematics syllabus, but this represents something of an extreme case.

The model also places pedagogy at the same level as a representation of the content through appreciation of the affordances of available technologies. This aspect of the model challenges many assumptions about how the use of ICTs necessarily favours certain pedagogies, especially student-centred, constructivist pedagogies as discussed earlier, since the process of mapping technology to content occurs in a situated, and contextually rich environment in which pedagogical decisions are made simultaneously. It is important to note a caveat that this is not to say that student-centred pedagogies will not be chosen by the teacher, or that ICTs might not favour more constructivist pedagogies. It is simply to say that it is not a necessary or even desired outcome of the Instructional Design process.

This alone renders the TM ID model a powerfully generative and valuable critique of the triumphalist narrative which dominates much of the debate around ICT integration. Teacher decisions around ICT integration are clearly largely predicated on the affordances of available technologies. Webb & Cox (2004) have suggested that the affordances of ICTs may well be changing perceptions of pedagogy, by redefining what is possible. The model works with the idea of technological affordances. There are two major approaches to the theory of affordances. It is on these that we must now focus.

2.3 The Affordances of ICTs

Gibson (2014) has argued that the environment offers or affords animals, such as ourselves, certain effects, either beneficial or not beneficial. For these he coined the term affordances. It is important to note that for Gibson these affordances are intrinsic to the environment. They are independent of the perception of the animal, although they stand in a relationship to that animal. What affords shelter to a mouse, does not depend on whether or not the mouse perceives it as shelter, but crucially what is shelter for a mouse may not afford me shelter. A hidden doorway that no-one perceives, affords entrance and exit every bit as much as one that is seen. Gibson is ontologically positivist, although he stresses the relationship between the agent and the object. A door knob only offers the affordance of turning if the agent has hands.

Norman (1998), who popularised the idea of affordances within the domain of Human Computer Interaction, however, argued the case that perception of an affordance is crucial. There is no question that a secret door exists even if it is not seen (ontological realism), but the affordances of that door cannot usefully be said to exist unless they are perceived. I cannot open a door that I do not see. To distinguish between these two positions Norman (1999) later coined the terms real and perceived affordances in order to remove this ambiguity.

This distinction may seem a fine one, but it has had important ramifications in the debate around how affordances and pedagogy articulate. Oliver (2005) has pointed out that this distinction renders real affordances essentially unknowable since we can only ever access what we perceive. This holds true for any individual, but I would argue that the distinction is powerfully generative. Because different individuals perceive different affordances, you may well perceive an affordance that I have missed, but which is nevertheless real. My perceptions are capable of change, especially if I am able to learn from your practice. The purpose of educational technology may lie precisely in closing the gap between perceived and real affordances, either through time as I perceive affordances which I did not perceive before, or socially as I learn from others. Gaver has suggested a framework for both actual and perceived affordances, as shown in **Figure 2.5** below (Gaver, William, 1991, p. 80). Gaver's framework allows us to identify false and hidden affordances, affordances which we perceive, but which are not real affordances, and affordances we do not perceive, but which are nevertheless real.

These are important distinctions in the classroom, and might help explain why sometimes teachers do not appear to be using technologies that other teachers are using – they do not perceive real affordances, or why sometimes teachers appear to use technologies in ways which do not work – the affordances they perceive are not real, are false.

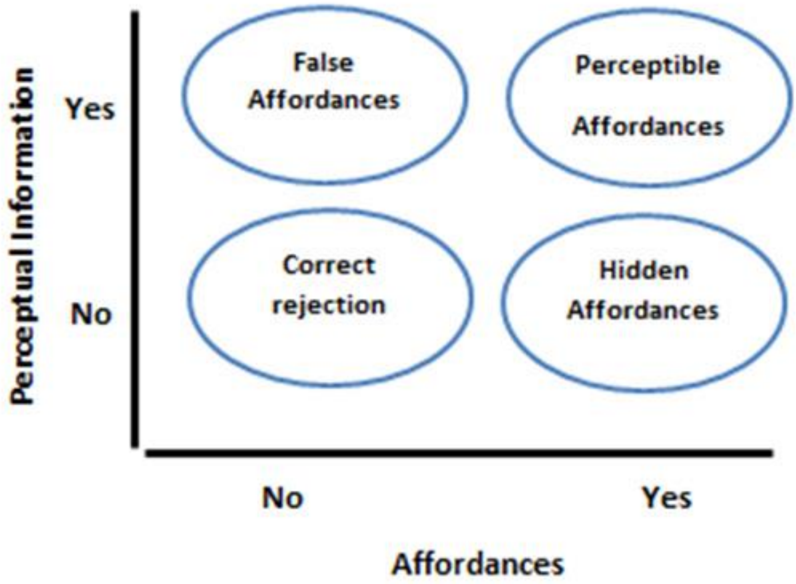

Figure 2.5 Actual & Perceived Affordances

He also introduces the idea of sequential and nested affordances, referring to affordances which are explored, and discovered in time and space. Gaver's framework attempts to resolve the relationship between perception of affordance and the realness of affordances which lies at the heart of most disagreements over the applicability of affordances. But it is a framework of polarities. Affordances are real or they are not, perceived or not. McGrenere & Ho (2000) argue that we need to extend this framework to include the notion of degrees of both perceived and actual affordances, as shown in **Figure 2.6** (McGrenere & Ho, 2000, p. 7) below.

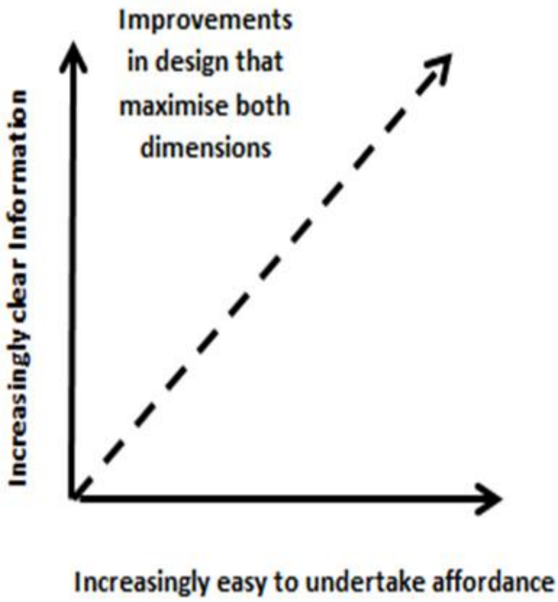

Figure 2.6 Degrees of Perceived & Actual Affordances

This insight is important, not simply in terms of improving design, but in how we perceive of affordances as operating along a continuum between weak and strong. A butter knife offers weak affordances for murder, for example, but strong affordance for spreading. A meat cleaver on the other hand might offer strong homicidal affordances, but weak spreading affordances. The same might be said for pedagogies. A lecture may offer weak affordances for discussion, but it would not be true to say that it offers no affordance. A Think-Pair-Share affords reflection, a jigsaw exercise affords collaboration, and a pop quiz might be said to afford recall.

I would argue that it therefore makes sense to speak both of technological and pedagogical affordances, and to treat these as degrees on a continuum as shown in **Figure 2.7** below.

Figure 2.7 Affordances as a continuum

As Abbott et al (2003) have shown, there is a strong correlation between the effectiveness of ICT and the pedagogical approach of the teacher. Joy & Garcia (2000) with respect to online learning conclude that the question is "(w)hat combination of instructional strategies and delivery media will best produce the desired learning outcome for the intended audience?" (ibid, p.38). This is in response to the debate between Clark (1994), who argued that media does not influence instruction in any way, that learning results from the instructional methods employed, the pedagogy, and (Kozma, 1994) who argued that instructional methods and media are interconnected. I would argue that teachers see both technology and pedagogy as affordances for delivering learning outcomes. They thus form, if we employ Bernsteinian language, the technological code, alongside the pedagogical code, which informs knowledge production, recontextualization and reproduction practices.

If we place Technological and Pedagogical Affordances on a matrix as in **Figure 2.8** below, we can conceptualise of a teacher's task as being to maximise both pedagogical and technological affordances to achieve learning outcomes.

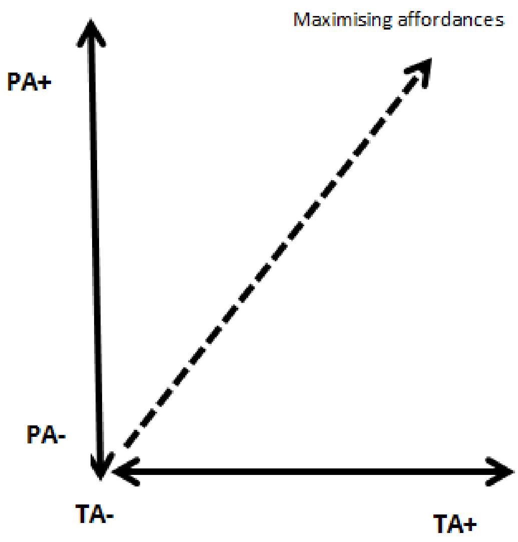

Figure 2.8 Pedagogical & Technological Affordances

The idea of affordances also encompasses the idea of constraints (Hammond, 2009). The two are not opposites, but stand in relation to each other, "suggest(ing) a way of seeing the world as a meaning laden environment offering countless opportunities for actions and countless constraints on actions. The world is full of potential, not of things" (ibid, p.2). This seemingly ontologically interpretivist stance lies at the heart of many of the disagreements over the notion of affordance. There is no reason, however, why an emphasis on perceived affordances should be seen as a denial of actual affordances. Perceptions change, and as Laurillard et al's (2000) study on the re-design of a CD multimedia course shows, the design and re-design of affordances to enhance learning is a crucial aspect to be considered. Not every teacher can re-design hardware or software materials, but teachers can learn to scaffold the affordances of ICTs better, or identify how the affordances of ICTs may be used more effectively or uncover unintended affordances.

In terms of this research, pedagogy and technology are seen as presenting inter-related, sometimes nested affordances. For example, a teacher might decide to teach summarising skills by using twitter (the technology carrying the affordance and constraint of brevity) using paired groups to compose each tweet (the pedagogy carrying the affordance of talk and shared explanation). Both the chosen technology and the pedagogy offer complementary affordances which together are designed to map to the content. As Kennewell (2001) notes, “in order to find general relationships within the teacher-learner-ICT triad and suggest ways of using ICT effectively, we will need to develop reliable measures of affordances, constraints and their orchestration by the teacher” (ibid, p.113).

How then do teachers see the affordances of technology? Angeli & Valanides (2005) have suggested that teachers are not able to distinguish between the functionality of technology and the educational affordances they offer, and that these skills need to be explicitly taught alongside pedagogical practice. Foo, Ho, & Hedberg (2005) have also highlighted how teachers need to make the cognitive processes behind the use of ICTs clear for their students for the use of technology to be effective, and clearly not all teachers are aware of these cognitive processes. Krauskopf, Zahn, & Hesse (2012) have argued that teachers need to develop mental models (Johnson-Laird, 2013) of how the affordances of technologies can be used to pursue learning goals. Mere ability to use technology does not translate automatically into effective use of ICTs to achieve teaching and learning objectives. These studies speak to a clear need to teach mental models for effective use of the affordances of ICTs to achieve educational goals explicitly.

A mental model of how the affordances of technology may be exploited to teach particular content represents the ways in which abstract ideas around technology and pedagogy are concretised for teachers (Krauskopf et al., 2012) and how TPACK is transformed to achieve pedagogical aims and objectives. Mental models are the means by which “individuals reason by trying to envisage the possibilities compatible with what they know or believe” (Johnson-Laird, 2013). Mental models tend to be effective in problem solving where similar problems have been encountered before, suggesting that teachers could benefit from seeing effective uses of technology in the classroom, and this would help them transfer this knowledge across to new contexts to improve their ability to successfully map the affordances of technology to achievable educational goals.

Mental models represent, therefore a way of unpacking what happens inside the diamond in the Technology Mapping model in **Figure 2.4** above, the point at which teachers assess the affordances of available technologies, the conceptual representations required, the context of learners and available pedagogies.

The concept of mental models is a rather crude concept, but carries three fundamental principles, namely that mental models carry a representation of what is common within any distinct possibility being considered, they are iconic in that their structures correspond to their referent, and they favour what is true above what is false (Johnson-Laird, 2013). A mental model of what happens when it is raining therefore would draw conclusions about what is common to every rain incident and would model possibilities based on real experiences of rain, and what was common to all such experiences. Not every rainy experience would involve a raincoat, sometimes umbrellas suffice, but my mental model would need to encompass both in order to be effective in shaping my decisions. Raincoats and umbrellas offer different affordances, and how these affordances articulate with any given context needs to be modelled. But sometimes the affordances of technologies are seen to carry almost pre-determined causal effects, and this is not the case.

Laurillard et al (2000) highlights how the lecture affords listening, while small group activities afford speaking. From this, it is easy to see how seductive the notion is that the properties of ICTs might be seen as affording certain pedagogies rather than others. For example a wiki might be seen as affording collaborative research, while a blog affords reflective thought. However, it seems that teachers tend to perceive the affordances which find a fit with their mental models, rather than the other way round. Teachers, in other words will not simply equate wikis with collaborative research, unless this forms part of their mental modelling of the likely affordances of technologies.

I would also argue that the activated affordances of technologies change with the pedagogy used. A wiki clearly affords collaboration, but if a non-collaborative pedagogy is used, for example if the teacher constructs the wiki herself, the affordance of collaboration is not exploited. There is therefore a complex relationship between perceived, hidden and real affordances. The pedagogical and technological codes are interwoven, and articulate with each other.

Is there a framework we can use when thinking about affordances and constraints. Conole & Dyke (2004) have created a taxonomy of affordances summarised below:

I. Accessibility: or changing patterns of accessing information, a shift from the importance of searching towards the importance of selecting.

II. Speed of change: or how to navigate the rapid change characteristic of late-modernity.

III. Diversity: or how people can be exposed to a range of diverse experiences.

IV. Communication and Collaboration: or the affordances of the new ICTs for enabling extended opportunities for dialogue and collaboration.

V. Reflection: asynchronous technologies have a capacity to enable increased reflection and critique by extending conversations, but the pace of communication may well militate against increased reflection.

VI. Multi-modal and non-linear: non-linear modes of narrative may offer affordances for new modes of learning.

VII. Risk, fragility and uncertainty: the choices people make, the fragility of networked systems and the unintended consequences of actions.

This taxonomy offers the advantage of pointing towards the linkages between affordance and pedagogy. Affordances need to be seen as affordances to teach something to someone, or for someone to learn something in a certain context. The taxonomy above presents one view of a range of modalities for classifying affordances. But for any given decision inside a classroom, the teacher’s concern is to map content to the available affordances according to the context and purpose of the lesson (Angeli & Valanides, 2013). When making these decisions, available technologies, and pedagogies offer stronger or weaker affordances for the purpose at hand.

The TM ID model (Angeli & Valanides, 2013) as reconceptualised to include mental models (Krauskopf et al., 2012) offers a way of conceptualising how teachers might make decisions around ICT integration which avoids both a technologically determinist and a pedagogically determinist view of the affordances of technologies. It is clearly not the only Instructional Design model, but is being used in this research as a heuristic because I believe it offers an accurate model for how teachers go about making decisions around ICT integration.

It does not, however, explain the role played by knowledge, or how the forms knowledge takes influences ICT integration. To understand the role played by knowledge requires an additional literature review, which is set out below.

Technological and pedagogical affordances, actual, perceived and hidden, represent the codes which inform knowledge reproduction practices in schools. What code matches and code clashes can be discerned between technological and pedagogical affordances and knowledge itself? What are the code clashes and matches between how teachers teach (pedagogy) their subject (knowledge) using technology (technology)?

2.4 Conceptual Models of Knowledge & Knowers

The writings of Basil Bernstein have become enormously influential, and generative in educational research, despite Bernstein's reputation for being difficult and overly theoretical (Singh, 2002). These ideas, and certain ideas from Bourdieu, have been explored and expanded, notably by Maton and others, and been developed into a framework of Legitimation Code Theory (LCT) which aims to be able to address many disparate areas of research interest by establishing an overarching theory which can speak to every level of educational research from broad sociological commentaries on education and society, to the individual level of the classroom. This ambitious project encompasses many closely argued points and any full explanation lies outside the scope of this literature review.

Nevertheless, even though I will only be using the bits that I need (Maton, 2014c), so to speak, for this study, it is necessary to situate this part within the context of the whole. LCT, as a whole, also impacts on the methodological assumptions of this study, answering, in part questions about the relationship between theory and data, and consequently speaks also to how knowledge claims within qualitative research can be objectified.

2.4.1 Bernstein's Pedagogical Device

I will now attempt to set out, as succinctly as possible, the framework around which this research study hinges. Bernstein's major theoretical positions take the form of binary opposites. Central to his ideas was the notion of restricted and elaborated codes (Bernstein, 1964), or the difference between every-day, common-sense knowledge (restricted code), which is contextually bound, and schooled, uncommon-sense context-independent knowledge (elaborated code). For Bernstein (2003) school acts as the primary socialization device. The purpose of schools is essentially to socialize an individual's identity by teaching them an elaborated code. Bernstein argued that schools are the primary medium by which inequality and power is reproduced through the three message systems of curriculum, pedagogy and assessment, which act as rule systems and operate in three fields: sites of production, recontextualization and reproduction.

The relationship between these sites is hierarchical. In other words the 'texts' which determine what knowledge is legitimated are produced in the field of production, such as universities. These are then recontextualized, or pedagogised by state bodies, educational publishers or teacher training colleges so that the knowledge is ready for use in the schooling system. This recontextualized knowledge is recontextualized again within the classroom, where restricted codes are recontextualized as elaborated codes through the pedagogic practices of teachers and students (Maton, 2014b).

At all levels of the pedagogic device what constitutes legitimate knowledge is contested and contestable (Singh, 2002) through mechanisms of power and control. Bernstein

(1975) termed these mechanisms pedagogical codes, and they comprise two mechanisms, classification and framing. They act as the means by which inequality is reproduced through these message systems. Classification refers to the ways in which power is constructed into discourse, the extent to which the content has clear boundaries. Subject specializations can have strong boundaries where there are clear demarcations between disciplines, or the boundaries can be weak, as in cross-curricular studies. But it can refer to all aspects of the school, such as geographical separations between staff and students or between grades, assessment of different skills, or access to computer resources (Cause, 2010). These boundaries reflect the ways in which power is being transmitted. Framing, on the other hand, refers to the measure of control within interactional practices, primarily who controls the pacing, timing and content of the delivery of the curriculum, who is allowed to speak, and when.

Pedagogic discourse, according to Bernstein (2003) is made up of two types of discourse, instructional discourse, which relates to the rules governing a subject, the subject knowledge, and regulative discourse which is constituted of the rules governing values and morality. Together they account for the ways in which knowledge is transmitted to uphold the dominant beliefs and values.

These ideas were brought together by Bernstein (1999) into a clear model of horizontal and vertical discourses, and horizontal and vertical knowledge structures. Horizontal discourses correspond to everyday common-sense knowledge – restricted codes. Vertical discourses on the other hand are elaborated codes, corresponding to academic or professional knowledge.

Within vertical discourses, Bernstein (1999) went on to distinguish between horizontal knowledge structures and hierarchical knowledge structures. Horizontal knowledge structures are constructed of strongly bounded specialised languages, unable to establish unifying claims between them. The Humanities are distinguished in this way, with competing disciplines, each with their own language, and little dialogue between them. Some of these knowledge structures are characterised by strong grammars, in other words fairly precise conceptual syntaxes which are able to advance formal models capable of empirical description, such as mathematics, linguistics or economics. Other horizontal knowledge structures have weak grammars where the language is closer to everyday language, and concepts less defined as in sociology or anthropology.

The Sciences, on the other hand are described as a hierarchical knowledge structure because they different fields are nonetheless capable of being integrated at a higher level by overarching concepts which are capable of explaining ever-expanding phenomena. The difference is usually illustrated as shown in **Figure 2.9** (Martin, Maton, & Matruglio, 2010, p. 438) below.

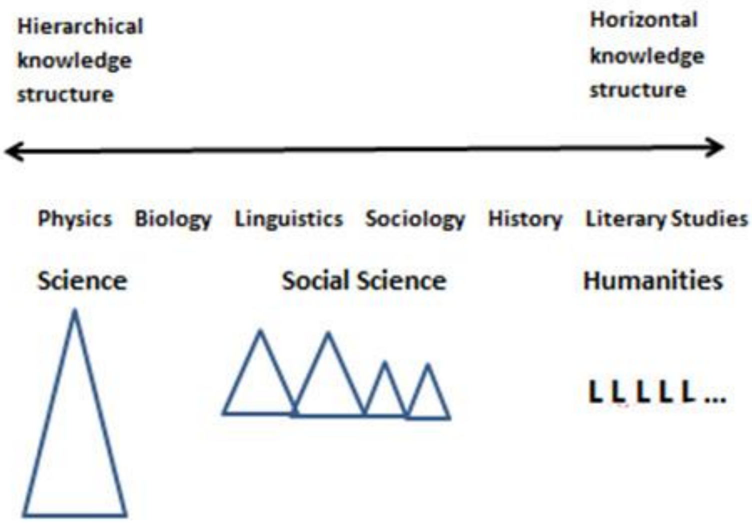

Figure 2.9 Horizontal & Hierarchical Knowledge Structures

In essence, horizontal knowledge structures expand knowledge by expanding fields of enquiry, new disciplines looking at the world from new perspectives. Hierarchical knowledge structures expand knowledge by integrating newly observed phenomena within an overarching structure, which shares a common language and set of procedures, and ultimately seeks to unify the fields.

The heart of the Social Realist perspective is an understanding that knowledge is advanced both through the legitimation of knowledge, but also through the legitimation of knowers, and that the two are intimately linked and on a continuum of possible polarities. Legitimation Code Theory advances the idea of specialization codes as one of the legitimation devices. One of the problems with conceptualising knowledge is that it has been viewed as either decontextualized and objective, or as being merely socially and historically constructed. The Social Realist perspective which draws on the work of Bernstein on knowledge codes and the pedagogical device (Bernstein, 1999), argues that knowledge, while socially constructed, is real, that different forms of knowledge affect educational practice (Van Krieken, 2014), that the forms knowledge takes, does matter. This view has obvious consequences for research into technological pedagogical content knowledge.

A powerful perspective developed by Maton (2014c; 2000c) has extended the work of Bernstein and Bourdieu, by arguing for the development of a framework which conceives of knowledge as modes of legitimation both in terms of Epistemic Relations and Social Relations, in other words a knowledge mode and a knower mode. While the knowledge mode is founded on strong vertical or horizontal discourses, the knower mode is based on the attributes or *habitus* of the knower. Weak Epistemic Relations would indicate horizontal discourses, while strong Epistemic Relations indicate vertical discourses. Weak Social Relations indicate that the knower requires no particular set of attitudes or dispositions, while strong Social relations suggest strong natural abilities or powerful habitus, a “cultivated gaze”.

2.4.2 Legitimation Code Theory

This account of the pedagogic device above presents a theoretical model capable of generating empirical research at all levels of the educational system, but its presentation of binary opposites has been expanded by Legitimation Code Theory to conceptualise not of simple polar opposites, but of gradations of strength to allow for a more nuanced understanding of a range of possibilities.

Maton (2014b) has also expanded Bernstein's model to include both knower and knowledge codes. Bernstein's focus on knowledge structures, while overcoming knowledge blindness, "would leave us blinded to anything but knowledge, offering only a partial view" (Maton, 2014b, p. 71). Maton (2007) extends Bernstein's model to include knower structures. These structures may also be described in terms of horizontal or hierarchical knower structures. A horizontal knowledge structure may thus possess a hierarchical knower structure in which legitimacy resides in a hierarchical structuring of authority residing in the knower. For knowers legitimacy derives from a born, social, cultivated or trained gaze. Science, a hierarchical knowledge structure, is characterised by a horizontal knower structure. All fields thus are characterised by both their knowledge and their knower structures.

Maton therefore developed the idea of Specialization codes based on a polarity of Epistemic relations (knowledge codes) and Social relations (knower codes), both described on a continuum between weak and strong, where strong indicates hierarchical structures, and weak indicates horizontal structures as shown in **Figure 2.10** below (Howard & Maton, 2013, p. 3).

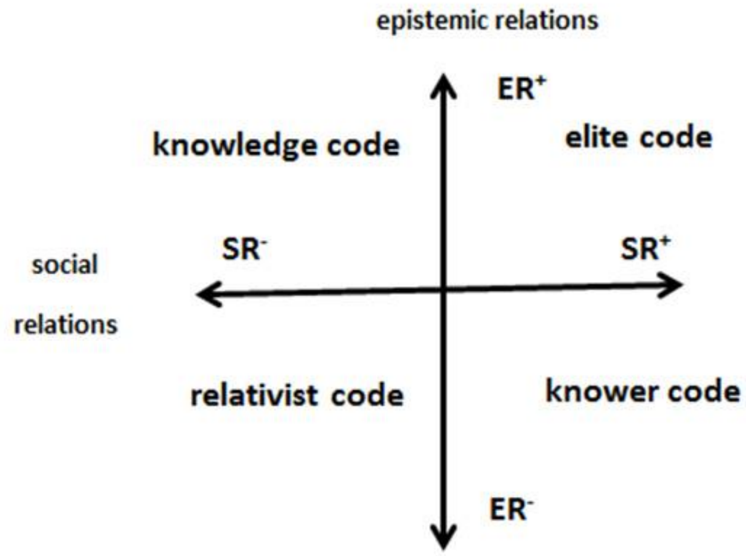

Figure 2.10 Specialization Codes

This quadrant establishes four specialization codes: a knowledge code, with strong epistemic and weak social relations, an elite code with strong epistemic and social relations, a knower code with strong social, but weak epistemic relations and a relativist code with weak epistemic and social relations.

This schema allows us to plot any field against its relative knowledge/knower structures. Howard & Maton (2011) have argued that Legitimation Code Theory offers a powerful way of explaining the ways in which the affordances of ICTs, the technological code, either matches or clashes with the positioning of different subject areas. They argue that Mathematics, with high Epistemic Relations but low Social Relations does not find a ready code match with the affordances of ICTs and helps explain why many Mathematics teachers, while valuing the contribution of ICTs, see little application in the teaching of Mathematics. On the other hand, English, identified as a strong knower code, dependent upon knower qualities such as natural ability or a knack for language, together with a cultivated gaze presents a much closer match with the technological code, the affordances of ICTs for self-expression and communication (Howard et al., 2014).

Interestingly enough, when considering areas of English as a subject, which does stress greater abstract knowledge, such as formal grammar, teachers find fewer matches with technology. When considering drill & practice, the repetition of more concrete and contextualised examples, on the other hand, Maths teachers find greater uses for technology. This suggests that we need to visualise the technological code as consisting of both affordances for knower and knowledge code practices.

Howard et al (2014) thus argue that ICT practices articulate better with knower code practices, but this notion needs to be more carefully examined. I would argue that by conceptualising technological affordances as being tightly interwoven with pedagogical affordances, and seeing these as technological and pedagogical codes affording knowledge or knower structures, we can begin to see how teachers'instructional design, and technological pedagogical knowledge represented by a model such as the Technology Mapping Instructional Design in Figure **2**.**4** above, articulates with knowledge and knowing as code matches and code clashes. But this needs to be unpacked further.

This argument assumes that the technological code presents closer matches with knower codes, and finds fewer matches with knowledge codes. This claim is difficult to assess, and I would argue needs to be set aside until we have discussed other aspects of Legitimation Code Theory. Czerniewicz (2010) has argued that educational technology as an academic field should be characterized as an horizontal knowledge structure and clearly ICT use usually presents itself as a knower structure, akin to a literacy, an acquired gaze, if you will. But the question really ought to be rephrased. As we have seen above, it is not technological knowledge which guides ICT integration, but technological pedagogical content knowledge, with an emphasis on the interplay of pedagogical and technological affordances. So the question we should be asking is what match there is between specialization codes and the affordances of the technology, the technological code.

When looking at how teachers conceptualise the affordances of technology to their specific subject, however, it is clear that we need to take into account not just subject specialization, but also the pedagogical intent of any particular lesson plan. ICT integration will not be influenced by content knowledge alone, but also by pedagogical knowledge. Code matches and clashes between ICT integration and subject specialization needs to be seen as a clash or match between codes, the knowledge/knower codes of subject content, and the technological and pedagogical codes which express a matrix of perceived, actual and hidden affordances offered by educational technologies and pedagogies. These affordances relate directly to the perceived learning outcomes within any particular context. It is not just about how a teacher teaches (pedagogical knowledge) a subject (content knowledge) using technology (technological knowledge), but it is also about the particular purpose of a particular lesson.

This speaks not just to code matches or code clashes between subject specializations and technological and pedagogical codes, but also to how knowledge is unpacked and recontextualized by students and teachers within the classroom.

The specific framework that I wish to apply in this study when assessing how the affordances of ICTs articulate with knowledge building practices, is that of the semantic wave. To what extent do the affordances of ICTs offer matches, or clashes with the building of semantic waves?

2.4.3 Semantic Waves

We need to start by unpacking the concept of a semantic wave. Semantic waves are a way of conceptualising how semantic gravity and semantic density changes over time, and the effect this has on knowledge building practices. It is grounded in Legitimation Code Theory, which is a fusion of the ideas of Basil Bernstein on knowledge codes, and

Pierre Bourdieu on the knower. In this section these ideas will be teased out, and a revised model for ICT integration will be suggested based on LCT and TM.

Semantic gravity has been developed from Bernstein's (1999) notions of hierarchical and horizontal knowledge structures, and refers to the degree to which meaning is context-dependent. Maton (2014b) argues that effective teaching depends upon effective knowledge-building practices, which successfully bridge the gap between high stakes reading (the ability to grasp abstract concepts), and high stakes writing (the ability to communicate within specific academic languages). This is dependent upon both the strengthening and weakening of semantic gravity (context dependence). All too often the result of teaching is that students remain grounded in context-rich knowledge, but are unable to transfer this to knowledge to other contexts. This segmentalisation of knowledge practices, and inability to apply knowledge to new contexts is a limiting factor in ineffective educational practice.

Bernstein (1999) distinguished between horizontal and vertical discourses. Horizontal discourse refers to common sense, everyday knowledge and is context specific, with very limited ability to transfer knowledge to new contexts. Vertical discourse, on the other hand, refers to hierarchically and systematically structured knowledge and to specialised languages and modes of knowing. These forms of knowledge are not segmentalised on the basis of context, but on the basis of meaning.

Bernstein then went on to distinguish, within vertical discourses, between the two types of knowledge structures, horizontal and vertical knowledge structures. Vertical knowledge structures are arranged hierarchically, and seek to generate theories and generalities at the level of the abstract, which serve to "integrate knowledge at lower levels, and in this way shows underlying uniformities across an expanding range of apparently different phenomena" (Bernstein, 1999, p. 162). Procedurally new knowledge is generated by integrating and expanding previous knowledge within overarching theories. These are the procedures favoured by the natural Sciences, for example in the attempt to unify the fields.

By contrast, horizontal knowledge structures are those which are created by the expansion of specialised languages and modes of inquiry. These are non-integrative codes in that they expand knowledge by adding new modes of inquiry, or theoretical stand points rather than by subsuming phenomena within an expanding explanatory framework. The human and social sciences operate in this way, expanding knowledge through the addition of new theoretical perspectives rather than seeking a grand theory. Bernstein (1999) characterises these specialised languages as idiolects and as serial rather than integrative codes.

Bernstein's model of horizontal and vertical discourses, and of vertical and horizontal knowledge structures offers a nascent theory of how knowledge is extended and recontextualised, but as Maton (2014b) suggests, the theoretical framework needs refinement in order to offer explanatory power. Maton argues that we need to consider semantics, specifically the idea of relative semantic gravity (SG), or how abstract or contextualized knowledge is, and semantic density (SD), the degree to which meaning is condensed within concepts or symbols, to situate vertical and horizontal discourses and knowledge structures and allow a more integrated account of education as a field, across questions of discourse, knowledge structures, curriculum structures and teaching & learning, as shown in **Figure 2.11** (Maton, 2009, p. 46) below.

Semantic gravity	discourse	Forms of: Knowledge structures or curriculum structures	learning
Weaker	Vertical	Hierarchical	Cumulative
		horizontal	segmente
stronger	horizontal		

Figure 2.11 Semantic Gravity and the structuring of knowledge

At the level of discourse, semantic gravity helps explain how teachers attempt to bridge the divide between horizontal discourse and vertical discourse, between what Bakhtin (1981) would have described as the dialogic voice of the student and the monologic voice of the teacher. At the level of curriculum it helps understand how knowledge is built upon previous knowledge in an integrative manner (vertical knowledge structures), or is advanced segmentally (horizontal knowledge structures) by moving from a binary model towards being able to describe knowledge building along a continuum of weaker or stronger semantic gravity. Maton argues that semantic gravity as a concept helps integrate accounts of education, of how knowledge is produced, recontextualized and reproduced through the pedagogical device.

Maton (2009) argues that powerful knowledge building practices are built upon both the strengthening and weakening of semantic gravity. A successful academic essay, for example will move between rich contextual description and generalised abstractions, drawing generalizable conclusions from specific examples. This creates a gravity wave. Unsuccessful essays, on the other hand, will flat-line, remaining either too abstract and general, or never veering from contextual description as depicted in **Figure 2.12** (Maton, 2014a, p. 38) below.

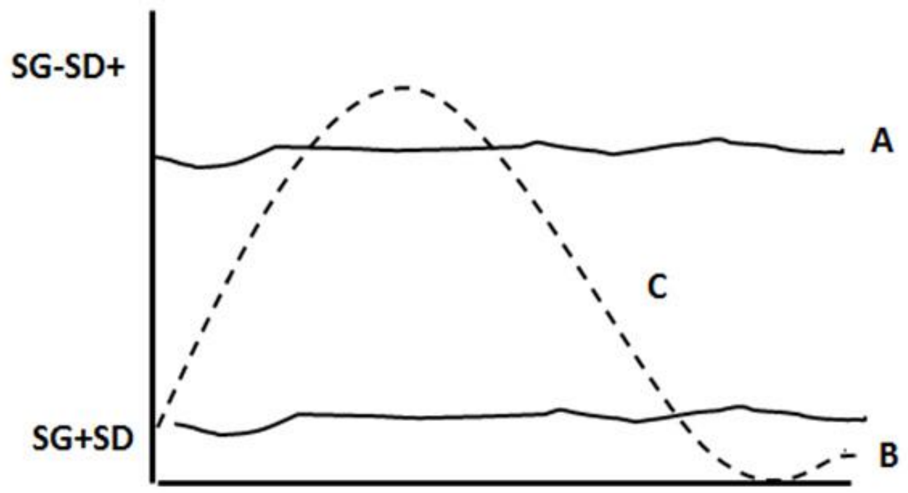

Figure 2.12 Semantic Profiles

This conception of knowledge building in the classroom helps to explain the process of teaching as semantic waves in which teachers mediate and unpack ideas, helping students understand abstract and symbolic ideas by making them more concrete and accessible, and then helping students construct their contextualized, personalised knowledge and express themselves in their writing, able to synthesise and reformulate ideas in abstract form, in academic discourses.

Maton argues that it is movements “up and down the semantic continua” (2011, p. 66) that crucially informs knowledge building activities. All too often teachers attend only to the question of movement from highly generalised and condensed meanings (SG-/SD+) to simpler, more contextualised meanings, often expressed in everyday language (SG+/SD-) (Macnaught, Maton, Martin, & Matruglio, 2013) and do not effectively scaffold student’s construction of knowledge in terms of moving from the everyday to generalised, abstract knowledge which forms part of the language, and understanding of the discipline being learned.

As Shalem & Slonimsky (2010) have shown, both Bernstein and Vygotsky highlight the ways in which generalisation and hierarchy are central to knowledge formation, and the ways in which knowledge is mediated. I would argue that this is more or less true of all pedagogical approaches, and that the Semantic Wave model offers a useful framework for analysing how teachers are using the affordances of ICTs both to "unpack" and "repack" ideas. Martin (2013) relates the semantic wave model to the use of power words, power grammars and power composition, within Biology and History, demonstrating ways in which weakening and strengthening semantic density and gravity forms part of teaching activity routines. See **Figure 2.13** (Maton, 2014a, p. 42) below. Abstract texts are read (unpacked and understood) and then understanding is reproduced in terms of essays which demonstrate that understanding.

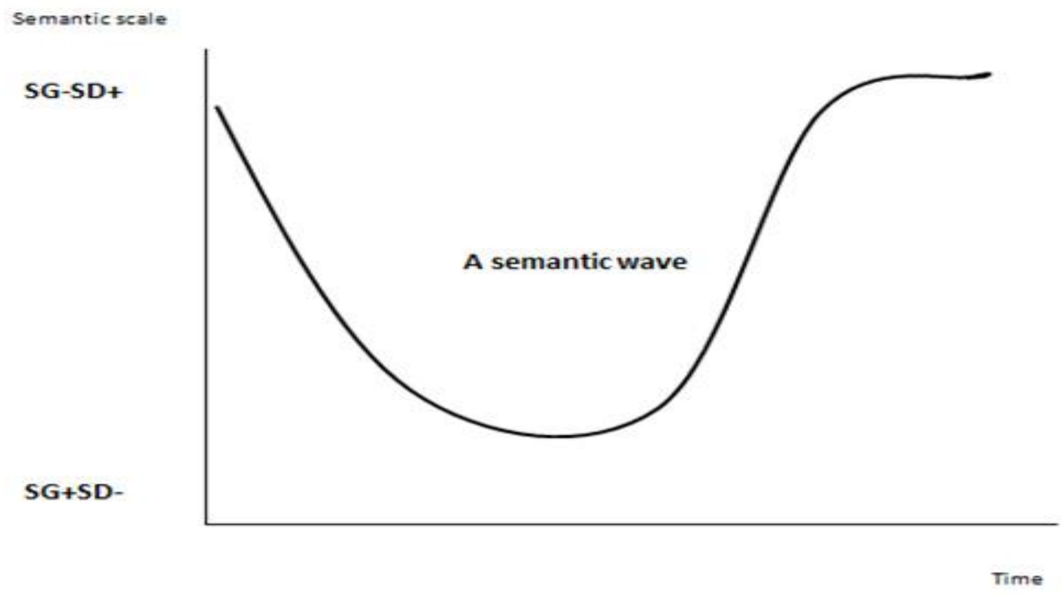

Figure 2.13 Semantic Waves

I would argue further that the communicative affordances of ICTs offer unique affordances for social constructivist approaches, emphasising Vygotsky's (1978) notion that all learning occurs first at a social level and only secondly at an individual level. This alignment of ICT integration with Social Constructivist pedagogies forms an enduring thread in the debates around ICT integration. LCT offers a framework for evaluating how the affordances of ICTs align or fail to align with how meaning is deconstructed and constructed in the classroom.

2.5 The Theoretical Framework

In this study I will use the framework of LCT to examine how the affordances of ICTs are perceived and used by teachers of different subjects in their teaching practice.

Semantic waves lead to effective knowledge building because they incorporate movement between abstraction and contextual detail (Maton, 2014b; Shalem & Slonimsky, 2010). Vygotsky argued that thought needs to move from the 'spontaneous' heavily contextualised knowledge, through a process of mediation by adults towards an understanding that is 'scientific' or abstract. But Vygotsky (1962) also noted that the 'scientific' concepts introduced to the student need to be contextualised by the child to be understood. This describes a similar upward and downward movement from strong semantic gravity to weak semantic gravity, and back again as is described by Maton (2013b) in building powerful knowledge. Powerful knowledge is the result of both gravitation and levitation. Consequently, the question of the effectiveness of ICT integration is in itself a pedagogical question. Can the affordances of ICTs find a match with both gravitation and levitation?

Shalem & Slonimsky (2010) argue that there is thus a disjuncture between the rules governing the field of knowledge production, where the emphasis lies on building vertical knowledge structures, and the rules governing the field of the reproduction of knowledge, where oscillations between abstract and concrete knowledge are necessary to build knowledge. Macnaught et al (2013) have shown how strategies can be developed and taught to teachers to help them scaffold students' ability to acquire these practices. Conceptualizing how the affordances of ICTs might enable similar effects requires two crucial bridging concepts, that of *gravitational affordances*, what affords gravitation, and *levitational affordances*, what affords levitation.

Examples of gravitational affordances might be technologies which afford visualization or contextualization, for example IWBs, YouTube videos, Google images, GeoGebra, Flash simulations and so on. Technologies which afford levitation might be authoring software, collaborative software, Mind Mapping software and so on. These, however, represent potential (real) affordances, and as the debate around the notion of affordances in educational technology has shown, we need to recognise the difference between perceived and actual affordances.

Maton (2014b) argues that these semantic waves can be expressed as two major semantic profiles, that of ***gravitation***, the strengthening of semantic gravity and the weakening of semantic density, and ***levitation***, the weakening of semantic gravity and the strengthening of semantic density. If we take this as a useful model of what teachers are engaged in, I would hypothesise that the affordances of pedagogy and technology that teachers perceive relate precisely to this movement between semantic profiles that generates effective knowledge building. Ineffective use of pedagogy and technology, on the other hand would lead to the flat-lining of understanding where understanding remains at too general a level, an abstract flat-line, or too contextually based, a narrative flat-line, as indicated in **Figure 2.14** below. In this diagram the semantic axis is extended by considering a continuum of Pedagogical and Technological Affordances, from strong (PA+TA+), where strong affordances are offered, to weak (PA-TA-) where there are fewer affordances. The extent to which activated affordances may be said to be strong or weak is clearly linked to context and purpose. Individual contexts will decide whether a forum or Google docs, for example, offers stronger or weaker affordance for any purpose. The same may be said of pedagogical approaches such as a fish-bowl or a Think-Pair-Share. When interwoven technological and pedagogical affordances may amplify or interfere with each other.

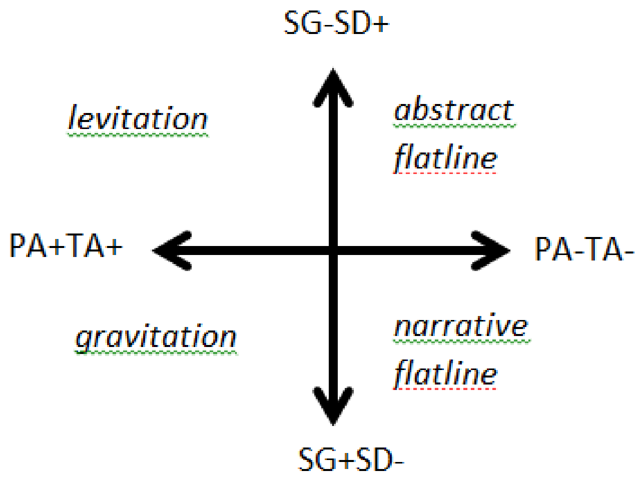

Figure 2.14 Affordances for Gravitation & Levitation

But in fact this diagram needs to be seen in three dimensions since technological and pedagogical affordances will not always be aligned – see Figure **2.15** below.

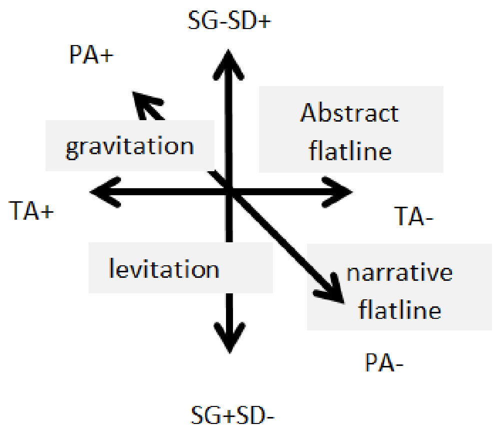

Figure 2.15 A conceptual model for aligning technological and pedagogical codes with semantic profiles

This expresses the extent to which teaching, reduced to pedagogy and technology, scaffolds and affords knowledge building along a continuum. It is cast in the idiom of Legitimation Code Theory, and I would suggest is generative of research into ICT integration practices in ways which do not privilege particular pedagogical paradigms or models of ICT integration, since ICTs are simply one of many technologies available to a teacher.

Using Bernsteinian language we may term these sets of affordances, and attendant constraints as composing a technological code to match the pedagogical code.

In the discussion on the conceptual framework for technology integration I suggested that the Technology Mapping Instructional Design model developed by Angeli & Valanides (2013) offered the most complete analysis of an ICT integration model which avoided both techno-centricism and pedagogical reductionism and together with Krauskopf et al’s (2012) addition of mental modelling as a mechanism for situating how the perceived affordances of technology are articulated. It is the model that I have chosen to use as a lens for this research, and indeed in my own practice.

For this reason also, the conceptual framework treats technological and pedagogical affordances as two distinct, but related entities and equates affordance with successful implementation, which, it must be recognised is not always the case. This is a speculative framework, one designed to pose a question rather than supply an answer.

3. The Research Methodology

This research study aims to explore how teachers are using ICTs in their classes to teach their specialized subjects. It is interested in exploring how the forms knowledge takes affects ICT integration practices, and seeks to unpack the concept of TPACK and how the affordances of ICTs are being used to teach particular content. It also seeks to ask whether the concept of semantic waves has explanatory power when looking at ICT integration, and whether ICTs offer affordances for gravitation and levitation.

The study employed a qualitative research methodology using in depth interviews and lesson observations. There were two phases to the study. In the first phase five teachers who were using ICTs in their lessons were interviewed. The purpose was to explore teachers' own perceptions and reasons behind their decisions around ICT integration. In the second phase two lessons were observed. The aim was to observe how ICTs were being used and any possible effects on semantic gravity and density.

3.1 Research Methods

In Chapter 1.3, I set out some of the concerns which have led me, as a practising teacher at a private girl's school in Johannesburg to investigate ways in which different subject teachers are approaching the integration of ICTs into their classrooms. I feel this discussion was particularly important to lay bare my personal perspectives, and help frame for the reader the overarching concerns which have shaped this research. Not necessarily because I want to counterbalance my own subjectivity, but because the question emerges out of personal practice in the classroom, and my understandings have been shaped by my lived experience of integrating ICTs in the classroom, and these understandings have very much influenced how I have set about trying to bridge the gap between theory and practice.

While I am not researching my own practice, I am researching the practice of colleagues, with whom I work closely, and my perceptions of their practice are heavily influenced by how I view my own practice. This is not a case study in that I am not attempting to study the implementation of an IT strategy at Girl's High, per se, nor is it a form of participant observation in that although I am researching my colleagues, I am using interview and direct lesson observation as instruments rather than general observation.

Nevertheless this study shares certain features in common with participant observation. In participant observation the researcher attempts "to learn what life is like for an 'insider' while remaining, inevitably, an 'outsider'" (Mack, Woodsong, MacQueen, Guest, & Namey, 2005, p. 13). This presents both opportunities for insights which would not have been possible for a complete outsider. One of the great strengths of participant observation is that it allows for these insights, and can access information which would otherwise not have been available, but the danger lies in the inherent subjectivity of this method.

While there are disadvantages attached to the fact that the researcher necessarily brings greater subjectivity to the inquiry, there are a number of advantages. An insider can observe things that an outsider cannot, the problem of reactivity may be lessened, and an insider may better understand what questions to ask and may be able to interpret the data more intuitively (Bernard, 2006). However, as Kawulich (2005) notes, where the researcher is also a participant there are a number of disadvantages in that there is necessarily a trade-off between the depth of data that will be revealed to the researcher and the level of confidentiality provided in return.

I took some steps to try and minimise my role as a member of the IT Strategy team, which may have been perceived as in opposition to teacher's points of view, as discussed in the first chapter. Since I was not primarily responsible for providing any teacher training, and I deliberately took a back seat in this regard, I tried to allay fears that I held uncritical views on the benefits of ICTs in the classroom. In approaching those I intended to interview, I stressed the extent to which I wanted to hear their candid views and impressions of the extent to which ICTs were useful, or not to the teaching of their subject specialisations. I did not sense any reluctance to be critical of the IT Strategy, and indeed felt that my colleagues were very open and frank in expressing their views, as can be seen in the transcripts of interviews. I was interviewing teachers who were known within the school to be champions of ICT integration, and with whom I had shared numerous discussions about technology in the classroom.

Nevertheless subjectivity is an issue which needs to be addressed. As Mruck & Breuer (2003) argue, all research questions begin, to some extent or other as a personal question, influenced by the personal beliefs and attitudes of the researcher. The very act of choosing what question to ask depends upon personal perceptions about what it is important to know. These personal beliefs continue to influence the methodological approaches taken, how the data is collected and interpreted, and of course how conclusions are drawn from the data.

Maton (2003) has described how reflexivity in the social sciences has moved from academic opprobrium to the status of *de rigeur*. The researcher is required to bare their soul in order to expose their biases to the view, in the hopes that this will, in and of itself, validate their observations, without ever explaining why this is the case.

My personal perspectives in Chapter 1.3 were offered partly in this sense. Nevertheless, this research endeavour is framed within a Social Realist perspective, as will be discussed later, in which the standpoint of the researcher is assumed to be subjective, but not necessarily problematic in the sense that the knowledge claims being advanced are open to scrutiny, and have an independent validity to the stance of the knower. The strong theoretical framing of this research and the dialectical relationship between theory and data that will be advanced means that the standpoint of the knower, while not irrelevant, is open to evaluation.

Bourdieu (Bourdieu, 1992) has argued that personal reflexivity, a simply narcissistic relationship with the object of knowledge, in which the author can effectively see nothing but the reflection of their social self can be avoided by appealing to an objectifying reflexivity, or relation between the knower and the known, the object of study, because the researcher is part of a social context which allows personal reflexivity to be critiqued. The error of positivism is that it assumes that the object of study, that which is to be known, can be known without taking into account the subjective view point of the knower. All thought, in other words has an historical dimension (Kuhn, 1970) to it. This requires that the social framing of that objectifying relationship is understood, the history of the problem that is being addressed and the collective understanding rather than that of the individual alone, since individuals strive to assert their versions of the explanation to win social capital. Bourdieu stresses that this reflexivity is not a matter of an individual sensibility, but the result of social and collective understandings. "Participant Objectivation" (Bourdieu & Wacquant, 1992, p.253), although difficult to achieve, allows the researcher to escape the narcissism of reflexivity.

Maton (2003), by contrast argues that Bourdieu falls into his own trap since there is no real collective methodology for ensuring the objectification of individual reflexivity. What validates reflexivity, in the end, is the objective nature of knowledge itself. From the shifting sands of the individual observer, and their social stand-point, ultimately the epistemic relationship rests upon the "structuring of knowledge itself" (Maton, 2003, p.62) and needs to encompass a concern with the Knower (A) and the object of study (B), but also with how knowledge claims (C) are made, the epistemic relation as illustrated in **Figure 3.1** below (Maton, 2003, p. 57). Knowledge building, in other words is ultimately what holds reflexivity of the researcher accountable.

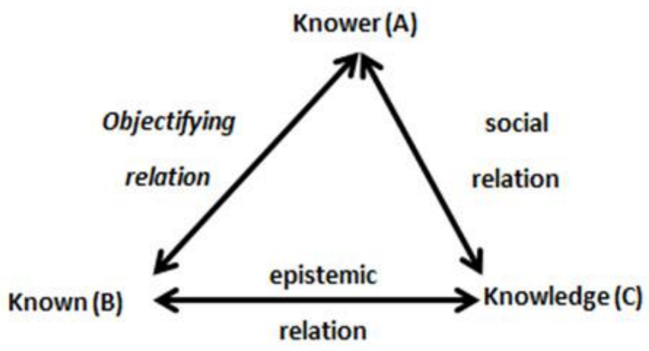

Figure 3.1 Three Relations of Knowledge Claims

This concern with establishing an epistemic framework for making knowledge claims, how knowledge is legitimated, is ultimately what enables epistemic reflexivity in research. Maton uses the Scientific method as an example of how the procedures by which knowledge claims are legitimated rest upon an interest in their epistemic validity. It is this concern with procedure which grants epistemic capital. Ultimately researchers do have a vested interest in seeking the truth, and it is this which validates academic endeavour. What needs to be made explicit is thus the theoretical stance of the researcher rather than their personal subjectivity (Maton & Chen, 2015).

Merriam (2002) begins her introduction to qualitative research with the claim that "(t)he key to understanding qualitative research lies with the idea that meaning is socially constructed by individuals in interaction with their world. The world, or reality, is not the fixed, single, agreed upon, or measurable phenomenon that it is assumed to be in positivist, quantitative research." (ibid, p. 3) This view sets up something of a false dichotomy between what are seen to be incompatible poles of positivist realism on the one hand where knowledge is objective and value-free, and interpretivist constructivism on the other, which where all knowledge is socially and historically constructed (Moore et al., 2010).

And yet there is no reason why an ontologically realist position should be incompatible with a socially constructivist epistemology (Maxwell, 2012b) or why all socially constructed knowledge should be seen as inevitably relativist. While our knowledge of the world is undeniably socially constructed, rational objectivity is possible. This view is rooted in a view which rejects the notion that there is only one objective view of reality. Multiple perspectives are possible, all theories are grounded in particular paradigms and knowledge is partial and fallible. But this is not to deny the existence of knowledge or that the forms that it takes have real effects on educational practices.

This interpretivist approach stresses the value of qualitative research in building theory. The purpose of the research is inductive, to gather data from which theory can be built. This stands in stark opposition to the process of gathering data to test a theory or hypothesis as is more common in positivist research traditions. This study takes the form of qualitative research, but sees itself as grounded in a social realist, rather than an interpretivist tradition, and sees the process and purpose of gathering data as standing in a dialectical relationship with theory (Morais, 2002).

Figure 3.2 (Morais & Neves, 2001, p. 187) below illustrates a research methodology based on Bernstein’s work, which seeks to conceptualise the dialectical relationships between theory and data which has descriptive, explanatory, diagnostic, predictive and transferrable power.

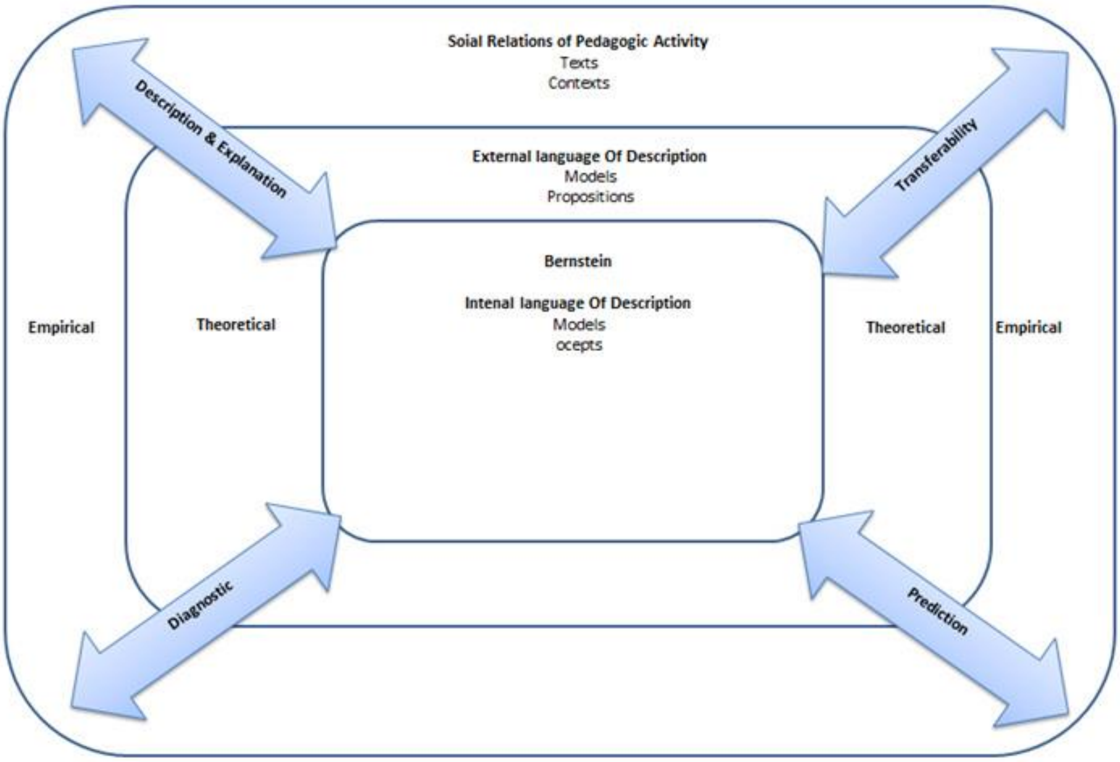

Figure 3.2 A Sociological Research Model of Methodology

This model allows for both strong theory, and for respect for empirical data to be maintained. This depends, as we shall see below, on a dialectical process in which the gap between theory and data is closed by bringing together the language of the theoretical stance and the language of the data. I would argue that my position as a colleague researcher has equipped me with intuitive insights, shaped also by numerous informal lesson observations, which has been enormously influential in facilitating this process in ways which are not transparent, or even discernible. For this reason I have taken pains to try to situate this research within the triangulated model proposed by Maton (2003) in **Figure 3.1** above.

Because teaching is a complex activity which resists simplistic models, the role of theory in educational research has been described as a wicked problem (Trowler, 2010), in that issues within education are ill-defined and there is a lack of common approach. Studies tend to speak to the particular and it is difficult to draw general conclusions.

This study aims to situate itself within the context of LCT research which carries a shared aim of developing a theoretical model capable of addressing this problem of the lack of a common approach. It uses a strongly defined theoretical framework rather than the usual aim of qualitative research, which is inductive and seeks new insights. This study is essentially enquiring into the extent to which the framework offers explanatory power. The strong foregrounding of theory presents its own problems.

Maton & Chen (2015) write about the difficulty in bridging the gap between theory and data in qualitative research. As Bernstein noted, the problem lies with the nature of theory itself. He sets out two types of language of description. He termed the first the **internal language of description** which works at the level of the theory itself, and how elements of the theory interrelate. And then there is the **external language of description**, which describes how the elements of the theory relate to referents beyond the theory. A strong internal language of description is one where the elements of the theory are closely interrelated, while a strong external language of description is where the elements of the theory relate most directly to external referents.

This formulation represents one way of expressing the recurring debates in epistemology around coherence and correspondence theories of truth and reaches to the heart of what makes for good research. A good empirical study without a strong theoretical grounding lacks an applicability beyond the study itself because it speaks only to the particular, whereas a strong theoretical piece, without any resonance in the data, represents a "sealed system within which concepts endlessly circulate, recognise and interrogate each other, and the intensity of its repetitious introversial life is mistaken for a 'Science'" (Thompson, 1995, p. 17).

Morais (2002) argues that while traditionally, quantitative research has focused on testing theory deductively, qualitative research has centred on the empirical and builds theory inductively. In her view, however, sound research in education depends upon an emphasis on both theory and practice. This is a dialectical process which must produce a theoretical model sufficiently strong that it is able to diagnose, describe, explain, transfer and predict effects. In a similar vein, Burawoy (2009) argues for a reflexive model of science based on engagement rather than detachment. Where “we continually engage theory with data, and theory with other theories” (p.15). Theory is forged and tested by a constant interrogation and elaboration with the empirical data.

Using Bernstein’s model of vertical and horizontal structures of knowledge, the field of educational technology can usually be characterised as a horizontal structure of knowledge with weak grammars (Czerniewicz, 2010; Morais, 2002), since it borrows its theoretical foundations from so many different fields: psychology, epistemology or sociology. This lends it very little power to diagnose, explain, transfer or predict, lacking as it does a strong internal language of description. There have been many calls for the development of more coherent theories in the field of educational technology (Jones & Czerniewicz, 2011) and educational research generally. In Bernstein’s theories, however, Morais sees a stronger grammar, compared to other sociological theories, able to be used as a more sound basis for educational research, with a strong internal and external language of description.

However, for the qualitative researcher, there lies a danger that where a theoretical framework with strong internal language is used, there will be difficulties in addressing the empirical data. Maton & Chen argue the need to develop a translation device to bridge this discursive gap between theory and data (2015, p.2). Theory is often either imposed on the data, or the data is viewed as being free of pre-existing theoretical categories held by the researcher. Neither case holds water – the relationship between theory and data is deeply problematic. Bernstein had argued for the use of a translation device, by building an explicit external language of description which corresponds to the theoretical outlook of the internal language of description. The internal language of the theoretical approach cannot, however, simply be imposed upon the data. Immersion in the data is necessary to understand how concepts are realised in different contexts. This is represented in Morais & Neves (2001) research model in **Figure 3.2** above by the bi-directionality of the arrows linking theory and data, indicating a dialectical relationship between the two.

The internal language of description was provided by the theoretical frameworks used, the Technology Mapping Instructional Design model (Angeli & Valanides, 2013) and its concern with mapping content to affordances of technologies, and Maton's (2014b) Semantic Wave model derived from Legitimation Code Theory.

Maton & Chen (2015) suggest ways in which data instruments, mediating language and translation devices can be used to foreground how the conceptual framework will be enacted in the data, as organising categories in data collection or in analysing the data. For this study the main organising categories of the theoretical frameworks used provided clear conceptual categories of the Internal Language of description as shown in **Table 3.1** below.

Table 3.1 Internal Language of Description

Internal Language Of Description	
Technological Affordances	Strong Technological Affordances Weak Technological Affordances
Technological Constraints	Strong Technological Constraints Weak Technological Constraints
Pedagogical Affordances	Strong Pedagogical Affordances Weak Pedagogical Affordances
Semantic Gravity	Strong Semantic Gravity Weak Semantic Gravity
Semantic Density	Strong Semantic Density Weak Semantic Density
Semantic Profiles	Gravitation Levitation Narrative Flat-line Abstract Flat-line

The external language of description, however, cannot be derived merely by extending the internal language of description, but needs, if it is to allow unexpected or new insights to emerge from the data, to arise from an immersion in the data (Maton & Chen, 2015). The categories of analysis need to emerge organically from the data. The gap between the two then needs to be closed by "iterative movements between theory and data" (ibid, p. 10).

I will now seek to describe how I went about organising this dialectical methodological approach in two phases.

3.2 Phase 1: Interviews

The main focus of the interviews was to examine the decisions being made by teachers around ICT integration. The lens was the Technology Mapping Instructional Design model and LCT.

I conducted five 40-50 minute interviews with different members of staff. The interviews were semi-structured, with some questions prepared in advance, see Appendix A: Interview Questions. The bulk of the questions, however, emerged from probing responses by the interviewee, and some of the pre-determined questions were not necessary to ask as ideas had been covered by other questions or were volunteered. I tried to make the interview as much of a conversation as possible, of the type that might have occurred in informal settings, as I felt this would elicit more candid responses.

In some instances I asked questions to probe what I had heard in previous interviews with other teachers, or to explore themes that had emerged in previous interviews or informal discussions.

When it came to analysing the data, the external language of description was provided by the categories described by the teachers interviewed. I annotated the transcripts of the interviews, summarising points being made, and then, in successive readings started to group responses into concerns and topics. In some cases there were immediately apparent matches to the *a priori* categories of the theoretical framework. In other cases there was no clear match, and the concerns raised organically by interviewees, were added to the coding, grouped and regrouped. For example Time emerged as a major determinant and was coded separately. I had to decide whether to view time as a category on its own, or to subsume it under affordance or constraint. I will explore this issue in the next chapter, but it illustrates the dialectical process which needed to be undertaken.

At this stage a table was drawn up with a summary of concerns raised by the interviewees mapped to the *a priori* categories where there was an apparent match and the new categories suggested by the data. This formed an interim translation device. As the data was interrogated it became possible to condense some of the categories by grouping them into higher order categories as I began to realise that concerns were being duplicated in the table. A list of codes used is attached in Appendix B: Interview Codes.

From this process, a final translation device was drawn up, to be found in Appendix C: The Translation Device For Interviews. This contained *a priori* categories directly from the theoretical framework, categories which after reflection were clearly able to be interpreted within the theoretical framework, and organic categories which fell outside these categories and were not open to ready interpretation within the model.

Some lessons were observed informally during the course of the research, but no recordings or transcripts were made. The purpose of these observations was to get a sense of what was being mentioned in the interviews, and this served the purpose of triangulation of the data to some extent, allowing me to understand more fully what the teachers were referring to in their interviews.

3.3 Phase 2: Lesson Observation

The main purpose of the lesson observations was to examine semantic profiles in two ICT integrated lessons. I observed two lessons, one a thirty minute Advanced Programme Maths lesson, the other a seventy minute Technology lesson. A recording was made and transcripts of audible sections of the recordings made.

An already existing translation device for Semantic Gravity was used as a starting point (Maton, 2011, p.74). I took the categories of this device as the internal language of description as they offered a workable gradation of semantic gravity from weak to strong as shown in **Table 3.2** below.

Table 3.2 Translation Device For Semantic Gravity

Low Semantic Gravity High Semantic Density	Abstraction
⇕	Generalization Judgement Interpretation Summarising Description
High Semantic Gravity Low Semantic Density	Reproductive Description

Two further categories were added to describe talk which was not related to the content of the lesson. As Laurillard et al (2000) noted in their study on the design and re-design of a multi-media program, there were two types of off-topic talk recorded, talk about the task mechanics, often reflecting difficulties in using the technology, and talk around the purpose of the task. A third possible category, talk that was entirely unrelated to the lesson was also added as in **Table 3.3** below.

Table 3.3 Additional Categorization of Talk

Talk about the Task Mechanics
Talk about the Task Purpose
Talk about unrelated matters

The external language of description was created by looking at the transcripts of the lesson and through successive attempts to interpret the relative semantic gravity and density of each clause, an understanding emerged as to what a typical example of each looked like in the context of these lessons. These transcripts were then re-coded using the translation device which emerged. A copy of this is to be found in

Appendix D: The Translation device for Lesson Observation.

A particular difficulty in looking at the Technology lesson was that students were engaged in a jigsaw exercise in which they had to “teach” content they had authored in Specialist groups in a previous lesson using Google docs to a home group of peers. This provided a somewhat problematic situation in which some of the previously authored content was read back rather than being delivered extemporaneously. This posed the question of how to characterise the semantic profile presented. Another, related problem was the possibility of extensive plagiarism. To what extent had the texts created by the specialist groups simply been copied and pasted, or to what extent were they the product of collaborative discussion and individual authorship. A plagiarism checker was used, and every effort was made to identify read from extemporaneous talk.

After coding each section of the lesson using the sentence clause as a unit of analysis, the results were graphed.

3.4 Ethical Considerations

I took particular care to ensure the anonymity of participants in writing up this report. Pseudonyms were used for all the participants and for the name of the school. Participants were given a copy of the transcripts of their interviews, and given an opportunity to change anything they felt uncomfortable with.

Ethics approval was given 2015ECEO14M.

4. Data Collection & Findings

In the first phase of the research, in depth interviews were conducted with five high school teachers across a range of subject specialisations to explore their beliefs around how ICTs are being used in their classrooms. The interviews were conducted with an English & Life Orientation, a Maths, a Science and a Technology teacher who was also responsible for overseeing Thinking Skills in the school. The teacher tasked with assisting teachers with ICT integration, an IT teacher, was also interviewed.

From these interviews, two teachers, the Maths and the Technology teacher were identified for conducting classroom observations. Lessons were audio-recorded, a transcript of audible sections prepared and coded using the relevant translation device.

Larry Cuban's (1993) now famous one line summary of the effort to integrate computers in the classroom "(c)omputers meet classroom; classroom wins …" is somewhat endorsed by my interviews with teachers at Girl's School. While integration of ICTs is certainly happening, and often in interesting and innovative ways, the culture of the classroom is clearly paramount. Cuban's maxim answers a crude technological determinism, a view that the mere introduction of computers will transform classroom practice. And yet, as these interviews reveal, teachers are finding ways in which the affordances of digital technologies does in fact open up opportunities for transforming their practice in ways which they see as beneficial to their students. But technology also has limitations and constraints, which in some cases discourages its use in the classroom.

4.1 Teacher Interviews

At Girl's High there is the widespread perception that educational technology is not being used effectively. The headmistress commented that she thought that sometimes the only one who touched the interactive whiteboard was the cleaner. Some equipment is left unconnected in classrooms, and Sue, the teacher responsible for training teachers to use ICTs detailed many instances of teachers, in her experience, not being able to use devices effectively. Some teachers use hand-written mark books, and some struggle to use email effectively. Other teachers, however, are clearly using technology to much better effect, as will be detailed in the discussion below.

4.1.1 Background

I felt that it would be counter-productive to interview those who were not using ICTs in their lessons, since the focus of this study lay with exploring how subject specialisation and the forms knowledge takes is influencing ICT adoption. All the teachers interviewed were not only personally comfortable with ICTs in their personal and professional lives, but were using it in their lessons. A summary of the teachers interviewed is given in **Table 4.1** below.

The approach taken was to engage in fairly free-wheeling discussion around how the teacher was using ICTs in their lessons, without trying to steer the teacher towards the theoretical framework or to use the internal language of description (L1). I was concerned to find out, as far as possible how teachers viewed the ICT integration they were all engaged in to one extent or another. I then used a translation device to map the concerns raised by the teachers to the conceptual frameworks used. As I was coding the transcripts, I continually updated and altered the translation device to find better matches between the internal and external languages of description. At times I became stuck over how to code a particular comment, and was challenged to update the translation device in response to the data. The data was then summarised in tabular form.

Table 4.1 Summary of Teachers Interviewed

Name	Subject Taught	Age	Teaching Service
Heather	English & Life Orientation	27	2
Frank	Maths	42	17
Sue	IT & IT Strategy	45	3
Abby	Science & Life Orientation	32	9
Mary	Technology & Maths	57	30

4.1.2 The Translation Device

The translation device emerged out of an iterative process of matching the conceptual categories of the framework to the categories and concerns thrown up organically in the interviews. In some cases there were obvious matches. In other instances the concerns raised by teachers being interviewed did not fit neatly into the categories of the conceptual framework. While the internal language of description (L1) was taken from the conceptual frameworks used, the external language of description (L2) was taken from the concerns raised in the interviews. As the translation device emerged I found typical examples from the data to clarify the interpretation being placed on the data. To facilitate this process I annotated and then coded the transcripts. The Translation Device is appended in Appendix C.

The dialectical process of working between data and theory led to constant revisions of the schema above.

4.1.3 Results

In this section I propose to summarise the major findings emerging from the interviews.

All the teachers interviewed presented a coherent perspective, or metaphor for their teaching, which appeared to guide their practice. Frank, a Mathematics teacher spoke about “eye contact”, “interaction” and maintaining the “flow” of the lesson. When I observed him teaching, it was clear that he values the ability to keep contact with every student in his class, to be able to ask questions and talk each student through the Maths problem being worked on. For this reason he gets a student to sit at his desk and change the parameters on the graphing software he uses, so that he does not have to break his own interaction with the students.

For Mary, the Technology teacher, the key idea seemed to be of “intervention”, being able to step in and comment before a student submitted their final version of any project. Her choice of Google docs as a medium is largely driven by the affordances this platform offers for synchronous and asynchronous collaboration. For her, given the importance of the Design process in the subject Technology, the ability to scaffold students’ understanding as they engage in the design process is key.

For Abby, a Science teacher, the key concept appeared to be “conversation”. Having observed two or three of her lessons informally, this describes what she was doing in the lessons very accurately. As the students worked on the Science simulation on computers, she walked round the room and had conversations with individuals and the class at large about the task, and about students’ approach to the task. Abby sees one of the main affordances of simulation software as the ability to represent idealized modelling of a concept, which then invites a conversation around the differences between the ideal and real world measurements and data.

Heather, a Life Orientation and English teacher, used the idea of “discussion” and of being on a “journey” to describe her classroom. For her, the ability to share similar readings online and on social media as her students, allowed for in-class discussions around shared perceptions and interests. Her view of the English classroom appears slightly different, and she stressed creativity and engagement as key ideas. Sue, the Information technology teacher, also spoke extensively about “engagement” and sees a key affordance of technology as lying in its ability to engage students and unlock their creativity.

These snapshots of what the teachers said, perhaps subconsciously, about their classroom teaching reveal an initial schema which matches well the Technology Mapping Instructional Design model, as teachers appeared to select technologies whose affordances matched the content they were trying to teach to their view of the learners and the context. But I think these metaphors for teaching - engagement, intervention, interaction, conversation and journey - reveal something more. They suggest to us that the mental model of the teacher governs how they perceive their role and holds powerful sway on how the affordances of technology and of pedagogy are perceived and therefore shapes how technology is integrated into their teaching practice. I will try to unpack this notion below by looking at the subject disciplines covered in the interviews, and what was revealed through an analysis of the interview transcripts.

In order to represent the conceptual framework developed for this study, Figure **2.15** above, different practices described in the interviews were coded as knower or knowledge code practices for each subject specialization in terms of affording gravitation or levitation using the schema represented in Table **4.2** below.

Table 4.2 Table for coding knower/knowledge code practices and technological codes affording gravitation or levitation

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices		
Knowledge Code Practices		

It must be acknowledged that representing a three dimensional concept (semantic code/technological code/pedagogical code) in this way is a crude instrument. It must also be acknowledged that the distinctions between knowledge and knower code practices are often fine ones, a matter of emphasis that might only be decided by the ability to observe the focus of any particular lesson. Maton's (2014b) insistence that all knowledge contains both knowledge and knower structures indicates the difficulties involved. Was the purpose of a lesson to transmit knowledge structures, or to cultivate gaze?

In relation to semantic profile, we have seen that specialization code practices (epistemic/social relations), technological code practices (strong/weak affordances) and pedagogical code practices (strong/weak affordances) can be described along a continuum, rather than as a polar binary.

4.1.3.1 – Mathematics

Two teachers of Mathematics were interviewed, Frank, who teaches Advanced Programme Mathematics and Mary, who teaches Technology, but previously taught Mathematics to grade 7.

Mathematics has been identified as a strong Knowledge Code and in Sackstein's (2014) study on tablet integration in South African private schools, with a strong orientation towards Instruction, with strong Framing and Classification. It is thus seen as a vertical discourse with a strong performance pedagogic mode. Accordingly, Howard & Maton (2011) argue for weaker code matches and stronger code clashes between Mathematics and ICTs, which are identified as carrying stronger code matches with Knower codes, with an emphasis on affording student voice and creativity. Frank, indeed, explicitly rejected the notion of using Knower Code practices such as student made videos, as irrelevant to Mathematics. Mary, likewise, rejected most of the iPad apps she had seen as being "gizmos … exciting to use … but lack the substance."

In terms of subject specialisation, Frank sees Mathematics in two senses, pure Mathematics, abstract, theoretical and often seen as irrelevant by students, and Mathematics based on solving real-world problems. The traditional approach to Mathematics teaching has been to teach the theory and then make the jump to its practical applications. Frank feels that Maths, viewed as abstract and theoretical is often used as a means of exclusion by making it a requirement for entry to tertiary studies in fields which do not really require them. He argues that ICTs might play a role in bridging the gap between theory and real world problem-solving by enabling the difficult calculations, freeing time for greater emphasis on problem-based approaches.

> *"… and that's the great thing about IT, you can move away from [learning a rule], you don't have to spend a month learning how to solve a cubic equation, because your calculator can do it in five minutes … then you can start putting in far more detailed problem-solving skills, which is what we need …."*

Embracing ICTs might help make Mathematics more relevant. He believes there should be two examinations, one a no-calculator exam which will keep numerical skills alive, and the other a technology enabled examination which allows for a greater focus on problem-solving. Frank's view of Mathematics as a field, reflects shifts in how Mathematical knowledge is viewed as tacit rather than explicit knowledge (Ernest, 1998) and forms part of the larger debate around situated cognition and Mathematics teaching. There is no space here to explore this further, but it raises interesting questions around how to conceptualise the semantic profiles of gravitation and levitation in Mathematics, which will be explored further when we look at the lesson observation section of this chapter.

Mary pinpoints a key constraint to any application of Knower Code practices in Mathematics, focusing on how students go about answering Maths problems, for example, the difficulty that "you can't really do numbers and things on Google." Writing formulae and solving equations is afforded by pen and paper, but cannot be done, yet, on a computer in the same way that an English student can use Google docs to compose a piece of creative writing. When students are working on Mathematical problems they almost always do the workings out on paper, and then select from a multiple Choice style menu in the software application.

Frank uses ICTs in two ways, as a visualization tool in the classroom, and for drill and practice exercises online from home and sometimes in class.

Firstly, he uses *Autograph* software when teaching algebraic functions. His classroom has an Interactive White Board (IWB) and a whiteboard side by side. The slide projector for the IWB is connected to the desktop pc on his desk. A few of his students in each class are trained to use *Autograph*.

> *"so I basically every lesson I've got Autograph open and if some equation comes up I image it on the graph section and just show them the link with the solution we find for the equation and the graph."*

This allows him to change the parameters of the function and demonstrate how each parameter change alters the graph. By getting a student to enter the parameter changes he feels he does not lose eye contact with his class and it does not interrupt the flow of the lesson. Wall, Higgins, & Smith (2005), looking at student perceptions of the value of IWBs indicates that the ability to visualise what was being talked about by the teacher was seen as its biggest benefit.

Frank sees *Autograph* as offering multiple affordances.

> *"and with trig graphs you can also see, so you can set it to animation so you see the flow and how it changes and you can talk them through it [um] yeah, as I say, I can't imagine teaching without Autograph now."*

Frank explains that the software allows his students to visualize how changes to parameters affect what an equation looks like. In other words it serves to increase the semantic gravity. These affordances for gravitation are linked by Frank to his instructional pedagogical style. In the lesson I observed this was apparent. Frank used the graph on the IWB alongside equations and workings out which he drew on the whiteboard. At times students were called to the front to indicate intercepts and draw tangents on the graph using the IWB stylus. Students were then asked to find the gradient of the tangent. Frank used question and answer to guide students toward what they needed to know to be able to solve the equation of the tangent.

Frank might have used the whiteboard rather than the IWB, the IWB and software did not alter the pedagogical approach, but the increased accuracy and speed with which changes to parameters could be visualized made the lesson run smoother and faster than it might have done were graphs to be drawn on the board, and the accuracy of the measurements in all probability serves to eliminate misunderstandings which might arise from badly drawn graphs. Interestingly enough, what Frank reported finding useful, is that the software allowed him to get a student to enter the parameters, meaning he did not have to draw the graph at all, and he could maintain his eye contact with the class. This marrying of pedagogical with technological affordances is what appears to be what draws Frank to using this as his "main tool."

> *"so if you are doing it manually for instance … but if you are drawing a normal parabola like $y=x^2$, how would it look like if you went $2x^2$, $3x^2$, $4x^2$, and what happens to the graph? And now you can just do it click on a button."*

Currently Frank uses his IWB with *Autograph* in this way, but he imagines that when all his students are bringing their own devices to class he will be able to use another, very similar, but free program *GeoGebra*, which will be able to be loaded on every student's device, tablet or laptop, and will allow for a more student-centred approach.

> *"when they bring their own devices to school, you know, instead of me putting it up on the screen, they can start playing around with the parameters themselves … and that would give them [indisctinct] develop concepts where they actually themselves, OK, and I think, yeah, it's the way to go …."*

What this comment suggests is that pedagogy is relatively more malleable than other factors at play. The technology is seen as unlocking a pedagogical shift, what Frank describes as a "paradigm shift" towards a more independent student-centred pedagogy.

Frank also argued that the use of online interactive textbooks (*Everything Maths*) and online drill and practice programs such as *MyMaths* would help develop more independent learners, capable of self-study.

> *"we de-skill them … because we don't give them the … faith that they actually can teach themselves. And I mean, if you don't have that skill and you go to University, you don't have a chance."*

However, Frank reports that there has been resistance from students, possibly echoing resistance from some staff to the online programs. He feels that his colleagues have not fully supported the introduction of online programs and have not trusted them where they were introduced, resulting in content being taught twice: once online and then again in a traditional manner. This extra workload has been onerous on both staff and students and increased resistance. He also feels that students appear to favour a model where the teacher teaches – "you're supposed to teach, not to tell us to go onto a computer."

However, the online Maths programs have been adopted well by the Girl's High Academy girls who come from inner-city, under-resourced schools and receive lessons in Maths, Science and English in the afternoons. This programme uses Maths and Science programs such as *Everything Science* and *Everything Maths* extensively and has been well received by the students. Abby, the Science teacher, who also teaches in this programme, felt that the reason for this might be that the students from the Academy, with greater deficits in Mathematics, do not find the slow pace of the drill and practice software off-putting, and are less dependent upon the teacher and private tutors. For many of the Girl's High students, from much more affluent backgrounds and with greater remedial support in the event of any learning deficit, the slow pace, and elementary entry level occasion resistance to what they perceive as drill and kill! Nevertheless, both Frank and Abby report positive benefits for those Girl's High students who do use the system for extra practice and for the interactive textbooks, and great benefits for the Academy students.

For Frank the main affordances of the drill and practice software lies in the huge database of practice examples and the use of data available on the teacher's dashboard to isolate which students need intervention. This fits well with the metaphorical sense of teaching as "eye contact", identifying who needs intervention at any moment. Frank also sees it as essential in preparing students for a future in which online learning is far more prevalent.

Mary, although not currently teaching Mathematics, sees a further affordance in recorded audio. She believes that if students explain their thought processes in solving a problem, by listening to the recording of this, made on the student's device, the teacher is able to analyse where the misunderstandings lie. She bases this on her experience teaching Technology, discussed in the next section.

> *"because if they explain it in Maths, if they explain it – then you see where their misunderstanding, misunderstandings are. Or if they explain it they then they really understand what they're doing."*

Once again, the technological affordance is layered with pedagogical concerns. The use of recorded reflections on thinking while engaged in a process crucially allow for asynchronous interventions.

> *"And it's very hard to get around to everybody if you're sitting in the front of the classroom, but you can look at the work late, later on and still make comment …."*

The technology, in other words, affords the ability to intervene in the middle of the process of knowledge building, even when the moment is missed in the classroom. This use of technology fits well with Mary's sense of what teaching is all about, based on the metaphor of intervention.

The examples of ICT use in the field of Mathematics at Girl's High partly supports the conclusions of the DER-NSW study (Howard & Mozejko, 2013) that ICTs were used for knowledge code practices by Mathematics teachers, resulting in fewer code matches with ICTs, which are seen as carrying greater knower code matches. The emphasis on drill and practice software and on visualization tools such as *Autograph* or *Sketchpad* supports a use based on the building of a strongly bounded hierarchical knowledge structure. But there is a sense in which both Frank and Mary see ICTs as offering affordances for unlocking a different set of practices which rely on knower code practices such as reflective metacognition (in Mary's case) or problem-based learning (in Frank's case). Frank envisages using *GeoGebra* as a replacement for *Autograph* in ways which emphasise the role of the individual in constructing knowledge inductively through problem solving. As Whitcombe (2013) has argued, problem based learning strategies are associated with knower rather than knowledge structures. Any shift from pure Mathematics towards problem-based approaches to learning Mathematics is likely to involve a greater emphasis on knower code practices such as emphasis on cultivating or training a Mathematical gaze, for which ICTs are seen as a closer match.

Differentiating between Knowledge and Knower practices is not cut and dried because every practice contains both knowledge and knower structures, so it is a matter of degree and emphasis in any given activity. The extent to which gravitation and levitation was afforded is also not a clear cut issue because most activities involve both deconstructing and re-constructing, re-contextualizing concepts. When interpreting the interview data I took as a guide then two questions:

> To what extent is knowledge founded on the gaze, the approach and dispositions of the knower rather than simply on knowledge structures?
>
> To what extent in the given activity, is the student engaged in constructing rather than deconstructing concepts. Do they begin with the detailed, specific, or with a general concept?

Using these guidelines most of the practices in Frank's classroom appeared to centre around knowledge codes. What a student knows appears far more important than how they know, although his suggestion that a move towards problem-based methodologies is necessary is suggestive of a greater emphasis on the dispositions of knowers. Solving Maths functions appears to involve both an understanding of how abstract concepts relate to particular equations (gravitation) and is mainly achieved by helping students visualise what the concept looks like when graphed, but it also involves taking particular examples and workings, expressing them as abstract functions. Watching students involved in online practice, it seemed to me that in the majority of cases students were applying a general rule to particular numbers, rather than working inductively from data towards the abstraction, and so was characterised by gravitation rather than levitation. However, problem-based methodologies seemed to work the other way, involving thinking through how to solve a particular problem, and extracting general approaches and concepts from this.

The table below indicates that most of the ICT practices described by the Maths teachers interviewed, described knowledge code practices, and most involved gravitation. Those practices which suggested levitation were speculative. Mary's suggestions around recording thinking processes and Frank's suggestions around the need for a more problem-based approach and the use of tablets to experiment more inductively were not part of their current practice. The use of ICTs in Mathematics were thus mainly focused around transmitting an understanding of concepts, and providing opportunities to consolidate this knowledge through practice.

Table 4.3 Knower & Knowledge Code Practices in Mathematics

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices		Students record themselves talking through how they went about solving a Maths problem (Mary)
Knowledge Code Practices	*Autograph* and IWB used to visualise functions, *Sketchpad* for Geometry. The animation functions allows the teacher to talk the class through the changes (Frank) Video created using *Explain Everything* to explain terminology (Mary) *MyMaths* online program allows students to visualise mathematical concepts and provides online practice which consolidates students' understanding (Frank) Khan Academy videos help students unpack concepts (Frank)	Students can use *GeoGebra* on their iPads in class to play with different parameters of functions to develop concepts (Frank) Need to develop more problem-based approach to teaching Mathematical concepts (Frank) Allowing calculators moves the emphasis from doing calculations to enabling problem solving (Frank)

This characterisation reveals that knowledge code practices predominated in Mathematics, confirming Howard & Maton's (2011) analysis. Gravitational practices appeared to dominate – with an emphasis on understanding. Nevertheless both Mary and Frank presented an alternative view of a problem-based Mathematics practice which would be more inductively based, for which ICTs were seen as key affordances.

4.1.3.2 – Design & Technology

Design & Technology as a field has been characterised as a specialization underpinned by different legitimation codes depending on the underlying knowledge practices. For example, Architecture presents as an elite code, engineering a knowledge code, and fashion as a knower code (Carvalho, Dong, & Maton, 2009). As a subject discipline in high school the emphasis is on both the design process, which may be viewed as a strong knower code practice, and on structured knowledge about electricity, for example, a knowledge code practice. Using the code match/code clash framework one might therefore expect a greater degree of code matching to ICTs, both in knowledge and knower practices.

In her Technology classes, Mary has experimented with, and used ICTs in a number of different ways. She has used ICTs alongside instructivist pedagogical approaches, using a Flipped Classroom paradigm to prepare instructional videos using *Movenote* and *Explain Everything* to create a resource base which could be accessed by students at any stage. She also used more constructivist pedagogical strategies using Google docs, the jigsaw method and Thinking Skills strategies to teach a unit of the sources of electricity. Students were placed in specialist groups, each one with a topic to research. Their research was guided by the use of the de Bono Thinking Hats.

> *"so they had to go and look at the sources of electricity and look at the benefits and the cautionary aspects [um] and red hat thinking …."*

The de Bono Hats are intended to ensure that all members of the group focus simultaneously on different aspects of a topic, such as the benefits or cautionary aspects, the emotional response, or the factual basis of what is being discussed.

Having researched their topic, each specialist group had to compile a set of notes on a Google doc, which they would share, but could adapt for themselves. At this stage Mary was able to interact with students, leaving comments on the Google doc, and engaging in in-class discussions around what was being written. Mary reported an interchange with a student. After seeing what the student was writing in a Google doc, and feeling that the student was not grappling with the task with sufficient thought, Mary commented in the Google doc. The student then spoke to Mary face to face about the comment, which concerned the amount of land occupied by a hydro-electric plant.

> *"so I said that's not right – have you thought about that, and then she went and read further to s … and that actually included the size of the dam ex, and all of that, that to make the hydro-electricity work, so … it's just to get them to go a little bit deeper into things."*

Mary also used audio reflection recorded by students explaining their thinking during the design process. Students use a Google doc, which they add text and pictures to as their design unfolds, allowing Mary the affordance of commenting and intervening at any stage.

> "It just enables everything to be digital instead of putting it onto paper. And as I said before you can just get it anywhere because it's in the Cloud. I can also comment on what girls are doing before, before they hand something in and it's just such more valuable learning."

This methodology allows Mary to interact with students even when they are not in the classroom, and to be far more thorough. Mary has also used videos with her grade 9 classes in which students produce a working model of an electronic circuit and an evaluation video.

> *"So they had to show me how everything worked, but then they had to evaluate the model and a circuit and the working process that they went through. The process … the making process they went through … and I get far richer information from them about the evaluation than if they … if they wrote it down because I find them talking about it they will say things that they probably wouldn't communicate if they were writing it down on a piece of paper."*

Perhaps because she teaches the design process, she sees in technology affordances for capturing moments in the process, and opportunities to intervene and scaffold student's understandings.

With a greater emphasis on Technology as a Knower code, on understanding the thinking process rather than just the knowledge structures alone, comes a greater emphasis on how technology can be used to scaffold student's ability to think about the content, engage with it and formulate their ideas in ways which express more sophisticated understandings. This process involves both gravitation and levitation.

Mary believes that most programs available are not very useful for teaching, that they are just "gizmos", but Google docs and recorded videos allow her to see what her students are thinking, and the time to make her own interventions in the process of learning. This presents a particular use of technology which offers strong affordances for levitation as students express their ideas and phrase them in increasingly sophisticated language and thought, scaffolded by Mary's online comments.

Mary's focus in her Technology classes appears to be far less on the knowledge structures, and more on the design process and cultivating student's gaze. Her focus on Thinking Skills illustrates this emphasis. In terms of semantic profiles, the activities she described appear to interweave affordances for gravitation and levitation. In the power source exercise students had to research and understand how their specialist power source worked (gravitation) but they also had to evaluate the strengths and weaknesses of that power source and come to a judgement of which was best for the country (levitation). This was done both within the specialist groups and the home groups, and will be examined in greater detail later.

Table 4.4 Knower and Knowledge Code Practices in Design & Technology

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices	Specialist Groups researched Power Sources and taught their home group (jigsaw method) using Google docs	Specialist and Home Groups evaluated the benefits and drawbacks of different power sources (jigsaw method and Thinking hats) using Google docs Students create an evaluative recording of themselves talking about their electronic circuit and reflecting on the design process Students use Google docs to create an ongoing portfolio of their designs Students made videos of load bearing constructions and could fast forward to the breaking point, drawing conclusions from this.
Knowledge Code Practices	*Movenote* used to create flipped learning videos together with the Cornell note taking strategies. Students used a bridge simulation program to design bridges. The stress and compression points were colour coded so students could visualize the forces acting on the bridge	

Table **4.4** above attempts to draw up a profile of the affordances for gravitation and levitation offered by ICT integrated activities. With a greater emphasis on knower code practices and cultivating Thinking Skills, Mary's classes focused more on building understanding, on cultivating an approach towards design. While knowledge structures were important, the emphasis appeared to shift towards cultivating gaze. There was a greater emphasis on student's evaluation of the data the encountered (levitation) rather than a focus on understanding of content or process alone.

4.1.3.3 – Physical Science

Abby, who additionally taught Life Orientation at her previous school, teaches Physical Science at Girl's High and in the Academy programme. Physical Science, as a specialization code is usually identified as a strong knowledge code, with hierarchical knowledge structures, and a widening gulf between every day and scientific understandings of the world (Maton, 2014b). One would therefore expect to see a need for strong gravitation and levitation practices as students grapple with how to understand abstract concepts, and re-construct that understanding. Abby uses the metaphor of conversation to describe her teaching.

Abby and her colleagues in the Science Department use a particular strategy called Predict – Observe –Explain (POE) to guide their pedagogical practice.

> *"(W)e will always have a what do you think's going to ha … be the outcome. Now it's your hypothesis. Now let's do it, now what's the answer."*

Abby sees ICTs as offering affordances for this methodology, particularly through the use of videos which allow for measurement in video. A series of motion videos have been made by a teacher in America, which allow students to measure motion effects very accurately, something not practical in real life experiments. This allows for a predict, then measure and explain method to work very well. She also uses simulations brought out by PHET and TedEd videos on various topics. She sees a key affordance of these as being that these videos of, and simulations of experiments produce very accurate ideal results, which then allow for a conversation around why real life measurements are not as accurate, and for a greater understanding of the "Science behind the Science". This level of reflection offered by simulations may be an important instructional design affordance (Harper, Squires, & Mcdougall, 2000).

> *"we use PHET, University of Colorado's PHET simulations [um] and it's quite a nice, I've got a couple of worksheets that they work through, and we, where they can set up the idealized, this is the ideal circuit, these are the ideal results, and then we take those and we look at a circuit board and we put it together and it gives us that combinat … conversation between in an ideal world this is what we want to see, and why didn't we see it … so we, I try and link the simulations with the, with the real thing."*

In her experience many students are haphazard in their measurements and this often leads to misunderstandings. However, Abby has struggled with numerous constraints around the use of these simulations. Because they were created using Flash, and Apple does not support Flash, they will not work on student's iPads. She has used Splashtop to display them from her desktop to the IWB, but found this problematic, and has to book out the computer room so students can use the simulations on pcs and complete the worksheets which she uses and finds vital to the success of the simulations.

> *"but I find that they, the simulations are only effective if we've got a … a worksheet with it. If, if I say to them, go and have a look at the simulation, then they're a bit like, well, I don't know what to do with this."*

What this reveals is something of the interplay between affordances and constraints. Abby cannot use the simulations as extensively as she would wish, because of these constraints, but the constraints are not just technical, they are linked to the context, the students and her choice of pedagogical approach. Just as Frank sees iPads being used to allow students to experiment with the parameters in graphing software in Mathematics, Abby wants students to use the simulation to experiment and learn more inductively on their own.

> *"I kind of said to them, when you're sitting at home, and you're doing your homework, and you're not sure how to answer an electricity question, build … open the simulation, build the circuit, look at what's happening and then answer the question. … it would be handier if we could run it on the iPads, because then I would do it, I could use it more in class."*

In this instance Abby is suggesting that the affordances of the software (the PHETT simulations) and the hardware, the mobility of the iPad are not able to be exploited because of the constraint that Flash does not run on the iPad, while the availability of desktop pcs is constrained by the necessity of sharing the resource with other classes, or the "schlepp" factor, the bother, of having to book the computer room and migrate her class. Neither constraint is insurmountable as Abby uses the simulations, but not with the freedom she would wish to have. It is her pedagogical approach which suffers in this situation.

In other contexts we can see Abby facing perceived constraints which were not real constraints. She confessed that she was so used to using Microsoft Office applications that she found it very difficult to use Google docs and Google sheets. This interference in the transfer of skills has led her to reject precisely the same affordances adopted by Mary – the ease of commenting and collaborating on Google docs – because she does not find it "intuitive". The affordances are not perceived as affordances, but are viewed as constraints. It is not that Abby does not know how to use Google docs for online comment or assessment. She describes the process, but highlights her frustration with how counterintuitive she finds it, and consequently rejects it as a platform. This highlights the need to assess real, perceived and hidden affordances, and the often inter-relationship between affordance and constraint. It suggests also that the interference of one skill set may well act as a constraint on another.

Abby used data loggers and mimeo at her previous school. Girl's High does not have data loggers, but Abby described how she used them to display the graph of data being logged, again "so that they can see an ideal scenario". The graph is plotted accurately, in real time as the data is logged. Once again, the key affordance for Abby appears to have been the ability to present an ideal representation of the concept being presented, acid-based reactions or heating/cooling curves, and through the visual representation allow the concept to be made more concrete.

> *"I found it was a, a big visual relationship for them, rather than always having to plot data and then draw a graph, and then try and see what's happening."*

The combination of data loggers and IWB thus afforded gravitation, the visualization of the abstract concept, in much the same way as Frank used the IWB to show changes to the parameters of a parabola. The accuracy of the graph plotting was seen as a key advantage over the inaccuracies of students' graphs. It allowed for an ideal representation of the data – one which reinforced the conceptualisation. This is what affords gravitation so powerfully.

Technology also offers constraints to students. Abby highlights the difficulties students had trying to create graphs on Google sheets, eventually printing the charts and scanning them in. It is unclear the extent to which Abby's own views about the difficulties of using the platform may have been transferred to her students, but it is certainly my experience that students will find aspects of any technological task challenging.

Just as online drill and practice software is used in Mathematics, Abby uses online Science programs, *Everything Science* and *ReThink*, an online Textbook format. Abby uses this in a flipped classroom method, where students are expected to read the online textbook (*ReThink*) as homework, and then complete the exercises in class on the *Everything Science* platform. Abby uses this, as does Frank, for both his Girl's High and Academy students. She finds that the students from Girl's High resist the online software, even though it gives instant feedback and guidance on how a wrong response should have been answered. Abby feels that the Girl's High students do not like using it because they hold to a teacher-centred model of the educational process.

> *"I wonder sometimes if it's not because, because it's not the teacher. You're the person that knows, so you must tell me."*

Abby feels, however, as Frank does, that the Academy students have embraced the online learning platforms because they prefer not revealing their vulnerability to a teacher.
"But I, but I feel sometimes that they are less inclined to engage with me. And I think more, for them it's easier to get it wrong to the computer than to get it wrong to me."

As with the Mathematics drill and practice software it could be that the Academy students, facing far greater learning deficits, find the slower pace and repetitive questions less onerous. Nevertheless Abby believes that the continual practice is important in increasing levels of achievement.

> *"I've got a few girls who really engage with it very productively and, and I can see it. I can see the, the growth in their understanding from one lesson to the next."*

Abby also feels that students may not be taking the online platforms seriously because they perceive that it is "not for marks".

> *"I find it's a conversation I have with them at the beginning of the year. We do it this way, the marks are not important at this point, except in so far as this knowledge results in marks eventually."*

In a high performing school such as Girl's High, where matriculation results will determine access to the university and course of choice, a marks-oriented culture is not surprising, but stands in opposition to the culture of independent learning and focus on thinking skills rather than the achievement which the teachers are trying to bring about. Abby, like Frank, felt that the students are relying on tutors rather than trusting the online platform for homework practice. They both see this as a culture of dependency, which the use of ICTs could break.

Abby expressed the idea that "any tool works if you're using the language". She means here the language related to thinking skills, the language of the de Bono Thinking Hats, Hyerle's Thinking Maps or Costa and Kallick's Habits Of Mind which form part of Girl's High's attempts to infuse thinking skills into the curriculum. A common language of thinking is seen as vital in terms of effecting change across the institution, creating a shift in emphasis away from an assessment oriented culture to one which values independent learning and critical thinking skills.

As we saw with Mary, who married the Thinking Hats with the jigsaw method and Google docs, Abby sees ICTs as tools which can be used together with the methodologies and pedagogies of thinking skills to make her delivery of the content more effective in terms of empowering independent learners.

> *"I want to do a Hats … with … also … so with a flipped classroom model, and then the Hats, so they come back in to the Hats space, having done the pre-reading and probably a, I've got a TedEd video I'm wanting to use, so probably on that format [um]. I think it's language, the Thinking Skills stuff, more than the tools that you use with it."*

What is revealing is that here Abby sees the outcome, the use of a universal language of thinking as being more important than the pedagogy or the technology. This was clear in the way that she saw the Predict – Observe – Explain method as being afforded by the motion videos she wanted to use in her class after being exposed to them at a workshop. Predict – Observe – Explain as a strategy in the Science classroom codifies the Scientific Method in a pedagogical routine that is easy to apply in any situation and, when the affordances of the pedagogy and the technology appear to align, leads to tangible excitement for the technology. The way in which Abby spoke about the motion videos with animation and enthusiasm was different to her rationale for some other technology uses.

> *"I quite like Khan Academy. And I think it could be a very useful … I use it in class as a way to sometimes not be the person doing the talking."*

She also uses videos created by a teacher in America which takes contemporary music and changes the lyrics to scientific content.

> *"The kids love it … I've heard them humming it in the corridors … so I use that in class quite a lot as well, also someone else saying it."*

This use of technology fits better with the engagement metaphor rather than the conversation metaphor Abby articulates to express her concern that the videos and simulations she uses establishes a conversation between the ideal, abstract quality of Scientific knowledge, and the messy, everyday nature of individual instances in data measurement or experiment, which she feels technologies are able to afford.

The use of simulations in Science appears to fit best as a Knowledge code practice affording gravitation. However, when used to allow students to explore different parameters and see what happens, the semantic profile is closer to levitation.

Table 4.5 Knower & Knowledge Code Practices in Science

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices	Predict – Observe – Explain codifies an approach to scientific enquiry and conjoins gravitation and levitation through a procedure designed to cultivate a scientific gaze.	
Knowledge Code Practices	Simulations used to visualise the concepts behind particular concepts. Khan Academy and TedEd videos explaining different concepts. *Everything Science* and *ReThink* used as textbook to explain and teach concepts ipAd apps displayed on IWB engaging and help visualise concepts better YouTube songs explaining scientific concepts	Motion videos. Students measure results and draw conclusions. Data loggers and graph plotted, displayed on mimeo Data gathered and plotted using Google sheets

The predominant mode in Science appeared to be one of knowledge code practices affording both gravitation and levitation, but crucially Abby saw ICTs as affording the cultivation of a scientific gaze through a pedagogical code practice. The interweaving of technological and pedagogical codes was strongest in Science, probably because the department has developed an explicit pedagogical approach. There are signs that through mutual discussion members of the department are attempting to develop a similarly explicit technological code practice. Indeed I observed another Science teacher use the same lesson outline involving the same online electricity simulation as Abby did, and Abby talked about the need to use a common learning management platform.

4.1.3.4 – English

The English Department at Girl's High has a reputation for being amongst the slowest in adopting ICTs. Senior members of the department appear to be less competent with

ICTs in their personal and professional engagements. Howard et al (2014) have highlighted how English teachers in secondary schools in New South Wales see active code matches between the Knower code orientation of English and the affordances of ICTs for empowering different forms of creative expression. Howard & Maton (2011) note, however, that English teachers envisaged fewer code matches where they were approaching aspects of the English curriculum which corresponded with greater knowledge code practices, aspects of grammar and technicalities of writing. I would argue that the emphasis on literature in the curriculum, also places severe constraints on ICT integration at Girl's High.

The culture of the department rests on an emphasis on the ability for close analysis of literary texts, and the ability to write sophisticated essays, represented by the Advanced Programme English curriculum. Personal reflections are seen as a stepping stone, especially in the lower grades, but the hallmark for success is the literary essay, objective, dispassionate and able to compare and contrast different interpretations of the text. This represents a strong knower code focused on cultivating gaze and an emphasis on the literary canon. The high performance culture of the school leads to an emphasis on ability to display technical knowledge of literary form and content rather than to valorize personal responses to the texts. In the lower grades this is less true, but teachers are under pressure to prepare students for the language and conceptual frameworks of literary analysis. For example the Head of Department insists that almost every word of the Shakespeare play be studied in grade 8 and students need to be prepared for assessments that include questions around form and structure as well as content and interpretation. In this way knowledge structures around technical aspects of meter, diction, different genres and forms and around knowledge of formal grammar serve to create relatively strong knowledge code practices in addition.

There is thus very little time for teachers to spend exploring student's own experience and response to texts. Heather teaches English to grade 9s and unlike most of her colleagues is a competent user of ICTs in a personal and professional capacity. She uses social media such as Pinterest and Facebook to pursue her professional interests, and finds that she is often reading the same posts as her students, allowing her to use shared interests, particularly in her Life Orientation classes.

> *"I find I'm following similar pages to them, and then in, in class discussions [um] we're all sort of on the same journey together.... "*

This metaphor of a shared journey holds a powerful resonance and speaks to an approach which rests strongly upon student's experience. This is a good fit with Life Orientation, as will be discussed in the next section, but is evident in her approach to English teaching as well.

The major example of ICT integrated teaching in English that she recalled was a project based on the set-work being read, *Buckingham Palace District Six* by Richard Rive. After reading the novel, students were asked to create either a movie re-enacting a scene from the book, a recorded dialogue or a scrapbook with audio reflection using *Explain Everything*. All of these projects aimed at exploring students' understandings of the novel, but Heather also wanted to use it for formal assessment purposes.

> *"so it's not just about creating something pretty and making a video, but you know, they know that they are being assessed on how they speak, their pronunciation, etc, etc."*

Heather will get the students to share their presentations on the IWB so that she can assess oral skills and other aspects of the curriculum at the same time as students are exploring the themes and concerns of the novel.

> *"I'm now assessing them, you know, on the screen, and at the same time all the girls are learning about the story about the book."*

This more student-centred approach replaced the way she taught it previously using PowerPoints she created. Heather sees this as part of an effort to give students greater ownership of the learning. While previously she had told students about Apartheid history, she now gets students to research the history of district six and use that research in their projects. ICTs are thus seen as offering affordances for a shift towards more student-centred methodologies.

Heather also uses YouTube videos as listening comprehensions, using a flipped classroom model in which students are expected to watch the videos at home and then answer questions on them in class. She allows students to take notes on the video, which develops their summarising skills, and then assesses their comprehension skills. She has also used the lyrics from YouTube videos for poetry study and has displayed texts on the IWB which students come up to the front to correct, with advice from peers. She finds that these work well, and this reflects a range of ways in which ICTs offer affordances for tasks that previously would have been presented on paper. The ability to make corrections visibly, and receive instant feedback from teacher and peers has major advantages over paper based exercises because it unlocks collaborative methodologies and harnesses social learning. Heather feels that these uses of technology are more engaging for students and finds that ICTs integrate seamlessly into many classroom activities.

> *"I've done a lot of things that I haven't really, I haven't kind of labelled as ICT."*

This is an interesting observation because it suggests that for Heather, decisions around ICT integration have become less conscious, more spontaneous. The uses she has found closely mirrors traditional ways of approaching teaching and assessing skills in English, and are largely shaped by the subject culture and the institutional context. They reflect some code matches with English as a knower code, using the affordances for digital authorship to support student knowledge building. But they also reflect code matches with ICTs which support knowledge code orientations.

Crucially Heather worries about the depth of understanding displayed by student made videos. While they may be engaging and unlock student creativity, she feels that often they afford only shallow understandings of the content knowledge. There appears to be within English in particular a greater tension around finding a balance between empowering student voice, cultivating a refined literary gaze, for example, and the knowledge structures felt to be crucial for student success, transmitting the voices of power inherent in received grammar or literary forms, which represents a hierarchical knowledge structure. Aspects of the English classroom thus resemble an elite code with the emphasis on a cultivated gaze and explicit knowledge of formal grammar and literary form. This insight may explain why students are often able to perform well in tests of grammar knowledge, using their knowledge code orientation, but fail to use correct grammar in their essays, when deploying their knower code orientation.

These are issues which teachers are grappling with, and need to consider when taking decisions around which pedagogies and technologies offer the best affordances for bridging the knowledge/knower code disparities within their subjects. In English this appears to be particularly acute. Heather saw the use of a text displayed on an IWB for peer editing as a handy way of approaching grammar teaching, perhaps because it brings a knower code ICT practice to bear on a predominantly knowledge code practice. In Mathematics, teachers, while acknowledging knower code practices within their discipline, and even predicting their growing importance, appeared ultimately to agree that it is knowledge structures that predominantly characterise Mathematical knowledge.

In English the terrain appeared more open to approaches based on both the knower and knowledge code structures. When analysing poetry, for example, it is possible to characterise the endeavour as both the cultivation of gaze and as the application of knowledge about the formal aspects of poetic form, for example how meter and tropes underpin semantics. Some uses of ICTs appear to afford knower code practices, and others knowledge code practices. Heather's music videos might afford engagement with the lyrics and open up opportunities for students to discuss the poetic content, but they might offer weaker affordances for advancing knowledge about metrical analysis. A PowerPoint might well do this more effectively.

Table 4.6 Knower & Knowledge Code Practices in English

Affordances for	Gravitation	Levitation
Knower Code Practices	Music video used to teach poetry iPads used in class for note taking	Students create videos and Explain everything scrapbooks around themes in novel *Buckingham Palace District 6* Students listen to video and create notes (summarising skills), then answer comprehension questions
Knowledge Code Practices	PowerPoint used to teach background history of Apartheid District 6 for reading novel Students research history of District 6 for reading novel	Correcting texts displayed on IWB

English was characterised by strong knower code practices, with sharp knowledge code practices punctuating the terrain, as foregrounded in Howard & Maton (2011). The predominant technological code was for levitation, with powerful affordances for student authoring, but interestingly enough gravitation was also afforded. In my own practice as an English teacher I use Google images and the IWB to unpack obscure vocabulary in literary texts by allowing students to visualize the referent.

4.1.3.5 - Life Orientation

Heather currently teaches Life Orientation at Girl's High, and Abby taught the subject at her previous school. Abby found that she was able to overcome constraints around lack of timetabling for Life Orientation. Although only able to see her classes once in a ten day cycle, she was able to use Edmodo to relay messages, post readings and host discussions on the forum.

> *"It worked very nicely in that context. But I also didn't have to do a lot of teaching, a lot of it had to come from them, and their background, and their putting information in because of the nature of LO."*

With horizontal knowledge and knower structures, Life Orientation can be seen as a Relativist code. Lived experience and shared social perspective is the focus of LO. The Edmodo platform allowed Abby to answer students' queries around the readings and two essays that were required per term. Abby tried to use Edmodo in the same way with her Science classes, but found that because she was seeing the students every day, there did not seem to be a need for using an electronic platform for maintaining contact in this way.

Heather also used Edmodo, and later Google Classroom for students to access readings and submit assignments, but found the technological constraints around submitting videos in particular, overwhelming. Problems around translation between Apple and Windows platforms, issues around formatting compatibilities and misunderstandings over project and rendered video files all meant that Heather had to chase students who had not submitted projects, making the process very stressful for both teacher and students.

While gravitation is clearly enabled through discussion unpacking ideas and concepts, students also clearly deploy levitation when taking their own lived experience and shaping it into essays exploring the concepts being discussed. ICTs appear to offer affordances for both routines. Knowledge structures are perhaps the least valorized in Life Orientation, with content being largely accessed through reflective practices such as online readings, watching videos and discussion. These activities are strongly afforded by ICTs.

Again, though the relative emphasis given to knowing and knowledge is dependent upon the context. Heather stressed those aspects of Life orientation, "journey" and "discussion" which fit most closely with a knower code characterisation of Life Orientation, and chose ICT practices which reinforced this view. But it is possible to conceive of another teacher for whom imparting knowledge assumes greater emphasis, and a Life orientation syllabus characterised by presenting research into the causes of HIV AIDS, or the biology of reproduction rather than discussions around attitudes towards sex. Such a teacher would probably employ ICTs with much stronger knowledge code orientations.

Table 4.7 Knower & Knowledge Code Practices in Life Orientation

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices	Online readings on Edmodo (Abby) Students watch videos online on Edmodo or in class (Heather) Similar interests followed on social media discussed in class (Heather)	Essays and assignments assessed on Edmodo (Heather) Online discussion using Edmodo (Abby) Videos made by students on topics such as health and fitness (Heather)
Knowledge Code Practices		

Not surprisingly knower code practices predominate in Life Orientation, and Heather appears to use ICTs predominantly to spark discussions to unpack and recontextualize student's opinions and attitudes in more formal discourse. Within the school Heather has a reputation as one of the most prolific integrators of ICTs in her lessons, and this is probably a result of her early adoption of online platforms as a vehicle for posting readings and videos for use in class discussion.

4.1.3.6 – Information Technology

Sue was interviewed because, as the teacher responsible for the staff training around the roll-out of the ICT Strategy she had valuable insights. Sue teaches Information Technology, which, with an emphasis on programing, might be characterised by stronger knower structures. The cultivation of dispositions and approaches to problem solving rather than any specific body of knowledge is what is considered important. Sue mentioned teaching how to do "for loops", rather than teaching a particular syntax, for example. However, coding and knowledge of computer and network architecture represents a strong knowledge code practice. We might therefore tentatively characterise Information Technology as an elite code.

Sue, however, from observation of lessons appears to place greater emphasis on knower code practices, as tabulated below, through focusing on problem solving rather than simply on knowledge structures.

While IT students are using their laptops all the time for programing, Sue feels that she needs to do more to use ICTs to make her teaching of theory (hardware, networking, ethics, etc) more engaging. In lessons I have observed informally, a common routine in theory classes is for students to research a topic and then present to the class using a Prezi or PowerPoint. Sue is particularly keen that her students explore different platforms, and review these as part of the process.

Sue would like to introduce more practical elements to her IT lessons, such as getting her students to design a network, but feels time constraints and the need to work on programing skills takes precedence. The major use of ICTs is thus the use of the programing interface, and students spend a great deal of time creating and debugging their code. The chief affordance of the programing interface that students use is largely that errors are highlighted in different colours, making debugging easier and helping to cultivate the student's programing habits and dispositions. Knowledge structures therefore appear to be less emphasised than knower structure practices.

Table 4.8 Knower & Knowledge Code Practices in Information Technology

<table>
<tr><th>Affordances for</th><th>Gravitation</th><th>Levitation</th></tr>
<tr><td>Knower Code Practices</td><td rowspan="2">Students watch videos on various topics and discuss them</td><td>Students research topics and platforms and create presentations for the rest of the class

Students create computer programs</td></tr>
<tr><td>Knowledge Code Practices</td><td>Students create computer programs</td></tr>
</table>

Information technology has a strong emphasis as a subject on computer programing and consequently uses computers constantly for coding. Nevertheless the emphasis appears to be on teaching good programming habits, ie. a cultivated gaze, rather than on specific programing knowledge of any particular language. The technological code afforded both gravitation and levitation.

4.1.4 The Affordances of Knower & Knowledge Code Practices for Gravitation & Levitation

What emerged from the interviews was a sense that knower and knowledge code practices within each subject were afforded, and constrained by different technologies, hardware and software, to varying degrees. All of the practices described by the teachers interviewed could be categorised by the degree to which they supported knower or knowledge code practices and the extent to which they supported gravitation or levitation routines in the classroom. This classification suggests that ICTs are being used to support both knowledge and knower code practices, with affordances for both gravitation and levitation, but that the contours of the terrain are determined by subject specialization and the extent to which each subject discipline reflects knowledge or knower code practices.

This pattern is likely to form part of a common pattern across schools, but may well be determined by particular academic departments or teachers and how they view their subject. The ICT practices of different subject disciplines will oscillate in broader, or narrower bands between practices which offer affordances for knower or knowledge code conceptions, and for gravitation or levitation. In below, for example LO and IT oscillate only within knower code bands, while English oscillates between knower and knowledge codes, and affords gravitation and levitation.

This chart is based upon very limited interview research, but I believe allows us to conceptualise of the ways in which ICTs offer affordances for both knower and knowledge code practices within specialization code frameworks, and for gravitation and levitation within semantic wave frameworks, offering a slightly more nuanced taxonomy.

Table 4.9 Knower & Knowledge Code Practices in Different Subjects and the Affordances for Gravitation or Levitation

Affordances for	**Gravitation**	**Levitation**
Knower Code Practices	Technology English LO IT	Mathematics Technology English LO IT
Knowledge Code Practices	Mathematics Technology Science English IT	Mathematics Science English IT

From this two points emerge. One trivial, that both knower and knowledge code practices are afforded by technological code practices, and a second that the degree of affordance is dependent upon context and semantic profile. Mathematics teachers, for example, appear to find fewer technological code matches for knower code gravitation practices. Understanding how (knower code) to understand a maths problem (gravitation) does not appear to be afforded by technology, while how someone comes to understand (knower code) how to go about solving a maths problem (levitation) does appear to be afforded by technology.

While no taxonomy of degree has been offered in this study – I would argue that the above results are indicative of an approach which carries explanatory power, and needs to be explored.

Nothing has been said about the semantic profiles which describe flat-lines, where knowledge or knowing remains at an abstract level, or at a concrete, narrative level. These could be seen as describing unsuccessful attempts at deconstructing or constructing knowledge. Mary, for example, felt that many of the groups in her Technology lesson, where representatives from each specialist group taught their home group peers about the power source she had researched, had been less than successful because they had simply read the texts created by their groups. This will be examined in the next section, but it is clear that flat-lining is common in the classroom, and may also be afforded by ICTs. Students simply using copy and paste to write an essay are clearly using the affordances offered by Google search – they are not doing anything to unpack or understand the concepts being read. Students who create a video which merely tells a story, and draws no conclusions or evaluations cannot be said to be using the affordances of the technology to construct useful knowledge. Heather worried about what she was assessing through a video, the depth of content, or the ability to create videos.

Anyone who has ever been in a classroom will recognise that these semantic profiles are all too common. They form a feature of any batch of essays assessed, feedback made on any activity or answers on a worksheet. However, they seldom represent what the teacher intended.

4.2 Lesson Observations

In order to gain greater insight into how the affordances of the software or hardware being used might affect gravitation and levitation in a lesson, I decided to observe two lessons, one by the Maths teacher, Frank, and the second by the Technology Teacher, Mary.

I casually observed some lessons by the Science teacher, Abby, but these all involved individual work in which students completed worksheets and used an online electricity simulation which allowed them to construct and test the results of different circuits. I also observed a few lessons given by the IT teacher, Sue, in which students, watched and discussed presentations made by their peers.

4.2.1 The Translation Device

At the time of analysing the research, no translation device for Semantic Density had appeared. Developing a suitable instrument lay beyond the scope of this research report, but the translation device drawn from Maton (2011, p.74) for Semantic Gravity, was adapted as to suit the data being collected, and is included in Appendix D.
Extracts from transcripts of the lessons were then analysed and tabulated as discussed below.

4.2.2 Frank – Maths Teacher

I observed a grade 11 Advanced Programme Maths lesson which dealt with tangents to parabolic equations. I captured about 30 minutes of the lesson, of which a fifteen minute segment was usable.

One student sat at Frank's desk and used his desktop computer to enter equations and changed parameters into *Autograph*, software licensed to the school which allows you to enter functions, which display as graphs. When an equation was entered the graph appeared, and was projected onto the IWB. Frank used these graphs to discuss how different changes in parameter affected the graph. On the whiteboard alongside the IWB he wrote out equations, which students solved in their exercise books, working at their desks. On a few occasions he called a girl to the IWB to demonstrate where the tangent would go for each equation. This was drawn onto the IWB using the IWB pen, and then, when entered into *Autograph*, would display on top of this for comparison.

Frank asked probing questions and a number of examples were completed in this way. At certain stages students were asked to predict certain features of the parabola or tangent from parameters in the equation. Frank explained that the ability to graph the equations was not required by the syllabus, but that he felt it was useful to help students understand the equations better.

In the fifteen minute lesson segment analysed, utterances were broken down into phrases and coded using the Translation device as shown below. Each occurrence represents a phrase.

Table 4.10 Lesson Coded for Semantic Gravity

	Teacher		Student		Total	
Category	**Occurrence**	**Percentage**	**Occurrence**	**Percentage**	**Occurrence**	**Percentage**
Abstraction	**12**	**7%**	**2**	**3%**	**14**	**6%**
Generalisation	**40**	**23%**	**4**	**6%**	**44**	**18%**
Judgement	**9**	**5%**	**2**	**3%**	**11**	**5%**
Interpretation	**45**	**26%**	**47**	**73%**	**92**	**38%**
Summarising	**52**	**30%**	**8**	**13%**	**60**	**25%**
Description	**18**	**10%**	**1**	**2%**	**19**	**8%**
Total	**176**	**100%**	**64**	**100%**	**240**	**100%**
All Content Talk	**176**	**67%**	**64**	**64%**	**240**	**66%**
Task Mechanics	**59**	**22%**	**22**	**22%**	**81**	**22%**
Task Purpose	**15**	**6%**	**1**	**1%**	**16**	**4%**
Off Topic	**13**	**5%**	**13**	**13%**	**26**	**7%**
Total	**263**	**100%**	**100**	**100%**	**363**	**100%**
	Teacher	**72%**	**Student**	**28%**		

Teacher talk constituted roughly 70% of the total, although at times students were working in their books, and this talk was not able to be transcribed because of inaudibility. Frank's sentences tended to be longer than students' responses to his questions. About a third of talk related directly to the content of the lesson. About 5% was off topic, reflecting a conversation at the beginning of the lesson between Frank and a student, and an interchange when Frank disappeared for a moment behind a wall for a few seconds. The mechanics of the task, some of it related to using the *Autograph* software, but most of it related to how to approach the equations, who needed to come to the board, what to do next, dominated the remaining quarter of the talk, with some talk around the purpose of the task, it's place in the curriculum, and so on.

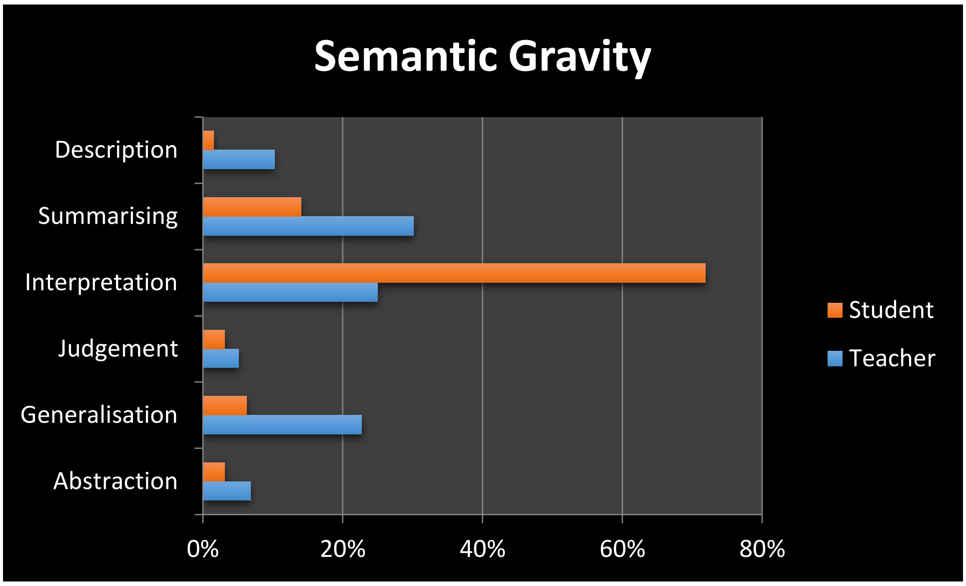

Figure 4.1 Graph of Semantic Gravity - Maths Lesson

If we look at a graph (above) of the semantic gravity as coded we can see two main patterns emerging. In terms of student talk, some 73% of phrase units were characterised by a response interpreting the content, either in terms of answering a question, or asking for an interpretation of the concept or data presented. For example:

> *"F:It's unique, so m is unique. What does c represent?*
> *G1: The y intercept.*
> *F: And how many y intercepts are there?*
> *G1: One*
> *G2: One. "*

In this interchange Frank is unpacking the function for a straight line graph $y = mx + c$. Because the values of these variables change, the function represents an abstract idea. Frank is therefore taking an abstract idea (SG-), and by looking at a particular parabola and tangent, making the idea more concrete (SG+). This calls for a strengthening of the semantic gravity. Frank asks the students to identify what c stands for? Whether the student who replies first uses recall, she remembers that c stands for the y intercept, or whether she is inferring that, a more abstract thought process, is unclear. I coded the exchange as follows:

> *"F: It's unique [Abstract], so m is unique [generalization]. What does c represent? [Interpretation]*
> *G1: The y intercept. [Interpretation]*
> *F: And how many y intercepts are there? [Summarising]*

G1: One [Summarising]
G2: One. [Summarising] ”

My reasoning was that Frank appears to be introducing a generally applicable abstract principle – that the gradient on any tangent is unique, from which he deduces that the value of m is unique [a generalization]. He then asks students what the variable called c stands for. This might have been calling for mere recall of a learned idea, but Frank seemed to be covering new ground with the class, or revising something after a period of time as students were struggling with the concept. I therefore decided that he appeared more likely to be calling for an interpretation of learned information in a slightly different context. His second question, however, appears more grounded in past knowledge, slightly less interpretive and more descriptive, as are the responses he receives.

This analysis therefore characterises the interchange as an overall strengthening of semantic gravity as the idea of the function is unpacked term by term. This analysis ignores the fact that the parabola (created in *Autograph*) and the tangent (drawn in by a student using the IWB stylus in red) were displayed on the IWB. If we re-code the interchange with this in mind, we can see that the semantic gravity is strengthened. Students are not being asked to infer ideas, reason them through in their heads or recall from past learning, so much as make observations about the graph on display.

“F:It’s unique [Abstract], so m is unique [generalization]. What does c represent? [Interpretation]
G1: The y intercept. [Interpretation]
F: And how many y intercepts are there? [Description]
G1: One [Description]
G2: One. [Description] ”

This demonstrates not only the difficulties involved in coding any interchange for semantic gravity, but also how the affordances of the IWB and *Autograph* software are being used to help students ground their understanding through visualization of the function.

Throughout the lesson Frank tried to strengthen the Semantic Gravity by interrogating students' understanding of what factors are at play in determining the function of the tangent, and what they needed to work out to be able to solve the function. Key to this was the moments when students interacted with the graphed representation of the equation.

This routine demonstrated a moment of gravitation. This pattern was repeated many times during the course of the lesson, and characterised the semantic profile.

There were times, however, when levitation was used. Here is a short interchange in which Frank uses the IWB to show what he is talking about, and builds towards a more abstract understanding of the particular graph he is working with, an approach for solving this type of problem.

> *"F:OK. So you're actually gonna go find, this is a function f. You gonna go find f of? -1. And that's what gives you that choice. So, when x = -1 you get $y = -(-1)^2 + 4$ which is what, [Name]?*
> *[Frank was writing on the whiteboard here]*
> *G1: 3*
> *F: OK. So, this is your point*
> *[Frank was showing point on IWB]*
> *F: OK, so it goes through the point -1:3 and you can see that from the graph. So now you've got a point on this straight line. But that's not enough, What else are you gonna go try find, [Name]?*
> *G1: The co-ordinate ...*
> *F: the tangent?*
> *G1: So you can finally find the ...*
> *G2: The gradient*
> *F: What else can I find about this line? I can only find one point.*
> *G1: A point*
> *F: I've got a point.*
> *G2: You're gonna find, like a gradient ...*
> *F: OK, How you gonna find the gradient?*
> *G2: [indistinct] ... the derivative ...*
> *F: OK. So, in derivative notation that gradient would be f dash of what?*
> *G1: Of ...*
> *F: on a tangent at x is equal to?*
> *G1: -1*
> *F: So I'm looking for?*
> *G1: [indistinct]*
> *F: f dash of -1. Before I can find f dash of -1 I've gotta go find? The derivative equation. So, if you had f of $x = -x^2 + 4$. [er, Name]? What is the derivative equation going to be?*

*G3:	-2x*
F: OK. So that's your derivative equation. What does that give you? If you sub any x value into this function, what does it give you? The gradient of the tangent at, for that particular x value ... on this particular function. OK. That's the derivative equation for that function. "

If we break this interchange down into smaller sections we can see a gradual weakening of semantic gravity.

"F:OK. So you're actually gonna go find, this is a function f. You gonna go find f of? -1. And that's what gives you that choice. So, when x = -1 you get $y = -(-1)^2 + 4$ *which is what, [Name]?*
[Frank was writing on the whiteboard here]
*G1:	3*
F: OK. So, this is your point
[Frank was showing point on IWB]
F: OK, so it goes through the point -1:3 and you can see that from the graph. So now you've got a point on this straight line. But that's not enough."

In this section Frank moves from summarising and interpreting the function to grounding the function of the tangent in the co-ordinates of the graph at the point which he shows on the IWB. At this point the semantic gravity is as strong as it can possibly be. The parabola, the tangent are both drawn on the IWB, and Frank has interpreted the function which he wrote on the whiteboard, has moved across to the IWB and shown where the point is on the graph where the tangent intercepts the parabola.

"F:What else are you gonna go try find, [Name]?
*G1:	The co-ordinate ...*
F: the tangent?
*G1:	So you can finally find the ...*
*G2:	The gradient*
F: What else can I find about this line? I can only find one point.
*G1:	A point*
F: I've got a point.
*G2:	You're gonna find, like a gradient ...*
F: OK, How you gonna find the gradient?
*G2:	[indistinct] ... the derivative ..."*

In this interchange Frank is trying to get students to see what they need to find to work out the gradient of the tangent, working from the point whose co-ordinates are known from the previous section. The semantic gravity starts to weaken as Frank tries to get the students to the point where they understand that they need to use the derivative to find the gradient. This moves the semantic gravity from a point of maximum strength to the most abstract, that of understanding a general principle that the derivative is needed. To do this requires a further strengthening of the semantic gravity from a statement of the function of the derivative to the values in the particular function being discussed, demonstrated with the help of the affordances for visualization of the IWB.

> *"F:OK. So, in derivative notation that gradient would be f dash of what?*
> *G1: Of ...*
> *F: on a tangent at x is equal to?*
> *G1: -1*
> *F: So I'm looking for?*
> *G1: [indistinct]*
> *F: f dash of -1. Before I can find f dash of -1 I've gotta go find? The derivative equation. So, if you had f of x = $-x^2 + 4$. [er, Name]? What is the derivative equation going to be?*
> *G3: -2x*
> *F: OK. So that's your derivative equation. What does that give you? If you sub any x value into this function, what does it give you? The gradient of the tangent at, for that particular x value ... on this particular function. OK. That's the derivative equation for that function."*

Frank ends by re-stating the purpose of finding the derivative, which is a principle applicable across all similar circumstances, and the semantic gravity is as weak as it could be. If the class has understood this, then they have understood how to find the gradient of any tangent of any particular function. Frank repeated this process, but with much greater specificity until the class appeared to have grasped the method, and was able to work on examples in their books.

The purpose of the levitation appeared to be to awaken an understanding of the generally applicability of the method. Most of the lesson focused on gravitation, taking functions and solving them with particular values.

All of this could have been achieved by drawing graphs on a more conventional whiteboard, so the key question becomes whether the IWB offered any unique affordances to facilitate this process. In my interview with Frank, he indicated that he believed that the *Autograph* software allowed him to display graphs, in this case parabolas, on the IWB, and change the parameters to help visualize the effects of changing parameters on the function. This was not necessary in terms of being able to solve the functions, but he felt it made it more accessible to his students.

Figure 4.2 Photograph of Maths Lesson

In **Figure 4.2** above, a student has been asked to come to the IWB and draw in the tangent of the function displayed on the IWB. She uses the IWB pen to draw it in free hand in a different colour. As this is being done, students offer advice from their desks. After drawing the tangent, Frank asked the student operating the software to enter the parameters for the tangent and this was displayed, allowing a comparison between the accurate tangent and the one the student had drawn.

Having the function drawn up in *Autograph* carries a number of advantages over drawing on the board. Firstly it is precise in ways in which free-hand drawing is not. The screen displayed accurately calibrated x and y axes which conceivably removes any circumstance in which inaccuracies in drawing might lead to misconceptions derived from an imprecisely drawn graph. It can also be re-drawn almost instantaneously without messy erasures possibly obscuring parts of the drawing and leading to confusion. Different pen colours are always available, and never become feint if a pen is over-used.

These affordances may appear trivial advantages over prior technology, but represent crucial reasons for preferring it over other technologies, and cannot be overlooked. In interview Frank spoke about being able to use a student trained to use the software to change the parameters on the graph so that he did not lose eye-contact with the class during the lesson, which he would do if drawing the function himself. Drawing on the board would take time, so the technology was speedier and could be updated by a student, freeing Frank to focus on whether what was being dealt with was understood or not, without having to worry about drawing the function on the board. At times during the lesson, Frank instructed the operator to change parameters, and apart from the very beginning of the lesson, setting it up, did not require any further intervention from Frank to display the functions. At one point the function was wrong, and Frank needed to get the student to enter different parameters, but this took less than 30 seconds of the lesson.

In this way Frank appears to have worked out a routine procedure which utilises the affordances of this particular technology seamlessly within his pedagogical practice to enhance the understanding of his students. Because it uses his desktop computer and the IWB it is not dependent upon the Wi-Fi to be effective. Once he has booted up his computer at the beginning of a day, it is available for instant use whenever it is needed, and he is relatively safe from any technical disasters. Again, this affordance appears trivial, but significantly enhances what it allows Frank to do spontaneously as well as when it is part of the formal lesson plan. This element of spontaneity is important. The display ion the IWB was available throughout the lesson, and was used in response to questions from students as well as being part of what Frank had planned to walk his students through.

The **SAMR** model being used by the IT Strategy committee (Figure **1.1**) suggests that the goal of ICT integration ought to be transformative, valorising the Redefinition aspect above Substitution: that it does not simply offer the replacement of one technology with another, but that it should transform pedagogical practice. In this view Frank's use of the IWB and *Autograph* software merely represents the use of a new digital technology to replace an older technology, the whiteboard, without transforming his pedagogical practice. The lesson was very much teacher-centred. Frank did the bulk of the talking, spent most of the time at the front of the classroom, and controlled the content and what activities students were engaged in. The software and hardware used did nothing to pass control of the learning environment over to students, even though one of the students was using the software and seated at Frank's desk. At times students drew on the IWB, but did most work in their books, listened, answered questions most of the time, and occasionally asked questions. Frank did a great deal of his explaining on the whiteboard rather than the IWB.

However, I think it would be wrong to simply dismiss this use of the technology as being inadequate or immaterial. Firstly, it was not simply cobbled on top of another lesson. There is a tendency to dismiss small incremental improvements and to see new technologies as disruptive and transformative. Frank feels that this use of *Autograph* and the IWB has become indispensable to his teaching, and it is easy to see why this is the case.

What we need to ask is to what extent the subject matter, parabolic functions and tangents dictated this approach and use of technology. The topic was located very much as a Knowledge code. As an observer, and not having done any Mathematics since I left high school, I found the content abstract and difficult to follow. The use of the graph helped situate the function in my mind and allowed me to follow most of what was being said despite the fact that I did not do any calculus at school. Being able to refer to the graph strengthened the semantic gravity or density, and also allowed me, as an observer, to do some of the calculations in my head, and substitute values back into the equations being worked through by the class so that when I saw a function written out in algebraic notation I understood what it meant in terms of the parabola and tangent. To the extent that I was able to follow the lesson, what was displayed on the IWB was crucial, and no doubt this was true for many of the students. The fact that it was a digital display, apart from making it easier to read, however, did not directly contribute to my ability to unpack meaning.

While Frank's aim is to use technology to achieve things which cannot be achieved without the technology, as with the use of drill and practice programs such as *My Maths* which he argues replaces the need for expensive tutoring and builds self-reliance and confidence in students, his use of *Autograph* represents more of an accommodation of the affordances of the technology into his existing ways of going about teaching a topic in Mathematics. Even though *Autograph* allows Frank to help students visualize the effects of different parameter changes in more efficient ways, it is the knowledge content and knowledge building routines which Frank uses when approaching this topic which shape how he goes about teaching it. In other words Frank believes that it is helpful when teaching the functions of parabolas that students are able to visualize the function.

What was clear from watching Frank use the software and hardware was that he finds that the presence of an IWB and desktop computer in his classroom affords him opportunities for using *Autograph* to render functions in graph form easily and efficiently. Had the computer and IWB not been there, it is probable that he would simply have drawn the parabola on the white board, and the lesson would essentially have been exactly the same.

If all the students in his class had mobile devices capable of using *Autograph* he might well adapt his teaching to this reality. Indeed, in interview Frank spoke about replacing *Autograph* with *Geogebra*, software with similar functionality which has the key advantage of being free.

Frank used the IWB and white board seamlessly to illustrate the functions being worked with, jumping between them to discuss points on the graph displayed on the IWB and to write out functions on the whiteboard alongside. This facility of being able to use twin displays in different ways also represents a considerable affordance of the technology.

What was apparent was the extent to which the technological affordances were aligned to strong knowledge code practices and to gravitation and to a lesser extent to levitation. Frank explicitly saw the affordances for visualization as the key to the efficacy of the technology, but the way in which the technological code dove-tailed with the pedagogical code is what seems to have made this use of technology indispensible for Frank. He used the technology seamlessly with a question and answer pedagogy which aimed at constantly refining and defining students' responses to unpack the knowledge being transmitted.

4.2.3 Mary - Technology Teacher

I recorded nearly an hour of observation of a lesson on different forms of energy, using students' own devices (iPads and laptops) and Google docs. The lesson was recorded in two parts, the discussions between members of one of the specialisation groups and then the report back by "experts" to their home group. The room was noisy with so many groups, and parts of the recordings were indistinct. The lesson was held in the Technology Lab, and began with Mary outlining the plan for the lesson. What became rapidly clear was that a handful of students were unable to use the Wi-Fi to access Google docs as required, and that a few did not have their devices at school. Mary offered some advice concerning the Wi-Fi, and used other students in the room to help get everyone on. She reminded the students that it was their responsibility to have devices at school.

This lesson was within a month or so of the IT Strategic Policy device roll out to grade 8s, and so it is to be expected that many of these issues were still being worked out in individual classrooms.

One student complained that not all teachers were using devices in their lessons. One girl had left her device at home because it had been charging and she's forgotten it, another had left it in her locker and was asked to fetch it quickly. Another one had sat on her device and it was broken, but she had no letter from her parent as she was a

Boarder. Finally one girl was using her phone as her device and she was reminded that this was not adequate for the purpose.

These discussions, which took up a good five minutes of the lesson, clearly show how any introduction of technology in the classroom is likely to be fraught with technical issues to be overcome. Until students are used to policies and classroom procedures have been negotiated with teachers, there is likely to be a fair amount of testing by students to see what they can get away with. This is not to say that some students did not experience genuine difficulties. Nevertheless, it is clear that the introduction of ICTs into the classroom does open up a space where students can challenge the legitimacy of the rules and procedures set up by a teacher. Any actual or perceived unfairness over lack of access through ICTs is fertile ground for challenging the legitimacy of the lesson. Mary, an experienced teacher, handled these challenges with firm and calm authority, but the discussions about the fairness of the policy were argued with one girl after her introduction, and when others were gathering in their specialist groups.

As discussed above, the lesson took the form of a jigsaw exercise in which students had been formed into Specialist groups, and in previous lessons had researched and co-authored a Google doc, or Google docs on one of many different power sources. I observed a group which had researched nuclear power. In the second half of the lesson students went to home groups made up of one member from each of the specialist groups, and head to teach each other about each power source and evaluate its advantages and disadvantages so as to recommend a suitable power source for South African conditions.

4.2.3.1 Specialist Group

Initial discussion revolved around being able to log on to the Wi-Fi and Google docs, and organising sharing between students. Generally speaking students were able to share what they had written previously and add to their own versions of the document. Much of this section of the lesson was procedural as students had worked on the research and writing beforehand, and used the time to share documents. Not much writing took place. What was clear from the transcript, which was largely too indistinct to draw much usable data, was that students needed a good deal of time to organise their documents, far longer than would have been the case with paper documents, but that they were able to share information in ways that would have been impossible with paper-based technologies.

Some of the discussion revolved around sharing Google docs so that all the students in the group would have access to the documents that had been created earlier on their tablets or laptops. This involved viewing and editing rights, and finding the file on Google drive.

> *"G1: Go to view it.*
> *G2: Are these the same as this?*
> *G3: Google docs ...*
> *G1: That's Google docs.*
> *G3: That's not the same as that, is it?*
> *G2: No.*
> *G3: So I'm on the wrong thing."*

Other talk involved the purpose of the task as girls added to the document, finishing it off before the next phase of the lesson began.

> *"G1: ... the definition of nuclear power.*
> *G2: The pros and cons of nuclear power. And ... obviously ... we should be challenging ... just say pros and cons*
> *G1: What can, what else can we add to our presentation?*
> *G2: I don't think we need a diagram..."*

Mary felt that students did not include enough video or visual content to help them explain how the technology worked to their home groups. Mary conceived of the purpose as being to create learning materials so that each member of the specialist group could effectively teach their home group what they had learned. She assumed that students would be able to do this because they had seen teachers teaching and would "know what works and what doesn't work". Students appeared to conceive of the task differently, to see it as more of a traditional essay writing task. While the videos and visual information Mary had given students undoubtedly helped to build understanding, they were not seen as important in presenting the information, probably because the teacher was seen as the main audience. Since these materials had been provided by the teacher, they were probably not seen as necessary to include in the presentation.

4.2.3.2 Home Group

Mary felt, in interview, that this part of the lesson had been somewhat unsuccessful because students had merely read from their Google docs instead of trying to summarise the information, and "teach" their peers as she had envisioned. It was clear from the transcript of the lesson observation that the students presenting each of the topics were at times not in complete mastery of the content, and therefore it is quite understandable that they resorted to reading. They were in effect trying to unpack the texts created by their specialist groups and make sense of them while presenting the material to their peers.

In the time available three of the students managed to present their findings, and the percentage of utterances that were read as opposed to spoken during discussion varied quite considerably. In two of the presentations the percentage read was 64% and 70% respectively. In the third group, however, discussion was sparked and only 31% of the utterances were read. This was partially due to the fact that girl presenting the third presentation spoke from her notes, rather than reading them verbatim, and partially because she appeared to be very uncertain of what was in her notes, and stumbled far more, eliciting many questions calling for clarifications over what she was saying.

A large part of the talk in the group consisted of procedural issues such as who was to speak next, whether they had to take notes, and how to share the Google docs that had been created in the specialist groups. There was very little off-task talk, perhaps because the students were aware that I was recording them. There was only one procedural interruption from Mary, who spent her time listening in to other groups, again probably because I was constantly with the group being observed.

I coded those parts of the transcript which were not procedural, which dealt with the content of the topic directly for semantic gravity. In using the translation device, I was acutely aware of the difficulties of deciding at what level any particular phrase or clause should be marked: abstraction, generalization, judgement, interpretation, summarising or description. Even highly abstract ideas, if simply read verbatim, are in essence simply descriptive, since the speaker is merely reading from the screen. Nor could I decide from the transcript which parts of the Google doc had been worked on by the students, and processed in discussion, and individually when creating the document, and which might have been simply lifted "copy & paste" or paraphrased from the Internet. I therefore ran the transcript through Turnitin, a plagiarism checker. Very little appeared to have been directly copied, but I marked these sections as under suspicion, although choosing to ignore that in the analysis of semantic gravity since the percentage of plagiarism noted by Turnitin was very low and was all related to papers submitted by students from other institutions rather than websites which the students may have used. The plagiarism marked by the plagiarism checker, such as "wind is used to generate mechanical power", may have come from a common website not picked up by the software, but reflects a collocation of words which in all likelihood would generally be used in any event.

I then quantified the semantic gravity by phrase units, and by whether it was read off the screen, or formed part of the discussion. I decided to use the phrase rather than the sentence as my basic unit of analysis because it helped regulate different sentence lengths, and because compound sentences may include clauses of general abstraction combined with descriptive examples or instances. I then tabulated the number of instances of the different levels of semantic gravity in the instrument for each of the three girls who presented their findings. These are recorded below, with a brief discussion on each of the presentations as different patterns emerged based on differences in the presentations themselves.

Table 4.11 Student A (Wind Power)

Category	Occurrence	%	While Reading	%	While Speaking	%
Abstraction	3	11%	3	17%	0	0%
Generalisation	2	7%	2	11%	0	0%
Judgement	12	43%	3	17%	9	90%
Interpretation	1	4%	0	0%	1	10%
Summarising	4	14%	4	22%	0	0%
Description	6	21%	6	33%	0	0%
Total	28	100%	18	100%	10	100%

This student's approach was to make a very detailed presentation of how wind turbines generate electricity, which moved from generalised abstraction to detailed description. Her summary of wind power did a fair job of taking the concept and strengthening the semantic gravity so as to unpack the concept (SG↓).

> *"Wind turbines do the opposite of what fans do, so instead of fans using electricity to make something cold or to move the air [um] wind turbines use the air and the wind to create electricity. So they have a propeller-like blade that is connected to a main shaft which just spins a generator, so it converts kinetic energy into electricity."*

She went on to quote some "interesting facts" about wind farms and how much electricity they provided, further strengthening the semantic gravity.

> *"Six, so far there are sixty wind turbines in the Eastern Cape that have been commissioned - the farm which spans 3700 ha - I don't know what [??] it is - will supply 460 000 MWH, enough clean renewable electricity to power [??? thousand] average South African households, which is obviously very helpful."*

From this general introduction she went on to list the benefits of wind power, and some of the disadvantages. I coded these as evaluative utterances, especially as she moved from reading verbatim to discussing the pros and cons in answer to a question. This reflected a weakening of the semantic gravity as she summarised her assessment of the mainly beneficial effects of this source of power (SG↑). The other students did not ask many questions at all, asking only for a clarification on what she had meant by saying that there was less of a risk for "disasters" to happen with this power source.

"So, not much, not many disasters or deaths or what happened from building, obviously there's still risk, but from building it there's nothing much that can happen and also it's less effec ... it doesn't have that much of a bad effects, it doesn't pollute the air, or anything like that and it's not, it's very simple to obviously like design and [??] so it's not a, there's not a big risk of there being like architectural mistake, or something, you know, it was an error.”

While the language is not very academic, she had already addressed the benefits of a renewable, non-pollutant source of power in her read presentation, and here seems to be reaching for a comparison with other forms of energy where mistakes in design might be costly. While she was reading her notes to the group, the main turn of the Semantic Wave was thus gravitational, from relatively weak (SG-) to relatively strong (SG+), as she unpacked the meaning of the term, and gave descriptions of how it worked and some interesting facts. But she then reversed the semantic direction in her assessment of the benefits and suggested comparison with other forms of energy, mainly as she responded verbally to a question asking for clarification. This reflected a turn to levitational directionality.

Table 4.12 Student B (Solar Power)

Category	Occurrence	%	While Reading	%	While discussing	%
Abstraction	1	2%	1	3%	0	0%
Generalisation	4	9%	3	9%	1	7%
Judgement	24	52%	18	56%	6	43%
Interpretation	2	4%	1	3%	1	7%
Summarising	9	20%	6	19%	3	21%
Description	6	13%	3	9%	3	21%
Total	46	100%	32	100%	14	100%

The second presentation on solar power was also mainly read from the Google doc. Once again the student strengthened semantic gravity (SG↓) as she moved from an evaluation of its advantages and disadvantages towards a more detailed, if flawed description of how photo-voltaic cells work.

“Solar power is the conversion of sunlight into electricity. Solar power is environmentally friendly, cost effective, long term, and somewhat easy to access depending on the area that you're in. Solar power is the collection of solar radiation to produce electricity. It is renewable and produces no pollution. It is not a constant source of energy. It is expensive and technologically challenging. The production of solar power panels produces large amounts of greenhouse gases."

And later

> *"Solar energy tech .. [er] techniques involve [um] with photo - vo - volatic systems where photo-volatic cells are used. It's weird, anyway, photo-volatic cells is the units that makes silicon, OK?"*

This unpacking of the technology involved was far less successful than that achieved in the previous example. Perhaps because the girl did not understand the concept as well, or because the mechanics of the conversion of sunlight into electrical energy is more arcane, this presentation sparked a great deal more conversation about the expense of installation as opposed to the savings resulting from freely available sunlight. One of the other girls recalled seeing a programme on television about being able to sell energy generated by solar power back to the grid, and this generated a great deal of discussion. This discussion about the cost represented a fair attempt at engaging with the question posed by the teacher, and a weakening of semantic gravity (SG↑) as the group moved towards evaluating the strengths and weaknesses of this form of energy.

Once again, then the discussion reflected both gravitational and levitational semantic profiles.

Table 4.13 Student C (Thermal Power)

Category	Occurrence	%	While Reading	%	While discussing	%
Abstraction	1	2%	0	0%	1	3%
Generalisation	0	0%	0	0%	0	0%
Judgement	25	43%	0	0%	25	63%
Interpretation	5	9%	5	28%	0	0%
Summarising	8	14%	7	39%	1	3%
Description	19	33%	6	33%	13	33%
Total	58	100%	18	100%	40	100%

The third presentation took the form of many questions and answers as the students tried to grapple with what was meant by thermal power. The idea remained relatively unpacked initially, as there was very little movement between the abstract and the concrete and the other girls were left asking for an example so that they could understand what was involved. This movement from SG- to SG+ came only later.

> *"G1: So a thermal power station uses a source of heat to turn water into steam. Which then moves the turbine, which turns, turns the generator and then that generates electricity. So [um] [um]*
> *G: Well would an example be a ...*
> *G: ... of thermal power*
> *G: Well, what do you mean, like ?? specific thermal power stations?*
> *G: Where they take from the water source, you have the water source and then they [um] they use, they don't use coal, [um] no ..*
> *G: don't you mean they use coal?*
> *G: Yes, fuel is used, fuel used is cheaper, they use coal instead of petrol or diesel. So they use that coal to heat up the water which then produces steam, and then the power ...*
> *G: I'm thinking of like this steam engine ... [laughing]"*

The discussion therefore moved on to the relative costs of coal, petrol and diesel, and the effects on the environment, representing something of an evaluation of the power source as desired by the teacher, but with a great deal of confusion remaining. The presentation ended with the girl presenting returning to her notes and reading a passage about the size of the thermal power plant and its closeness to the water source. "Thermal power plants are able to respond to the load demand more effectively and support the performance of the electrical grid. Steam plants can withstand the overloading for a certain ..."

The girls were able to unpack the idea of what a thermal power station was through questioning, and to conduct an extensive, although somewhat messy conversation around its benefits and drawbacks which included questions around cost, effect on the environment and geographic placement and sustainability.

> "I don't know. I mean both of them are, well coal is something that we're really running out of."

In many ways, despite being less structured this discussion was able to touch on more issues in greater depth than the other two presentations. Perhaps the girls were getting into the swing of it, or perhaps the number of points being made by different people added depth to the discussion, or perhaps by interrogating the meaning of the presentation verbally they were able to unpack more. While gravitational and levitational profiles were more chaotic, both were evidenced.

4.2.3.3 Conclusions

In essence students had been presented with a task which required them to come to an understanding of how the source of power worked, and then to evaluate this in discussion. The texts that all three students produced were high in semantic gravity (SG+) and apart from one or two phrases, clearly understood by the girl presenting. During the discussion some points were clarified, and the impact on the country evaluated, representing a nett weakening of semantic gravity (SG↑) as the discussion moved from describing the power source to evaluating its use.

What this suggests is that the use of Google docs to compose texts which reflected student understanding, and to help them evaluate which power source was more appropriate for a South African context, did help to produce texts which were descriptive and suitable for the Home Group discussion which followed.

There was evidence of the creation of semantic waves, in both directions, (SG↓) and (SG↑). Substantive issues were raised and discussed. Videos and graphics recorded on Google docs were used in some groups to help explain the concepts to their peers (levitation). At moments in which students talked the issues through, they were busy constructing knowledge from the examples, and trying to use their everyday understanding to understand the scientific concepts involved (gravitation). While a small part of the lesson, these moments when students were able to bridge the gap between every day and scientific discourse seemed to generate genuine excitement.

4.3 Interpreting the Data

There appears to be a link between the metaphorical descriptions teachers used to characterise their classroom practices (interaction, intervention, conversation, journey and engagement) and the decisions taken around pedagogy and technology. This suggests that teachers have a coherent, though probably subconscious, mental model of what it means to teach their subject specialization. Their decisions around both pedagogy and technology appear relatively malleable, and appear to be based on the affordances both offer for their practice.

This was especially apparent when teachers were asked about what they would do if the technology did not work. Abby said that she was comfortable enough with the content that she could simply "revert to chalk and talk". If a video did not work she could put it aside and engage with them writing on the board". This was echoed by all the teachers. Instructivist practices appear to be the default setting, and although teachers are clearly concerned about creating more student-centred environments, and clearly many lessons are structured this way, decisions around what pedagogy to employ are relatively flexible. This holds true of the technology as well, although it seems as if the two are woven together.

Sackstein (2014) found that there was a greater enthusiasm for tablet use amongst teachers who shared a competence rather than a performance based pedagogical practice. While this question has been largely outside the scope of this study, this alignment between constructivist models of learning and ICT use is often drawn, as discussed in the literature review. Tablets represent technologies which offer strong affordances for particular tasks such as creating a video, searching the Internet or recording voice. They offer rather more limited affordance, or even constraints around lengthier writing tasks, or writing Maths symbols. Laptops offer different sets of affordances, as do all technologies. We could therefore expect some technologies to offer greater affordances around competence based pedagogical practices, and others to favour performance based pedagogical competences.

Frank, for example uses the IWB and *Autograph* software for teacher-centred instruction, while acknowledging that if his students had iPads and could use *GeoGebra*, his lessons would be much more student-centred. Mary uses her students' tablets and laptops together with Google docs to encourage student-centred research and knowledge building. Abby wants to use the iPads for Science simulations, but because Flash does not run on iPads, needs to book the computer room to do this. She uses more student-centred approaches, where students use the simulations and worksheets to explore topics such as electrical circuits. Heather uses video creation and apps such as *Explain Everything* to encourage students to explore the background history of Apartheid and themes within the novel, using constructivist approaches.

Teachers appear to be using certain tools, not because that tool predetermines particular uses, but because they perceive affordances which work with particular pedagogical approaches in particular contexts. As Abby put it, "I think any tool works if you're using the language". She was referring to how she perceives ICTs as integrating with the language of thinking skills which Girl's High teachers are embedding in their pedagogical practice. There is a sense in which this comment reveals both that the affordances of technology and pedagogy work together to guide her practice, and a sense in which it is the pedagogy, particularly around the thinking behind the discipline, which is seen as paramount. Abby, however, revealed that in many instances the perceived affordances of the tool did matter. She found Google docs unintuitive, preferring Microsoft Office, and therefore was unable to use it for scaffolding student writing, which Mary saw as one the major affordances of Google docs.

I have described pedagogy as offering affordances, and by this I mean that different pedagogical practices appear to support particular outcomes. Almost all the practices described wove together technology and pedagogy. At Girl's High teachers are attempting to integrate pedagogical approaches, instances of technology and Thinking Skills strategies which forms part of the twin strategic imperatives of the school. In some instances this was explicit. For example Mary used the jigsaw method (pedagogy) together with Google docs (technology) and the de Bono Thinking Hats (thinking strategy) to approach her lessons on different sources of power. Abby wanted to use motion videos (technology) together with Predict-Observe-Explain (thinking strategy) in group-work (pedagogy) for her lessons on the laws of motion.

In other instances the thinking skills were not explicit, but the technological and pedagogical affordances appeared to be working together to create a successful lesson. Frank was using *Autograph* (technology) together with question and answer (pedagogy) in his lesson on finding the gradient of the tangent. Heather was using the IWB (technology) together with peer editing (pedagogy) in correcting punctuation. This is an obvious point to make, but this working together of technology and pedagogy appears to be what motivates teachers in their instructional design decisions. While other factors in the equation, the context, learners and learning outcomes are relatively fixed in stone, what can be changed quite easily is the technological tools used, and specific pedagogies employed in any given unit of work.

Where technology and pedagogy appeared at odds, for example where Heather saw the Life Orientation videos students had made as having been a failure, it was unclear whether this was because of technological constraints or because of pedagogical failures in that the task had not been sufficiently scaffolded.

Using Howard & Maton's (2011) analysis of the code matches and code clashes between knower and knowledge code specialisations and ICT practices, we can speak of knowledge and knower code ICT practices, ie. ICT practices that support knowledge code and those that support knower code practices. Frank's use of *Autograph*, for example represents an ICT practice which carries strong affordances for knowledge practices – in this case visualising a mathematical function. Mary's use of Google docs, on the other hand appears to support knower practices – constructing an argument in favour of one or other power source.

The assumption behind Howard & Maton's (2011) assertion that ICTs offer greater affordances for knower code practices is not refuted by this research. I have argued instead that we need to employ the framework of semantic gravity and semantic profiles to unpack how the affordances of different technologies and pedagogies support knowledge and knower code practices. We have seen how Frank's use of *Autograph* together with question and answer offered affordances for both gravitation and levitation, but appeared particularly to afford gravitation. Mary's students used the Google docs they had created to grapple both with gravitation (understanding the knowledge) and with levitation (evaluating the knowledge). Mary's feelings that the lesson had been less than successful rested not on a lack of understanding, reflecting a knowledge code emphasis, but that students had not approached the task as she had intended, reflecting an emphasis on knower code.

5. Conclusions & Recommendations

This study set out to examine the extent to which the forms knowledge takes influences ICT integration practices, and in particular to look at how the affordances of the new technologies are translated into the integration of these technologies within particular pedagogical practices, and to what extent it alters or changes practice. The secondary question was to examine the extent to which the concept of semantic waves held explanatory power when looking at questions of ICT integration.

5.1 Conclusions

What emerges clearly from the research is the centrality of subject discipline in shaping how the affordances and constraints of new technologies play out in teacher's practice. Howard & Maton's (2011) suggestion that subject specialization is an important indicator of the shape ICT integration will take, the extent to which knowledge and knower codes articulate with the predominantly knower code framing of ICT practices, is largely supported, but a more nuanced interpretation is suggested.

Knowledge code practices are being supported by ICT practices which align with knowledge code structures, while knower code practices are being supported by knower code ICT practices. Teachers, are, however, also exploring both knowledge and knower code practices within their subjects, and are alive to the extent to which the affordances of ICTs can transform the nature of their subject. ICTs are generally conceived of as affording the nurturing of more independent learners and more student-centred approaches. Teachers are alive to these possibilities, however, only to the extent that it fits their conceptions of their subject and what it means to teach particular content to particular learners in particular contexts.

We need a more nuanced view of what it is that ICTs afford within both knowledge and knower code ICT practices. Semantic waves offer a way of viewing classroom interactions that helps bring together many different approaches to the instructivist/constructivist instructional design debate. This research sought to explore semantic gravity as an explanatory framework for ICT integration to further unpack what it is that ICTs afford.

ICTs are clearly being used by teachers to afford gravitation, most notably by aiding visualization of abstractions through graphing software or simulations, but also through enabling discussion using tools such as Google docs. Levitation appears less common as a classroom routine in classrooms strongly controlled by knowledge code practices, but equally afforded by ICTs. Levitation may be more common in classrooms governed by strong knower code practices, but further research is needed to establish how this is afforded by ICTs.

It also seems clear that teachers are using ICTs for a range of purposes which support both knower and knowledge code practices in terms of specialisation code, and gravitation and levitation, in terms of semantic profiles. I believe that layering these two approaches provides a more nuanced picture of what it is that ICTs afford in the classroom. When we speak of code matches and code clashes it is important to include semantic gravity. This allows us to unpack notions of TPACK more meaningfully. It is not just about how teachers are teaching (pedagogical knowledge) a topic (content knowledge) using technology (technological knowledge). It is also about the purpose behind what they are teaching. Are they teaching for greater gravitation or levitation, to scaffold greater understanding (reading) or better expression of understanding (writing)?

Seeing ICT practices as affording both knower and knowledge practices, and as affording gravitation or levitation allows us to start to unpack further how the forms knowledge takes influences decisions around ICT adoption. There would appear to be sufficient explanatory power behind the view that gravitation and levitation are afforded by ICTs to warrant further, more detailed research.`

I would also argue that the dialectical approach towards analysing the internal and external languages of description carries descriptive power, allowing data taken from interview and from lesson observation to be analysed in terms that not only help explain why teachers in different subject areas use technology differently, but also help pin point commonalities and generalities that help explain how the technological, pedagogical and specialization codes articulate.

5.2 Limitations in the Research

This research relied primarily on interview rather than observation, although some lessons were observed, allowing for a degree of confirmation of the practices being reported. The limited number of interviews conducted, and lessons observed, places limitations on the conclusions that can be drawn. Surveys might have been employed to assess wider ICT use by more teachers in more subject disciplines, which might have provided a greater degree of context for the research.

With hindsight, greater emphasis might have been placed on lesson observation to have provided a wider range of examples of practice from which to draw more detailed conclusions.

5.3 Recommendations

5.3.1 Further Research

Further research into how ICTs afford, or constrain gravitation and levitation is needed across a range of subject disciplines. This research did not consider semantic density, and clearly this area needs to be explored in order to develop a fuller understanding of semantic profiles. Work in press by Maton & Doran (Maton & Doran, 2016a, 2016b) is suggestive of useful categories of analysis for undertaking this.

Because teaching is such a wicked problem (Trowler, 2010), research into what ICTs afford gravitation and levitation needs to be conducted across a range of contexts for a clearer picture to emerge.

5.3.2 Recommendations for Teachers

I believe that teachers, who are currently facing considerable pressure to integrate ICTs in their classrooms could benefit from a clearer understanding of how the forms knowledge takes shapes ICT integration and how the affordances of ICTs shape adoption within different subject disciplines according to the purposes and subject specialization code practices of the lesson. By understanding what affordances particular technologies offer for unpacking student understanding and helping students to articulate their understandings using academic language, teachers will better be able to do what they do using technology, free from unrealistic expectations that it is their job to transform education.

Appendices

Appendix A: Interview Questions

What ICTs do you use in your personal or professional life?

What purposes do you use them for, and how comfortable do you feel using them?

What ICTs have you used in the classroom?

How did you use them? What was the purpose?

How did they enhance or detract from the lesson?

What successes and failures have you had using ICTs in the classroom?

Do you think ICTs work well with your subject?

What areas of the curriculum lend themselves to ICTs?

Where are they not useful?

Do you have plans to use ICTs in future lessons?

What do you intend doing? / Why not?

If you were to re-teach any area of the curriculum, what might benefit most from using ICTs? Why?

Appendix B: Interview Codes

Translation Device **Mapping issues raised to Theoretical Frameworks**	
Organic Concerns	**Theoretical Frameworks**
Competence Personal Use Of ICTs PU+ confident PU- not confident	TPACK - Technological Knowledge
Competence Professional Use Of ICTs **In Classroom Management** CM+ classroom management effective CM- classroom management not effective **In Pedagogy** LU+ use in lessons effective LU- use in lessons not effective **Professional Development** PD+ strong affordances for professional development PD- weak affordances for professional development	TPACK – Technological Pedagogical Knowledge TPACK – Technological Pedagogical Content Knowledge - Technological Content Knowledge
Pedagogical Alignment Ped+ ICT use aligned to way teaches Ped- ICT use not aligned to way teaches Ins+ use supports Instructivist paradigm Con+ use supports Constructivist paradigm	
Content Specialisation What do students need to know in the subject specialisation. Goals and aims of the curriculum	**Specialisation Codes** ER+SR- Knowledge Codes ER+SR+ Elite Codes ER-SR+ Knower Codes ER-SR- Relativist Code **Code Matches/Clashes**

Translation Device **Mapping issues raised to Theoretical Frameworks**	
Organic Concerns	**Theoretical Frameworks**
	CM+ Strong Code match CM- Weak Code match CC+ String Code Clash CC- Weak Code Clash
Affordances AS+ Software offers strong affordances AS- Software offers weak affordances AH+ Hardware offers strong affordances AH- Hardware offers weak affordances AP+ Platform offers strong affordances AP- Platform offers weak affordances	**Technology Mapping** TA+ Strong Technological Affordances TA- Weak technological Affordances
Skills Transfer Interference STI+ strong interference in Transfer of Skills STI- ease of migration from one set of skills to another	
Time T+ Use of technology saves time T- Use of technology consumes time	
Explaining/unpacking ideas **Creating/constructing ideas**	**Semantic Waves** SG+ SD- SG- SD+ Levitation Gravitation
Resistance To Change TR+ Strong Teacher Resistance TR- Weak Teacher Resistance SR+ Strong Student Resistance SR- Weak Student Resistance	
Acceptance Of Change TA+ Strong Teacher Acceptance	

Translation Device Mapping issues raised to Theoretical Frameworks	
Organic Concerns	**Theoretical Frameworks**
TA- Weak Teacher Acceptance SA+ Strong Student Acceptance SA- Weak Student Acceptance	
Organizational/Infrastructural Contexts Cost Wi-Fi Resources Curriculum Student engagement/desire to learn Subject Ethos Institutional Ethos Time-tabling Teacher as Authority Belief Teacher/student relationship Student Distraction	Contextual factors
Assessment OA+ strong alignment to online assessment OA- weak alignment to online assessment	
Paradigm Shifts Flipped Classroom Problem Based Learning Critical Thinking/Thinking Skills	

Appendix C: The Translation Device For Interviews

Conceptual Framework	Internal Language Of Description	External Language Of Description	Examples
TPACK **Technology Mapping ID**	Technological Knowledge (TK)	Personal & Professional Proficiency	*I can't basically function without using computers*
	Content Knowledge (CK)	Curriculum, learning Outcomes	*The framework of Maths at the moment is, is I suppose the wrong way round. It's you do all the theory and then you show it's got its uses*
	Pedagogical Knowledge (PK)	Constructivism, Instructivism, Teaching Methods, Thinking Skills	*But I think sometimes they just like the fact that it is someone else*
	Technological Pedagogical Knowledge (TPK)	Classroom management with ICTs, Flipped Learning Model, tie-ins with Cognitive Education	*I want to do a hats … with … also … so with a flipped classroom model, and then the Hats*
	Technological Content Knowledge (TCK)	Specialist hardware/software	*The program I really use a lot is Autograph and … in terms of setting papers*
	Technological Pedagogical Content Knowledge (TPACK)	Use of ICTs in lessons	*You can set it to animation so you see the flow and how it changes and you can talk them through it*
	Strong Technological Affordances (TA+) Weak Technological Affordances (TA-) Perceived and Real Affordances	Platforms, hardware & software which is seen as useful	*And now you can just do it, click on a button*
	Strong Technological Constraints (TC+) Weak Technological Constraints (TC-)	Platforms, hardware & software which is seen as not being useful	*[Name] wanted to use my class today … for a lesson because her YouTube isn't working, she comes here, and my, and mine's not working either.*
	Learners	Learners' resistance, acceptance of change, engagement, achievement	*It's getting better now, but there was a huge push back here.*
	Contextual Factors (CF)	Learning Outcomes, institutional factors, Time, Professional Development, Age, subject culture, teacher resistance, cost, etc	*You've got to have time to do that sort of thing.*
Conceptual Framework	**Internal Language Of Description**	**External Language Of Description**	**Examples**
Legitimation Code Theory **Specialisation Codes** **Semantic Gravity/Density** **Semantic Profiles**	ER+SR- Knowledge Code ER+SR+ Elite Code ER-SR+ Knower Code ER-SR- Relativist Code	Subject characteristics, cultures, relevance and framing within the curriculum	*Maths is largely used … it's a means of exclusion* *We're all sort of on the same journey together, well on the same sort of path*
	Strong Semantic Gravity (SG+)	Student voice, student authoring, concrete, narrative	*They love, you know, finding Google images and, you know,*

Conceptual Framework	**Internal Language Of Description**	**External Language Of Description**	**Examples**
	Weak Semantic Density (SD-)	modes	*being creative in their compilations*
	Weak Semantic Gravity (SG-) Strong Semantic Density (SD+)	Academic language, abstractions, symbolic understandings	*they can set up the idealized, this is the ideal circuit, these are the ideal results*
	Gravitation (SG↓)	Unpacking meaning, making meaning concrete, explaining, visualising, reading with understanding, relating concepts to experience	*If you're drawing a normal parabola like $y=x^2$, how would it look like if you went $2x^2$, $3x^2$, $4x^2$, and what happens to the graph?*
	Levitation (SG↑)	Shaping meaning into academic language, writing from concrete to abstract, inductive reasoning from experience to generalisation	*The grade 9s did their working model with their electronic circuit, then they did an evaluation video … they had to evaluate the model*
	Narrative Flat-line (SG+SD-→)	Explanation remains at the level of experience, is purely concrete or narrative	*What would happen if the boys would realise, OK, you can get thirty points without even trying another one like this, so simple, simple simon … without going on to the next level.*
	Abstract Flat-line (SG-SD+→)	Explanation remains at a generalised, abstract level, and is never extended by examples, anecdote or evidence	*But I find that … the simulations are only effective if we've got a … a worksheet with it*

Appendix D: The Translation device for Lesson Observation

Internal Language Of description	**External Language Of Description**	**Examples**
SG-SD+	Abstraction	*F: First of all I want you to do that, sketch* $3x = -x^2 + 4$*. Ok, tell me what that, [Name], what does that graph look like? U, u, [Name]* *G3: It's a parabola* *F: OK and happy or sad?* *G4: Sad.*
↕	Generalization	*G: but basically wind turbines do the opposite of what fans do, so instead of fans using electricity to make something cold or to move the air [um] wind turbines use the air and the wind to create electricity.*
	Judgement	*G: No, no, no. Diesel is going to be more hazardous to the environment.* *G: I don't know. I mean both of them are, well coal is something that we're really running out of.*
	Interpretation	*so it's not a, there's not a big risk of there being like architectural mistake, or something, you know, it was an error.*
	Summarising Description	*photo-volatic [sic] cells are only able to convert up to 50% of the light energy that receives [um] that they receive into electrical ch ... energy. This makes them inefficient*
SG+SD-	Reproductive Description	*G: The materials used to manufacture the panels are toxic materials: mercury, lead, etc.*
Talk Off Topic	Talk about the Task Mechanics	*G: You've got to share the doc with us.* *G: Ok, there we go, I've got yours* *G: I've got it.*
	Talk about the Task Purpose	*G: What are we? Ok , can I ask a stupid question? What are we actually doing in this project?* *G: [laughing] I think we are supposed to like write, 'cause after this we have to write ... like a report or something ...*
	Talk about unrelated matters	*G: So where'd he go? [laughing]* *G: Where'd he go?*

This eternal language for description of semantic gravity is drawn from Maton (2011, p.74)

Appendix E: Sample Interview Transcription

Interview with Abby (Science Teacher) 46:06 minutes recorded on 5 August 2015

D: So, perhaps we could start just by talking about your own use of ICTs in professional development, personal life and so on?

A: [um] I haven't used, I haven't used as much as I'd like to [um] and I think just because I haven't really had time to get round it, but I have flipped the classroom a little bit, which I quite like. [um] Using mostly YouTube as my platform, but also TedEd, and TedEd has some very nice videos and then they do the [um] integrated questions so you can run it [um] you can run the video and the girls can then, yeah, [???] the girls can answer questions and and TedEd gives levels of questions. So they can, you can ask very basic pick one, two or three answers or you can ask them to give paragraph answers and then it feeds back with email. So that, that was the platform, along with just YouTube that was the platform that I use for flipping, that I've used the most for flipping.

D: OK

A: [um] and I quite like it because it's already structured ...

D: yeah

A: [um]

D: With what year groups is that?

A: I did it with grade 10s. With grade 10s and there's quite a few videos around the periodic table which are quite nice [um] TedEd do animated, and you can actually email TedEd and say we'd quite like a video on this topic and

D: OK

A: they'll put it together.

D: Phew!

Appendix F: Sample Lesson Observation Transcription

Technology Lesson:

G1: Did you get it?
G2: Yes
G1: Well done [Name]!
M: Girls, who's doing Wind Power? OK [Name] you going to share with every body else?
G3: Yes, Madam.
G2: use a double RR?
G1: Yes
G2: And the one S.
G4: You've got to share the doc with us.
G2: Ok, there we go, I've got yours
G3: I've got it.
G2: OK, cool, thank you
G4: OK. [um] Got it.
G1: OK, here we go. So, basically wind turbine, OK, it's not [???], but basically wind turbines do the opposite of what fans do, so instead of fans using electricity to make something cold or to move the air [um] wind turbines use the air and the wind to create electricity. So they have a propellor-like blade that is connected to a main shaft which just spins a generator, so it converts kinetic energy into electric ity. So that's the, the outline basically of what they are. Wind energy or wind power is the term used to describe how wind is used to generate mechanical power or electricty. The turbines convert the kinetic energy into wind, wind into mechanical power - Ok, so this mechanical power can be used for sp, specific tasks such as grinding grain and pumping water. That's what they mostly use it for or a generator can convert this mechanical power into electricity to power our homes also a lot of businesses, so this is very like helpful and useful thing because the, it's renewable, it's a renewable energy source and wind is free to use for everyone. There's hardly any pollution and the wind won't run out, it's safer and like healthier for the earth and planet. [um] Yeah and it has a less [??] of [um] [???] or disaster and that. Then there're not a lot of cons - it's hazardous to birds, not aesthetically pleasing, it's noisy, wind is not always available and c an affect military radars and airports. So tht's, that's - then there's some intersting fact, which is just some basic information about famous wind turbines around teh world. And then they planned, across South Africa, they plan to create fifty large scale wind farms and they are currently under constructions and they are approaching finacial close. [um] Six, so far there are sixty wind turbines in the Eastern Cape that have been commissioned - the farm which spans 3700 ha - I don't know what [??] it is - will supply 460 000 mwh, enough clean renewable electricity to power [??? thousand] average South Afdrican households, which is obviously very helpful. And [um] yeah that's the - that's wind power.
G3: OK, who's next?

Appendix G: Consent Letter to Parents

27 November 2016

Dear Parent,

My name is Dorian Love, and I am a teacher at Girls' High School. I am currently completing my Masters in Education at the School of Education at the University of the Witwatersrand.

I am doing research on ICT integration in the classroom. My study is titled "The Role Of Knowledge in ICT integration in a Johannesburg private school."

My research involves looking at how teachers are integrating Information & Communication Technologies into their lessons. I will be interviewing teachers to try to understand their attitudes and beliefs around ICT integration in general, and ICT integration in their subject area in particular. I will also be observing a few lessons to see how the subject content affects how ICTs are used. I will not be observing students per se, but obviously students will be involved in the lessons.

The reason why I have chosen your daughter's class is because the teacher has indicated to me that s/he will be using ICTs in a particular way. I was wondering whether you would mind if your daughter was part of any lessons being observed and audio-taped, so that I can analyse the transcript in detail. I would also like to take a few photographs to help contextualize how ICTs are being integrated into the lesson. No faces in any of these photographs will be published so that anonymity will be preserved.

Should you object, your daughter will not be excluded from the lesson, and no data will be collected from her at all. Your child will not be advantaged or disadvantaged in any way. She will be reassured that she can withdraw her permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your daughter's name and identity will be kept confidential at all times through the use of a pseudonym in the transcript of the lesson. Her individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3-5 years after completion of the project, and will be stored securely at the University by the Supervisor of this research.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Dorian Love
45 5th Street
Orange Grove
Johannesburg
leogends@iafrica.com
082 596 3570

Parent's Consent

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: "The Role Of Knowledge in ICT integration in a Johannesburg private school."

I, **_________________________** the parent of **_______________________**

Circle one

Permission to observe my child in class

I agree that my child may be observed in class.
YES/NO

Permission to be audiotaped

I agree that my child may be audiotaped during interview or observations.
YES/NO
I know that the audiotapes will be used for this project only
YES/NO

Permission to be photographed

I agree that my child may be photographed during the study.
YES/NO
I know that I can stop this permission at any time.
YES/NO
I know that the photos will be used for this project only.
YES/NO

Informed Consent

I understand that:

- my daughter's name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- She does not have to answer every question and can withdraw from the study at any time.
- She can ask not to be audiotaped, photographed and/or videotape
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_____________________________ Date___________________________

Appendix H: Consent Letter to Teachers

27 November 2016

Dear Teacher,

As you know, I am completing my Masters in Education in the School of Education at the University of the Witwatersrand. I am doing research on Information and Communication Technologies (ICT) integration in the classroom. The title of my research is "The Role Of Knowledge in ICT integration in a Johannesburg private school."

My research involves looking at how content knowledge in different subjects affects how ICTs are integrated in the classroom. I would like to interview a few teachers in different subject areas about how they view ICTs, and where they can help teach their subject content better, and where they do not. I would then like to observe a few lessons where ICTs are being used, audio-tape these and take a few photographs to help understand how ICTs are being used to mediate content knowledge.

The reason why I have chosen to conduct the study at Girl's High School is because the school is involved in an ICT integration programme and I believe the research could benefit teachers by helping to understand the role played by subject knowledge in driving integration decisions. I was wondering whether you would mind if I could interview you about your thoughts and feelings about this, and perhaps observe a lesson that you give which involves ICT. I would like to audio-tape such a lesson and take a few photographs to help analyse how subject content is mediated by the use of ICTs.

Your name and identity will be kept confidential at all times through the use of a pseudonym, and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study. I would also like to give you the opportunity of reading the research report before it is presented so that you can comment should I misinterpret anything you say. The school and its location will not be revealed so your identity will be totally private. Your face in any of the photographs taken will not be published.

All research data will be destroyed between 3-5 years after completion of the project, and in the interim will be kept secure by the Supervisor at the University.

You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for this study.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,
Dorian Love
45 5th Street
Orange Grove
Johannesburg
leogends@iafrica.com
082 596 3570

Teacher's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: "The Role Of Knowledge in ICT integration in a Johannesburg private school"

I, _________________________ give my consent for the following:

Circle one

Permission to observe you in class
I agree to be observed in class.
YES/NO

Permission to be audiotaped
I agree to be audiotaped during the interview or observation lesson
YES/NO
I know that the audiotapes will be used for this project only
YES/NO

Permission to be interviewed
I would like to be interviewed for this study.
YES/NO
I know that I can stop the interview at any time and don't have to answer all the questions asked.
YES/NO

Permission to be photographed
I agree to be photographed during the study.
YES/NO

I know that I can stop this permission at any time.
YES/NO
I know that the photos will be used for this project only.
YES/NO

Informed Consent

I understand that:

- my name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date____________________________

Appendix I: Consent Letter to Students

27 November 2016

Dear Learner,

I am currently completing a Masters in Education in the School of Education at the University of the Witwatersrand. I am doing research on how ICTs are being used in classrooms to teach different subjects. The title of my research is “The Role Of Knowledge in ICT integration in a Johannesburg private school.”

My research involves interviewing teachers to find out what they think about using ICTs in the classroom, and how they do, or do not use it in their subject discipline. I want to find out if ICTs are used differently in Maths, English or Science, for example. I would like to observe a few lessons to see how ICTs, such as cell-phones, iPads or laptops are being used within lessons.

I was wondering whether you would mind being part of the observation of the lessons. I would be audio-taping the lesson so that I can analyse it in depth afterwards, and taking photographs so that I can understand how the devices are being used in the classroom. I am not observing you; I am interested in how ICTs are used in the lesson. I will be looking at how ICTs are used in the classroom, and how they help in the teaching and learning process.

Any comments you make in the lesson will be recorded and some photographs will be taken of the way ICTs are being used in the lesson. You might appear in these photographs, but no faces will be published.

Remember, this is not a test, it is not for marks and it is voluntary, which means that you don’t have to do it. Also, if you decide halfway through that you prefer to stop, this is completely your choice and will not affect you negatively in any way.

I will not be using your own name but I may make one up so no one can identify you if I do decide to quote anything you said. All information that involves you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3-5 years after I have completed my project.

Your parents have also been given an information sheet and consent form, but at the end of the day it is your decision to join me in the study.

I look forward to working with you!

Please feel free to contact me if you have any questions.

Thank you

Dorian Love
45 5th Street
Orange Grove
Johannesburg
leogends@iafrica.com
082 596 3570

Learner Consent Form

Please fill in the reply slip below if you agree to participate in my study called: “The Role Of Knowledge in ICT integration in a Johannesburg private school”

My name is: ______________________

Circle one

Permission to observe you in class
I agree to be observed in class.
YES/NO

Permission to be audiotaped
I agree to be audiotaped during the interview or observation lesson
YES/NO
I know that the audiotapes will be used for this project only
YES/NO

Permission to be photographed
I agree to be photographed during the study.
YES/NO
I know that I can stop this permission at any time.
YES/NO
I know that the photos will be used for this project only.
YES/NO

Informed Consent
I understand that:

- my name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotaped.
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_______________________________ Date_____________________________

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