CHAPTER 1: The epistemological framework of classroom work and research.

This work is squarely rooted in the words of John Dewey.

"*Understanding has to be in terms of how things work* ***and*** *how to do things. Understanding by its very nature is related to action, just as information by its very nature, is isolated from action or connected with it only here and there by accident."* (Dewey, 1987, p184).

Dewey was a pragmatist, as I am. Pragmatism is a way of thinking in which the value of an idea is determined by whether or not it has any empirical support in the here and now of life (Dousa, 2009). That is, if you think you have an idea that is going to make a difference to the lives of people, get some data to prove it. Empirically supported ideas may then become knowledge and therefore something of value within the social framework in which it was tested, to remain so until debunked by another empirically tested idea; much like the geocentric model of the solar system was replaced by the heliocentric model. Dewey gives a central role to the interaction of one's life experience (background, interests, passions, desires, personality etc. etc.) with one's social framework as the fertile source from which perceptions of new ideas may spring. In so doing, Dewey perceived that generating new knowledge was a creative process and that one's life experience was a tool to be applied to the knowledge creation process (Elkjaer, 2009).

The aim of pragmatism is the seeking of the meaning of phenomena and their consequences in their social framework (Elkjaer, 2009). This meaning is not ascribed by appeal to the dictations of the grand theories of human endeavour (like Marxism, capitalism and the most hubris-clad of all, leadership and academia) but by the everyday 'what if' imaginings of life. 'What if I did that? What may the consequences be?' It is from answering such what if imaginings that Dewey perceived that the development of cognitive processes would be the natural consequence. That is, cognition is the mechanism by which people generate continuity between their experiences of the past and sought experience of the future.

In pragmatism, the central role that the teacher plays in developing cognition is in the use of verbal language (Elkjaer, 2009). It is through verbal language that ideas and understandings are introduced to students and in that very act of communicating, students acquire the tools needed for the bridging of their past and future worlds into the here and now. In doing so, cognitive development occurs as the student resolves and communicates their newly created knowledge about the world.

On the creative process of knowledge generation, counterfactual thinking has been found to play a part in the production of creative thought (Markman, Lindberg, Kray & Galinsky, 2007; Hofstadter, 1985). Indeed, counterfactual thinking is so pervasive that it is regarded as having a central role in human thought and emotion (Epstude & Roese, 2008). It has also been found to improve the accuracy of group decision making by enhancing the discussion of important yet out-of-field information. Such discussion tends to prompt group members to seek and build on each other's ideas in a synergistic manner (Galinsky & Kray, 2004).

Counterfactual thinking is thus logically exemplified by 'What if?' thinking in which alternative futures are imagined from an actual event in the past. Roese (1997) notes that the past factual event is mutated and from which various future imaginary outcomes are formulated. These imaginings may represent two counterfactual mindsets, additive or substrative (Roese & Olson, 1993). Additive mindsets have imaginings like, "If only I taught my students this way, maybe they would have gotten better grades." Subtractive mindsets have imaginings like, "If I only I didn't spend so much time on that topic, maybe they wouldn't have gotten such bad grades." Roese and Olson (1993) noted a distinction in the outcomes of these two mindsets. Subtractive counterfactuals remove only the problematic factor from imaginings to leave the mind analytically focused on solving the problem at hand, i.e. I will take time spent on topic A and shift it to topic B and students should get better grades. Alternatively, additive counterfactuals focus on any number of imaginings that may lead to success should they be implemented, i.e. the additive counterfactual mindset is associated with the more creative alternative imaginings of future outcomes (Markman et al. 2007). These authors indicate that the additive mindset promotes an expansive type of brain activity that broadens conceptual attention, thereby facilitating more fecund imaginings. For example, 'If I present this topic in that manner and get the class to do this activity, then maybe that will also help students gain a deeper conceptual appreciation of the subject.'

The counterfactual mindset is also inherently sceptical about the authority of accepted paradigms (Markman et al., 2007). That is, it is human nature to imagine what the world would be like if… The simple inference being the dominant paradigm may not be as good as it seems to be because alternate realities can be imagined that exist outside the scope of the dominant paradigm. So, the counterfactual mindset is pragmatic. The benefit of this is that counterfactual thinking cancels out the strong human tendency to accept information as knowledge simply because of its coherence with pre-existing ideas (Kray & Galinsky, 2003). But as Höfler (2005) observes, one's ability to imagine alternative futures depends upon a substantive understanding of how that imagined future would work. In the world of the classroom, this means that one needs a firm experiential grip upon the actions that underpin classroom teaching practices before any future imaginings may be entertained for implementation into the professional practice of teaching. (Something that I argue is beyond the ability of academics to fully grasp from literature.)

Jacob (2000) characterises pragmatism (counterfactual) thought as something in which anything and everything is open to questioning. It is pluralist (many claims to knowledge of any phenomena are permitted), fallibilist (anyone's ideas and beliefs are open to challenge and improvement), socially embedded (knowledge is created and evaluated in a social framework), contingent (a change in knowledge can be triggered by new experiences) and antifoundationalist (there is no absolute way to determine the validity of one's belief).

Pragmatism as a method of inquiry into classroom teaching is validated by the very nature of the environment. Because decisions about student learning needs must be made in the absence of complete knowledge about how student learn, pedagogical practices are more a function of intuition, experience, observations and beliefs that have no formal empirical justification. That is, pedagogical practices are not likely the result of rational, impartial and scientifically informed decisions (Daniel & Chew, 2013). Nonetheless, the teacher plays **the** central role in creating the learning environment that classroom students experience and which moulds their own experience in how to learn (Tytler, 2003). Furthermore, the diversity of research lenses that may be brought to bear upon teaching to provide avenues of improved teacher practice preclude any one lens as having supremacy (Tytler, 2003); if for no other reason than such lenses also lack adequate empirical justification to establish supremacy.

Hence, pragmatism can be viewed as metatheory, a counterfactual stance in which the subject of investigation is other theories. As a metatheory, pragmatism permits the recombination of ideas from other theories to form practices that reveal the real world veracity of the assumptions that underpin those theories and the practices they espouse. (Wallis, 2010).

Pragmatic inquiry.

Pragmatism does not make specific demands of the types of methods employed to inquire of the practical value of ideas and the veracity of underlying assumptions. Rather, it takes scientific inquiry as the process by which the practical value of an idea can be empirically investigated (Wallis, 2010). Scientific inquiry possesses seven characteristics (Science Council, 2014):

1, Experiment and/or observation to test hypotheses;

2, objective measurement of data (preferably by the use of mathematical methods);

3, evidence;

4, inductive reasoning by which general rules are drawn from the facts;

5, repetition;

6, critical analysis and;

7, exposure to peers for critical review.

From scientific inquiry, two processes can be applied to determine the 'truthfulness' (i.e. the degree to which the knowledge of inquiry represents reality) of acquired information. These are correspondence (Bunge, 2012) and coherence (Stern, 2004). Briefly, correspondence seeks for distinct mathematical patterns in data that is above and beyond what is randomly (naturally) present. This permits one to infer a causal relationship between the dependent and independent variables. Hence, information is factually (mathematically) true if it 'corresponds' to the facts to which it refers. Coherence also seeks inferential support but not from data: It draws inferential support by the extent to which information 'agrees' or 'disagrees' with pre-existing information; the greater the agreement, the greater the coherence and the more likely a causal relationship exists between the independent and dependent variables.

The importance of correspondence and mathematical methods in the scientific process cannot be underemphasised: It permits the assignment of a numerical value to a variable, relative to a control that can then be compared to other values. Bunge (2012) identifies two mathematical events that must be addressed if a factual status is to be assigned to an observation. First, a sequence of treatment data has its average calculated, including the error of that average and second, the treatment average is compared to its control. If the difference between the experimental and control averages does not encompass a similar error range, a value (like an effect size) may be assigned to that fact. Bunge (2012) notes that the two criteria are that and only that; they are not definitions as they only point to how to find the truth. He gives the analogy that a recipe for a cake is simply the criteria by which a cake may be made, it does not define a cake (nor whether the cake will turn out to be edible). Pragmatically, the value of any fact is only partial because there is always a small chance that what was detected may be in part due to an unaccounted variable(s). Thus, if asked why the effect size is true, reference can be made to a variety of objective mathematical criteria (as distinct from preferred ideological criteria) that gauge the probability of the observation occurring. Evaluating that information for its practical value can then proceed along objective lines of thought.

Coherence, in its broadest terms, indicates that something is 'factual' if it coheres with other beliefs (Stern 2004). For example, if statement A agrees with belief system B, then statement A is true. However, it can then be asked why belief system B is true and so on and so forth, *ad infinitum*. Eventually, an infallible position will be reached, resulting in a statement like, 'that's just what I believe so it has to be true'. To divorce such foundationalism as the justification for claiming statement A is true, Stern (2004) proposes a criteria: If accepting statement A over statement B as true brings more order to one's belief system, statement A should be accepted as true. That is, if it makes sense and brings more clarity (normality) to the world, accept it as fact and use it. Pragmatically, wishful thinking may bring more normality to one's world but not necessarily to others sharing that world; "What is normal for the spider is chaos for the fly" (Morticia Addams). Hence, applying coherence only to assess practical value cannot proceed along objective lines of thought because it is an inherently relativistic process.

To connect information to action and thus promote understanding of professional practice in the classroom, the work in this thesis subjects my metatheory of how students learn in the Bios classroom and its counterfactual case, the Conventional classroom, to correspondence criterion **and** coherence criteria in order to gauge their practical value. It is at this ragged edge of theory and practice, i.e. professional practice, that statistical correlations play their part (Barbey & Patterson, 2011). Statistics permits one to gauge the likelihood of whether or not theory and practice merge to satisfy correspondence and coherence truth criteria. The pivotal assumption about which my metatheory of professional practice differs from conventional professional practice is in the role that the teacher plays in the students' formation of memory in response to classroom learning: Specifically, my metatheory proposes that it is the nature of the engagement between the teacher and students about which students organise the memory of their classroom learning. In action, my metatheory requires that the teacher be an active participant in establishing and sustaining the attentional environment of the classroom if student engagement (and thus learning) is to be sustained. Surely, you have sat through classes in which the presenter's boring presence overrides the information being presented, causing your attention to be anywhere but in the class?

In such cases, Willis (2014) suggests that boredom may have long-reaching consequences for the educational attainment of students. The amygdala, anticipates an unrewarding emotional event with an external source (the teacher), becomes accustomed to this state and consequently, disengages with higher level functioning. In this state, students may become habitually 'zoned out' from their classroom learning. This may create a stressful state in the brain of students, leading to disruptive classroom behaviour and minimal progress in learning.

To this end, by monitoring my own behaviour and that of my students' as I taught my classes, five actions were derived from my metatheory for application in my classroom, the metalesson plan. This states the procedure by which I routinely managed and engaged with students in my classroom. My perspective of the teacher as the focal point of classroom on-goings is diametrical to conventional professional practice, which proposes that it is the students who should place themselves at the centre of classroom learning so that they learn to manage their own learning whilst the teacher manages behaviour of the class. To juxtapose practices:

Students actively construct knowledge in partnership with the teacher according to my metatheory whilst students passively mould knowledge under teacher management according to convention.

The information and action schism.

In hindsight, it seems that the events surrounding my work reflect a conflict between my professional judgement (i.e. my metatheory and metalesson plan for student learning) as a practising classroom teacher and the information possessed by education academics about how classroom teaching practices ought to be conducted. On teacher professional judgement, Allal (2013) qualified it as professional when it was an all things considered judgement. That is, professional judgement is an overarching perspective that is constrained by managerial and other organisational factors of the workplace and which is founded upon workplace experience (i.e. practical knowledge) and formal educational training. Professional judgement is not the same as academic judgement and it is my view that the latter is subordinate to the former; if for no other reason than it deals with the life of real people, not just ideas; ideas whose function ought to be the creation of a whole range of cognitive niches that facilitates creative thought and action in the real world of the classroom (and beyond); not the homogenisation of professional thought according to a preferred ideology. Thus, professional judgement requires of me the integration of a greater number of variables than academic judgment requires. That is, my professional judgement requires me to integrate legal, social, moral, student socioemotional needs and, in my case, religious factors, into how I formulate my classroom actions to maintain each child's access to learning opportunities with the teacher. Additionally, teachers are also expected to engage in reflective practice. This aims to improve teacher professional practice by enhancing pedagogical content knowledge, improving one's effectiveness at positively influencing student learning outcomes and finally, contemplating of the broader social and political systems to influence processes and promote social justice and equity and education opportunity (Thorsen & DeVore, 2013).

Verloop, Van Driel and Meijer (2001) depict the practical knowledge that teachers develop as a consequence of their professional experience as an 'inextricably intertwined' cognitive entity, composed of consciously considered opinions as well as unconscious instinct. To the unconscious working of this entity, Bromme and Tillema (1995) also include images, metaphors and attitudes as cognitive tools that influence the working of practical knowledge. On the developmental sequence of this practical knowledge, Tillema (1995) characterises its progression as novice teachers personalising academic rules learned at university to workplace contexts which then become habits of mind: A mind that does not challenge or experience conflict with new ideas and that only accepts that which supports its beliefs. Regarding the changing of teacher practical knowledge, Tillema (1995) observed that the greater the degree of coherence between teacher practical knowledge and what is presented as professional training, the more likely that training will result in professional learning that may benefit classroom practice. Finally, as Alexander, Shallert and Hare (1991) observe, whether or not something is objectively true or not, one's belief in it being true will make it a part of one's practical knowledge. That is, coherence (not correspondence) is how teachers assess the practical value of information.

Leinhardt, McCarthy Young and Merriman (1995) describe university education as something that focuses on students acquiring a body of knowledge (about teaching) that can be subjected to rational cognitive processes. Conceptually, that body of knowledge is general enough to be applicable to all schools and settings, is formal in that it is organised and available to all and explicit in that its aim is the development of professional knowledge. Learning at university (indeed, even primary and high school students) is thus evidenced by the ability of students to label, codify, describe, analyse and justify their thoughts on the applicability of theories of learning and behaviour as they pertain to the classroom. The assumption is that student teachers will then be able to enter the working classroom, diagnose the learning needs of those students and apply the appropriate measures to ensure that the class progresses in its learning. However, Leinhardt et al. (1995) note that the validity of this assumption is questionable; the development of the cognitive processes as they relate to professional knowledge is different from the performance of practice. As Bunge (1967) observed, (university) theory always needs transformation before it can serve as a platform to guide practical activity. He indicates that this process is not reducible, i.e. it cannot be labelled, codified, described, analysed and justified.

On academic use of information, research is examined foremost for its degree of coherence to pre-existing literature[1]. In this case, it is assumed that the body of academic literature is representative of the real world and so a vicarious appreciation of classroom learning is constructed by academics in order to 'peer through the doors and windows of classrooms'. However, it is axiomatic that one's ability to unpack literature about classroom practices with any degree of fidelity is relative to one's lived experience of classroom teaching. For instance, though I live with many farmers (as family and friends), it is preposterous of me to think that such vicarious knowledge of farming would make me a profitable farmer.

Though correspondence is highly prized by scientists and academics in their pursuit of knowledge, empirical data in and of itself has been reported as an inadequate justification for altering the belief of scientists. Coll and Taylor[2] (2004) reported that scientists were dismissive of empirical data that was not accompanied by a theoretical explanation that was coherent with their personal beliefs. Consequently, scientists and academics in general tend to be isolated from the 'here and now' of teacher-student interactions and compromised in their ability set aside their personal beliefs and engage with empirical data 'at face value' if that data does not

[1] I make this assertion based upon experience in academia, where I wrote grants and reviewed publications.
[2] One of these authors was my co-supervisor.

cohere with their personal beliefs. They thus tend toward an impoverished perspective on what is happening as learning occurs in the real world of the classroom; yet paradoxically, they possess a sophisticated schema of what that reality should be. Nonetheless, information is garnered and subjected to coherence criteria by academics to propel theoretical slants on what teachers should be doing in the classroom and inevitably, *is isolated from action or connected with it only here and there by accident*. All too often, such information is of little practical value to the classroom teacher yet its quantity keeps burgeoning.

Evidence of the little practical value of university theory to the classroom is the ‘Literacy learning in the early years’ (2014) review of teacher education programmes by the Board of Studies Teaching and Education Standards. The report focused on the teaching of reading skills and found that despite research evidence overwhelmingly supporting the use of phonics, not all university graduates or primary school teachers would be able to apply phonics to their classroom practice. The report notes that wide variation on the teaching of phonics existed amongst the providers of tertiary teaching qualifications in NSW. Hence, the report calls for the setting of guidelines on what is essential learning about phonics at university and also for an appropriate balance of theory and practice in learning to be a teacher. The Australian newspaper (Ferrari, 2015) reported that The NSW Minister for Education, Mr. Adrian Piccoli, laid this state of affairs squarely at the feet of universities by stating in The Australian newspaper: “*Universities have this attitude that nobody should tell them what to do and who to enrol. ... They enrol students on the understanding they will teach those students how to be a good school teacher and it lets down schools and it lets down those students if they don’t deliver that.*”[3] The article also noted NSW universities were reluctant to cooperate with this review into their practices.

[3] They also reject students if said student is not to their preference.

Leinhardt et al. (1995) describe the difference in professional knowledge gained from university and practical knowledge gained from work experience. The former tends to be declarative (stating facts and figures), abstract (focusing on theories and philosophies of education) and conceptual (identifying aesthetic and developmental trajectories of theories). Practical knowledge tends to be procedural (how to do things), specific (what can I do to stop the class talking?) and pragmatic (how can I best illustrate this idea with the resources at-hand?). However, all the university education in the world cannot prepare a student teacher for the spontaneity or idiosyncrasies of the workplace (Walkington, 2010).

Loughran (2006) suggests that the locus of difference between academic knowledge and practical teacher knowledge may reside in how each thinks of students. Academics think of students in classrooms as single entities whilst teachers think of the classroom as a single entity. The lack of professional classroom experience probably leads academics to expect that theory is simply extrapolated in to classroom teaching practices so every single child benefits equally from whatever theory is the flavour of the moment, independent of context; In which case academics consider teachers and students as automatons to implement theories that have little (if any) pragmatic value. There is also a time element associated with the locus of the single entity: As a teacher, I simply do not have the time available to focus on every individual student. To do so would be to deliberately exclude the other 20-plus students in my classroom, which would be professionally negligent. Hence, as a teacher I need to focus on the learning needs of the whole class as the single entity for which I am professionally responsible. And as there is no unified model of human learning that has been empirically verified across the global contexts in which student learning occurs, it is my professional judgement borne of life experience and intellectual creativity that is the arbiter of what is in the best interest of student learning needs in my classrooms.

The paragon of unconnected academic information that pervades teaching literature is 'The Unified Learning Model: How motivation, cognitive, and neurobiological science inform best teaching practice' by Shell et al. (2010). The preface states, "To the best of our knowledge, we are able to account for *all* the known *data* about learning." Yet no account of Hattie's 2009 metareview of educational interventions is attempted. Nor is any accounting offered of any empirical classroom learning data indicating that though teacher effectiveness is only a third of student effectiveness in accounting for student exam scores, teacher effectiveness has greater leverage in influencing the exam outcomes of the whole class (e.g. Slater, Davies & Burgess, 2012). And what of these Authors' corroboration that observed teacher characteristics provided minimal explanation of estimated teacher effectiveness in exam scores? On page 1, the ULM authors go on to state, "Hence, all current models and theories of learning, teaching and instruction can be subsumed within the ULM." Even more, on page 202 it is stated, "…the ULM ultimately could be developed into a fully realized unified theory of cognition." Surely this statement needs to be balanced by the radical interactivity that memory displays in response to the plethora of endogenous and exogenous stimuli constantly bombarding the human mind? (Sutton, 2011). Interactions that may occur over different timescales and in ways not imagined, let alone modelled in the laboratory. Further, there is no account of the default mode of brain activity (Greicius, Krasnow, Reiss & Menon, 2003) or autobiographical knowledge construction processes (Conway & Pleydell-Pearce, 2000). Additionally, the authors of the ULM make no account of what cognition is and how it relates to language, that medium by which the vast majority of student learning occurs. Is it words that the brain uses to think or do words represent the means by which thinking is communicated to others? (Perlovsky, 2009). Does the brain really think in a universal mentalese language? (Pinker, 1995). Is the meaning of a word automatically carried with the sound of the word? (Chomsky, 2011). How does the acquisition of language influence thinking? (Gentner & Christie, 2010). It would seem that the authors of the ULM made a political decision to cherry pick scientific literature to suit their own coherence agenda. Science at its best? Aside from these and other a bombastic statements on the merits of the ULM, none of these authors appear to have had substantial work experience as high school classroom teachers (a classical information versus understanding dichotomy).

To highlight the isolation of the ULM from action, its authors state that the ULM is an educational theory based upon neural mechanisms (not classroom mechanisms). However, the understanding of these neural mechanisms was derived largely from *in vitro* and *in vivo* methods. Because this information can be applied *in silico* to generate neurocognitive computational models of human thinking, the authors anthropomorphise the ULM in an attempt to give it 'real world' credibility without actually applying it to the real world. The naiveté of the ULM as a real-world, classroom-ready model of best teaching practice is illustrated by Brooks and Shells' (2006) precursor paper. In this publication, the role of the classroom teacher is to insert 'motivation' into one of four working memory slots so that it acts to facilitate student learning. As a classroom teacher, it would be wonderful if all I had to do was walk to the self-help book section, find the appropriate motivational cassette and slip in into the mind of my students. Voila, instantly motivated students! Unfortunately and for the betterment of human culture, the psyche of humans is not as simple as Brooks and Shell perceive it to be.

The ULM is thus an idiosyncratic, theoretical laminate that has been transposed on to the human mind; A mind that has evolved through tens of thousands of years of natural selection and whose workings is still largely unknown. It has been formulated by cherry picking from the scientific literature those ideas that suit the autobiographical memory construction needs of the authors. So, the ULM is, in my professional judgement, merely of professional interest; if for no other reason than it provides a satisfactory (nonetheless speculative) overview of how some but not all 256-plus different memory systems (Tulving, 2007) **may** function and contribute to learning. To wit, no mention of relational memory (Konkel & Cohen, 2009) exists in the ULM!

Another example of understanding without action is Slavich and Zimbardo's (2012) 'Transformational Teaching'. The theorising in this literature is, commendably, meta-theoretical in nature: It takes several individual theoretical perspectives and reduces these to a series of actions that a teacher may implement in the classroom to promote improved student learning. Most importantly, they incorporate a spiritual element to the work that teachers ought to address in their professional practice to help students build resilience and overcome life's obstacles. To give their work professional credence in the classroom, it would have been a worthwhile activity for the authors to have implemented their metatheory in high school classrooms for a couple of years. Consequently, they could have empirically determined whether or not their proposed actions had any practical value to the learning of students in the classroom. Alas, they too are not classroom teachers and the lack of empirically tested advice in this literature means it too, by my professional judgement, is merely of professional interest.

A different take on understanding without action is the work of Kent (2013). She offers many observations of how her own professional practice coheres with best teaching practice according to neurobiological concepts. Unfortunately, she did not provide any empirical assessment to support her assertion that her professional practice led to improved student learning. Clearly, she felt a degree of connection and emotional gratification with the students she taught, with which I can professionally empathise (because I too am a teacher acting on similar neurobiological concepts). But is that as good as it gets? What of the empirical investigation of her work and thus of its practical value beyond her own classroom? Is there some more fundamental and important fact to extract from emotional gratification that may serve as something generalizable across professional contexts, as well as academic contexts? My thesis argues that yes there is.

The difference between theoretical and practical research.

In his '*Rebooting the Ed.D.'* essay, published in the Harvard Educational Review, Wergin (2011), makes analogous observations of the difference between academic (Ph.D.) research and professional (Ed.D., M.D. and J.D.) research. He notes that as capstone qualifications in their respective fields, the Ed.D. needs greater differentiation from the Ph.D. in order to prevent it being perceived as a diet flavour of the Ph.D. Taylor and Maxwell (2004) make similar calls and indeed restructured their Ed.D. at the UNE to accomplish this end. Wergin (2011) notes that Ph.D. research is that which upholds the intellectual tradition of that discipline. To achieve this, all variables are tightly controlled and validated instruments employed to dissect the phenomena under investigation. Hence, the explanation (theory) of phenomena can proceed in an incremental manner to steadily build ever more comprehensive theories of phenomena that are generalizable (theoretically) across all contexts, the *raison d'être* of Ph.D. research. Barsalou, Breazeal and Smith (2007) note that such a 'divide and conquer' mentality is the typical approach taken to the scientific study of human cognition and that despite the wealth of literature, it does not necessarily follow that a coherent account of human cognition will arise; the reason being that cognition is a multifaceted process dependent upon the context and other processes not accounted for in the experimental paradigm employed in the research laboratory. That is, laboratory-based research lacks the ecological validity needed to grasp the workings of the human mind as it is doing its thing in its habitat.

From this 'theory for theories sake' perspective, the application of theory (as occurs in professional contexts) is seen to bear little scholarly rigor. That is, the Platonic/Aristotelian heritage of university thought carries an implied belief system that favours abstract and hypothetical events over the actual use of the information (Aristotle, 1961). Consequently, the application of theory is perceived by the Ph.D. guardians of the Doctoral honorific to be a routine matter, subordinate to the colossally creative endeavour of generating theoretical explanations for as yet unsolved phenomena (Levinson & Thomas, 2005). But this Ph.D. perception may also result from an unconscious bias. Taylor and Maxwell[4] (2004) observe that the examination of Ed.D. research should involve academic as well as professional input. Though such was the policy for their Ed.D. at the UNE, these authors acknowledged there was a bias toward academic examiners. Further, academia tends to not waste energy in adequately describing and expounding upon the complexity of applying theory to the real world or indeed, challenge itself on its assumption that the application of theory is just a matter of routine (Levinson & Thomas, 2005).

In general, the information derived from theory is myopic as to how it is applicable to the real word. Daniel and Chew (2013) describe how research into teaching and learning is driven by theory and basic research in cognitive psychology. Such research argues for the application of principles related to working memory and attention (amongst others) into classroom practices. However, as these studies are performed under well controlled conditions, they are therefore limited in their generalisability to the uncontrolled conditions in the real classroom. As such research settings do not possess the ecological validity of the real classroom, the result is often trite recommendations of what teachers should be doing, e.g. Shell et al. (2010) and Dunlosky, Rawson, Marsh, Nathan and Willingham (2013). Daniel and Chew (2013) then describe how researchers view the translation of information into classroom practices; that it is one big jigsaw puzzle to be stitched together by the teacher, focusing on the largest and most complex piece, with all the smaller pieces naturally falling into place around that central, most important piece of the puzzle (but most important to whom?). The authors note that though one piece of the puzzle may be well characterised, e.g. the importance of working memory and attention as they contribute to academic success, it is the interactivity of all the pieces of the puzzle that is important in the classroom. Specifically, how the teacher perceives the variables influencing

[4] Again, one of these authors was my co-supervisor.

the learning occurring in that particular classroom, how these variables are manipulated in the mind of the teacher and then translated into action to promote classroom learning; a process that may differ from class to class. Finally, there is no theoretical framework to guide the development and/or evaluation of pedagogical methods (Daniel & Chew, 2013). Let this point be emphasised:

"In the deepest sense, we do not know how information is processed, stored, or recalled; how motor commands emerge and become effective; how we experience the sensory world; how we think or feel or empathize." (Institute of Medicine, 2008, p.5).

So, how can there be a 'realistic' theoretical framework to evaluate pedagogical practices if we know so little about the workings of the mind? Ipso facto, professional practice is not reducible to a single theoretical perspective.

This lack of knowledge is only accentuated when placed into the context of the classroom. Nonetheless, Daniel and Chew (2013) note that for any teaching method to be effective, it must mesh with the cognitive architecture of the human mind; the absence of such grounding being a presage to its failure. And in the light of such deep, cosmic ignorance about the working of the human mind, surely correspondence is the pre-eminent mechanism by which the real world value of pedagogical methods are evaluated (not one's wishful opinion as it pertains to whatever flavour ideology one is biased)? So, how can the Ph.D. of academia (that doyen of theory) possibly serve as adequate experience of '*understanding in action*' if one's experience of the classroom is vicariously derived from publications? (A matter acknowledged by Taylor and Maxwell (2004) in their assessment policy for Ed.D. examinations but forgotten about in practice.)

At this point, I would like to highlight an information and knowledge schism. My ex-cosupervisor published information that a bias towards the academic doctorate examination of professional doctorates exists in his Faculty of Education and that coherence (with its wishful thinking pitfalls) may precede correspondence as a truth criteria (even in that bastion of objectivity, science) should it conflict with personal beliefs. Alternatively, my ex-principal supervisor published work calling for greater ecological validity (i.e. research in the classroom by educators as teaching is occurring) when exploring multifaceted and dynamic theoretical constructs, like self-efficacy and engagement (Phan, 2012). Nonetheless, the possession of such information was not put into action in dealings with my work. This represents a 'do as I say but don't do as I do' schism. Simply, this thesis did not cohere with the personal beliefs of my co-supervisor and so it was treated differently and unfairly[5]. In the classroom, the keen sense of justice that all students possess seeks out and argues such unfairness with much glee. Consequently, there is constant monitoring and critical reflection of myself as I am teaching to ensure that words and actions gel together to ensure that classroom on-goings are fair to everyone, not just my perceptions of what is fair. Who is monitoring the academics?

Professional Ed.D. research is very much about the application of theory that is situated in the professional practice of the classroom teacher. In professional settings, Wergin (2011) notes that discipline specific theory is something that is always unconfirmed and poorly generalizable across different contexts. He describes how physicians do not apply the latest theory to their professional practice unless and until they have had the opportunity to explore that theory with their peers in the context of their professional practice. Even then, that theory may or may not change professional practice.

On the importance of context for the application of theory, Levinson and Thomas (2005) note that everyday thinking about a problem is intimately intertwined with the context in which the

[5] As Pinker states, "The evaluation of ideas also must be wretched away from the mindset of authority: department chairs can demand larger offices or higher salaries but not that their colleagues and students acquiesce to their theories." (Pinker, 2010, p.8998).

problem is encountered. They give as examples how a comprehensive theoretical knowledge of radio waves will not suffice in the making of a radio, just as a comprehensive theoretical knowledge of the mathematics of Maxwell's electromagnetic theory will not result in a theoretical physicist engineering a linear induction motor. These theoretical understandings must be brought to bear in a context: For it is in the context that solutions to problems are formulated and for which the solutions continue to refine the problem as the process of being creative with theory unfolds. Regarding this creative process, Staudenmaier (1985) observed that theory (scientific ideas) must be appropriated and mutated to serve the needs of the context in which the theory is to be applied. That is, theory must be actively sought and used in contexts (environments) where it undergoes a process of natural selection; if the theory is fit in that context, it will survive and become knowledge in that social framework. To emphasise the point, theory must be put into action if that theory is to be proven to be practically useful, otherwise the odds are that theory is nothing but blue sky mining.

A critical skill in the contextualisation of theory is reflection, i.e. asking oneself what it is that needs to be done to get something to work and/or why something isn't working. Dewey (1933), who Thorsen and DeVore (2013) described as the father of reflection in the educational world, described reflective teachers as those who are impassioned, unbiased and scholarly in the pursuit of their profession. Schön (1992) identifies three levels of reflection through which a teacher may cultivate their reflective practice; reflection *in* action, reflection *on* action and reflection *for* action that represent a progression in reflective practice. One understanding of this progression is that reflection *in* action requires the teacher to observe oneself as one is teaching, to then think back about the course of action taken and explore alternative actions (reflection on action) and finally, to formulate different modes of action so that past events do not re-occur or are refined to generate greater student learning (reflection for action).

Wergin (2011) borrows from the work of Schön (1983 & 1987) to give perspective to context and the types of research, i.e. reflection that may be engaged with in professional settings. In professional practice (e.g., teaching in the classroom), there exists the high hard ground (where it is easy to walk and navigate around obstacles) that overlooks the swampy lowlands (where it's difficult to see obstacles let alone navigate around them). The teacher may engage with high ground problems, like obstacles to the whole school use of information and communication technology. In this case, technical rationality, the application of theory and models, is applied in an attempt to successfully formulate and manage the process. Ph.D. research may even evolve out of this effort, like investigating whether or not students may prefer tablets over laptops to aid their learning and then using that to develop ICT policy (even though that preference may not manifest as improved learning by students). Alternatively, in the swampy lowlands of the classroom, the teacher may engage with matters of more human and thus, important concern; like how to motivate the class to take an interest in the lesson so that prior learning is more effectively established in their minds for later use in learning endeavours. In this case, the problem is less clear-cut because of the complexity and variability of human nature. Consequently, the application of technical rationality is of limited use in the classroom of professional research: It must be supplemented with professional judgement informed by the teacher's own pragmatic assessment of theory.

It is in this blended environment, in which theory contributes potential solutions to problems in the swampy lowland of the classroom but which is itself subordinate to the professional judgement of the teacher, where professional Doctoral research resides. As a capstone qualification, the Ph.D. demand for theoretical rigor is almost a cliff too steep when demanded of the Ed.D in the swampy lowlands. To climb this cliff, Wergin (2011) proposes that to be equal in rigor but different in substance, Ed.D. research ought to apply critical reflection to the professional practice of oneself and one's peers via a stringent and systematic (i.e. scientific) inquiry process. In this manner, best practice co-evolves within the professional context.

On critical reflection, Wergin (2011) is calling for teachers in the swampy lowlands to think about their personal theories and assumptions that underpin their actions in the classroom. In the classroom, learning is scaffolded by the teacher to facilitate the students' construction of and progression of knowledge from basic understandings to more elaborate understandings. It is the teacher's professional practice, that cognitive structure according to which teachers scaffold their students' learning (i.e., their lesson plan as it consciously or unconsciously unfolds during the lesson), which was critically reflected upon in my work: The actions underpinning the older, conventional lesson plan of my own and my peers' classroom practice was contrasted against the new set of assumption of my metalesson plan and empirically investigated. Hence, by bringing forth intuitive knowledge of student learning, gained from classroom experience, i.e. knowledge in action, dialogue with one's peers will be stimulated and a shared metatheory of practice may co-evolve. The benefits to this are two-fold: First, theory that has real-world utility could be identified and built upon in the real world and second, ideas could be imported from other disciplines that may provide a different perspective or even world-changing view on student learning, but which would otherwise remain outside the intellectual scope of any one theoretical perspective.

On the magic that is human cognition, Barsalou et al. (2007) indicate that the individual pieces of knowledge that science extracts from its experiments need to be put back together in a context to make sure that it actually works as a whole. Indeed, these authors call for researchers that study human cognition to be more holistic in their efforts; namely to investigate how non-cognitive aspects like affect effects the integration of individual cognitive processes and the developmental trajectory of cognition in social and situated action types of settings (i.e. the classroom). It is this reconstructing of scientific knowledge in the natural environment of the classroom that is, logically, at the heart of professional practice. And it is this setting that differentiates academic (Ph.D.) research from professional (Ed.D.) research.[6]

The words of Prof. Kelly Tremblay of Speech and Hearing Sciences at the University of Washington most accurately depict the border that distinguishes academic and professional judgment. On the use of auditory brain training software, which aims to restore the aging brains ability to distinguish sounds, she states, "I don't think we have evidence at this point to state that this will help everybody, so as a scientist I can't endorse it *(exercising academic judgement)*. But as a clinician (*exercising professional judgement*[7]), I think that if somebody feels they are gaining benefits from it, and it motivates them to work with their auditory system and becomes a better listener, then I would encourage that." (Tremblay, 2015, p38, as cited in Mackenzie, 2015). This latter state is even more justifiable when it is supported by empirical evidence that meet academic criteria.

The classroom workplace and education theory.

This work took a pragmatic (atheoretical) view to the professional practice of myself and that of my peers to develop a metatheory of practice. That an atheoretical view is valid one in my workplace was affirmed at a staff meeting when all teachers agreed with the statement that the practice of teaching requires skills and knowledge beyond what one gained from their university education and that the myriad of theories learned at university were basically irrelevant to how they do their job as a teacher. This absence of a scientific (i.e. theoretical) foundation is a

[6] Let me emphasise this point: I have formulated, *a priori*, a pedagogical plan by extracting fragments of knowledge from many fields of scientific endeavour; relative to my scientific background and as it coheres to my observations of student behaviour and learning in my school. In my profession, I reconstruct knowledge (according to the professional need to be as inclusive as possible of the learning needs of ALL children) that science has acquired by decomposing natural processes according to some experimental paradigm or other under artificial laboratory conditions, the profession of scientists and academics. The real world value of the intersection of these two professions can only be fairly gauged by a means that is independent of the bias that coherence may introduce into one's thoughts. It is possible that what is coherent in my professional judgement may contradict your coherence criteria, something that is entirely relative to your social context. So, set aside coherence and let the statistics be the arbiter of the real world value of my efforts and thus let it be something to reflect upon for how your scientific and academic coherence criteria may not reflect the real world.

[7] Author italics.

characteristic of my workplace (and also of other teaching workplaces, as revealed through professional conversations with colleagues).

This is not a new observation. Desforges (1995) explored this 20 years ago. In asking the question, 'How does *teaching* (my italics) experience affect theoretical knowledge for teaching?', he developed a perspective of teacher knowledge as something that is atheoretical in nature, that is intimately coupled to beliefs about teaching derived from school and classroom contexts, that is sustained over decades of practice, that is not likely to be questioned by the teacher on its veracity and which, on the whole, results in teachers becoming short sighted in how their own practice may or may not be facilitating student learning. Simply, experience of teaching does not affect the theoretical knowledge of teaching. Experience of teaching provides a platform from which a teacher can deduce pragmatic solutions to classroom events as they unfold, that may or may not be best teaching practice but which, at the end of the work day, provides a mechanism for teachers to keep on doing the job. In this mode of professional practice, the focus of the teacher was (and still is!) the maintenance of a smooth running classroom, characterised by student discipline in acquiescing to the teachers' expectations of how students should behave in the class with student attention being focused unwaveringly on the task at-hand. So, nothing much has changed since I was a high school student some 35 years ago.

In Minter's (2011) essay on the 'Learning Theory Jungle', 27 learning theories/models of pedagogy and andragogy were identified. So, which theory on the global academic market is best placed for a teacher to implement in the classroom so that all children have equal access to learning opportunities, given they are all more or less compatible and competitive with each other? (Illeris, 2009). Logically, Minter (2011) observed that discussions of professional practice usually subscribe (pragmatically) to a mixed model of theory and educational practice for which the theoretical and/or research underpinnings remain largely beyond the consciousness of teachers. Hence, Minter's observation that instructional practices are idiosyncratic models of what effective teaching and learning entails.

So, it is my professional judgement that theory in general provides little more than the raw information upon which professional judgement is exercised. Following is a list of classroom observations and theories that were appropriated and subjected to the intellectual tools of my life experience for adaptation to the context of my workplace. Of these, only one (working memory) has any explicit, conscious, cognitive role in my professional practice. The rest remain largely in my unconscious mind, forming a structure against which intuition is exercised as I do my job as a classroom teacher. From this fecund interaction, I developed, *a priori*, my meta-theory of practice. I cannot provide a conscious rationale as to why I valued these ideas nor how they influenced my perceptions and thinking; it is simply my professional judgement that these ideas had immediate relevance to the student behaviour that I observed in the classroom and that they also offered a creative alternative to what I, the teacher, can do in the classroom to improve student learning, in the here and now of the lesson.

1. **The genomic action potential**. Clayton (2000) created this electrophysiological analogy to describe the effect that novel song had upon immediate early gene expression in the brain of zebra finches. Subsequently, Clayton (2013) noted that the pattern of genes expressed is not conserved, i.e. different genes may be expressed at different times and in response to different stimuli, and that once habituated to the song, early gene expression was suppressed. As a classroom teacher, I find a striking resemblance in the way teenage students chatter amongst each other and the chatter of birds, both of which seem to be the bouncing back and forth nothing more than similar sounds. *Perhaps if I allow as much classroom chatter and am a part of the chatter, would I will help activate gene expression that may aid memory formation and cognitive development of my students*?

2. **Neural endophenotypes**. Allelic variation in genes can have a major influence on how that gene functions. Whelan et al. (2012) describe how allelic variation in the norepinephrine transporter gene was related to inhibition control and illicit drug use. They also observed that differential functioning of several subcortical neural networks was associated with success or failure in inhibition tests and that the associated lack of impulse control in teenage brains may reflect neurodevelopmental processes. *Perhaps if I as the teacher alter my expectation of what normal teenage behaviour is and work* ***with*** *the behaviour that I have of the students, would students be more engaged with the classroom and less with oneself?*
3. **Neuroplasticity**. The brain has the ability to rewire itself as it acquires new experiences (Doidge, 2007). *As the teacher in control of the experiences that students have in the classroom, perhaps letting students have more say in how the classroom works will result in their brains more favourably rewiring itself?*
4. **Epigenetics**. Environmental events can cause chromatin to be methylated, subsequently altering how that genetic material functions (Graff and Mansuy, 2008). Such epigenetic modifications help regulate synaptic plasticity and so have an influence on behaviour, learning and cognitive functions. *Perhaps I can manage the classroom environment to induce favourable methylations of chromatin that will be of benefit to the learning of the student in my classrooms?*
5. **Working memory**. Where is it that all these memories come from and how do they interact to make new ideas from the same memories? *If working memory has two primary inputs, speech and text* (Baddeley, 2007) *and text must be converted to sounds in the brain before it can be understood, and working memory is where incoming information is given context and meaning, and from where actions originate, perhaps a speech rich classroom will help students develop better memories of their classroom learning experiences?*

6. **Mirror neurons**. Humans, being genetically very similar to chimpanzees, must also have a mirror neuron system (Rizzolatti and Craighero, 2004). *Perhaps if I mirror the students, they will come to emulate my thinking processes and learn science just that bit better than their peers?*
7. **Linguistics**. Words, how they are spoken and how they are ordered, can have a major and long lasting influence upon how one thinks. For me, Oscar Wilde is a major influence on how I sometimes think and communicate about things. "*How would Wilde think about this? Or what would this piece of text sound like if it was written by Wilde*?"
8. **The knowledge instinct**. I have an innate push to bring together information to create something new and give it structure to share with people. This is known as the knowledge instinct and is something that I see nearly every lesson (Perlovsky, 2009). Central to this instinct is the use of language but for which very little is known about how the brain uses it to think and create knowledge. My PhD supervisor, Prof. Murray Fraser, was around when the genetic code was discovered and met many of those people. He shared these experiences and that was a real source of motivation, to be somehow yet distantly connected with history. *Perhaps by giving students comparable creative latitude in their ideas and words in the classroom like I had during my Ph.D., their knowledge instinct will also strive to create order and share something bigger with people in their future?*
9. **Quantum entanglement**. The state of one photon can affect the state of another photon without any physical connection between those photons (Georgescu, 2013), i.e. Einstein's spooky action at a distance). Perhaps, it's possible that some weird entanglement may occur between how I think and how my students learn?
10. **Reflection on why I found high school boring**. High school was boring because most teachers did their job but didn't really enjoy doing their job. The few that did (my maths and physics teachers) were able to generate in me a feeling that they were encouraging me to be

courageous in my attempts to understand what the hell this stuff was about. *Perhaps really enjoying my job as a teacher will have the same effect on my students as my maths and physics teachers had on me*?

11. **Sound is more meaningful than sight**. "*If I had to lose either my sight or hearing, which would I chose to lose*?" It would be sight because if I only had myself to talk to I would drive myself insane and I would go insane if I could not hear the laughter on my children.
12. **Reflections on why I found my university teaching qualification a waste of time.** *"Why aren't I being taught anything about memory and how we learn?"* Because my lecturers do not have a scientific mind and do not use mathematics in their own research work.
13. **Plus other factors** that are meaningful to me but which will seem contradictory and possibly ridiculous to others; like my belief in the soul and my belief in the multiverse.

Mayer (1999) observed that though the experiences (and ideas) teachers have may be far removed from their workplace, they nonetheless shape their beliefs about teaching. Additionally, Nias (1996) noted that a teacher's self-image is more important to them in their job than it is in other jobs, like science, where one's identity can be separated from the practice of the job. That is, in teaching one is always being observed and at a distance; by students, colleagues, by parents and by oneself in asking how one can improve. Because teaching is so personal, improving one's professional practice is not as easy as simply switching to a new experimental system, adding some new technology for greater experimental pizazz and milking that for its worth before repeating the whole process over again. The classroom is the system, the teacher is the technology and human nature of children is notoriously difficult to analyse and change.

The context.

As a practising teacher in a Catholic school with about 2784 hours[8] of face-to-face classroom contact with students that ranged in age from 12 to 18, and a Ph.D. qualified cell biologist/biochemist with post-Doctoral neuroscience work experience, I reacted against conventional teaching practice in my school and exercised my professional judgement. I **appropriated** scientific ideas and mutated them to derive a pragmatic and scientifically logical metatheory that bridges scientific ideas with the actions of classroom teaching. I formulated, *a priori*, my metalesson plan which placed the teacher (myself) standing in front of the students as the central factor about which students organise the memory of their classroom learning; Specifically, that how I use language to do my work is the single most important variable that I can manipulate to do a better job of promoting student learning. I then implemented this metalesson plan in to my classroom practice for another 2784 hours of face-to-face contact, collected the data and analysed the data with conventional statistical methods at the 95% confidence interval. Simply, I was able to assign statistically significant effect sizes to classroom learning variables and thus infer the causal involvement of working memory processes in response to my metatheory of student learning, relative to control groups. Coherence of this quantitative data with current scientific literature was then used to explain and reconcile the differences in student learning responses.

As this point, the metatheory behind this work must be differentiated from cognitive load theory. Both of these focus upon working memory as that key cognitive process underpinning learning and both aim to make learning easier and better; the former gives the teacher a central role in the process of memory formation as learning is occurring via the use of language whilst

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[8] 50 min per class x 7 classes per fortnight x 5 fortnights per term x 4 terms per year/ 60 min =116 hours per annum per year level. Year levels include Yr. 7, 8, 9, 10, 11 and 12 per annum. 116 hours per annum x 6 Year levels per annum =702 hours of face-to-face contact teaching time per teaching year. Four years of conventional teaching practice x 702 hours per annum = 2784 hours of face-to-face teaching experience, less time lost for assemblies and other such unplanned for events that contribute to the school learning experience.

the latter dictates how learning materials should be designed and used to facilitate memory formation. Cognitive load theory is described by van Merriënboer and Sweller (2010) as being composed of three variables that interact during learning. These are germane load, intrinsic load and extrinsic load. Extrinsic load describes the extent to which the teacher adapts learning resources to reduce the demand placed upon students' cognitive processes. Professionally speaking, design a task that is easy to understand and the students will be able to dedicate more effort to their learning than understanding what it is that they're supposed to be learning. van Merriënboer and Sweller (2010) provide five illustrations of how this may be accomplished. These focus primarily upon the use of verbal exchanges between the teacher and student as the principal mechanism of learning; ask students to …, let students criticise …, provide student with instructions… and give students spoken explanations. The last of these five recommendations is to not use verbal exchanges when using a diagram. Simply, the teacher needs to adjust learning materials so that they focus on one of the two routes of information access to working memory, with a distinct bias towards verbal over text.

Intrinsic load describes the interaction between the materials being used to support learning and the cognitive resources 'intrinsically' available to support student learning of that material. That is, one's prior learning of that material will reduce the cognitive load associated with processing the learning of the resource, leading to deeper and better learning of that material. Because one's cognitive resources are so idiosyncratic, manipulation of these factors is effectively beyond the control of the teacher (van Merriënboer & Sweller, 2005). Nonetheless, van Merriënboer and Sweller (2010) make the recommendation to scaffold the learning process from easier to harder and from general to specific as learning progresses. On the final variable, germane load, the introduction of variability into the learning process provides a range of stimuli with which any individual learner may, idiosyncratically, call upon as being more favourable to their learning needs. That is, increase the likelihood of an event being encountered by the student that is within their zone of proximal development and which will serve as some form of prior learning; therefore learning of and application of that new learning will, with greater likelihood, be improved.

Cognitive load theory does not explicitly address how teacher language can be manipulated by the teacher to ease the cognitive load experienced by students as they encounter new learning material. It does focus upon language as a, if not the, central means by which learning can be made easier and more effective; but that focus is on instruction and not engagement with the personhood of the student. Cognitive load theory does not require of the teacher to reflect upon their own knowledge construction processes and use that to benefit the learning of one's students. Cognitive load theory does not offer any mechanism to tap into autobiographical knowledge construction processes nor does it exploit the means by which memory transitions itself from remembering to knowing; an event that is at the beating heart of working memory processes. Cognitive load theory assumes that individual knowledge construction processes are rational and that teaching in a manner that is rational relative to the cognitive architecture of the mind will generically result in better knowledge construction processes and therefore better student learning. How students learn is not rational; successive classes will react differently to the same learning material and ask questions that are so wildly different that I frequently ask myself, "What was going on in that kids head to come up with such an insightful question or bizarre association?" As the constant variable in the process of student learning, it is axiomatic that how I use language to engage student minds must somehow contribute to the generation of those insightful questions and bizarre associations.

Understanding mapped backwards to information.

To shed light on the extent to which my metalesson plan may have influenced working memory processes, I sought comment from Prof. Alan Baddeley. He responded, "*While it would be nice to attribute your observations to the effects on working memory, I suspect that they are more* *social and personal in nature. As a good teacher you are able to explain to them why the material they are encountering is interesting, and to trust you as someone who can explain it. In short, although working memory is involved in concentration, the reason for their concentrating on the class rather than what they are going to do that evening stems from your personal qualities."* Prof. Baddeley's response (Personal communication, 21st November, 2013), to my query hit the nail on the head: The single personal quality that I adjusted was myself and how I do my job as a classroom teacher in the professional workplace of my School. My explanation focused upon the episodic element of the multicomponent model of working memory: Specifically, I figured that it was the nature of the episodic engagement between the teacher and students about which the student mind organises its learning and that this was the origin of the patterns in the observational and quantitative data.

Subsequent personal communication with Dr. Suncica Lah (26th August, 2014) about her publication exploring episodic future thinking supports my induction of the importance of episodic engagement with students. Indeed, it is this future thinking, i.e. predictive, aspect of episodic memory that is a key tenet of my thesis. So, most pertinent was her finding that,

"*… participants who recalled more episodic details had better developed relational memory and executive skills*." (Gott and Lah, 2014, p637).

In response to my question, "*Is it possible that by developing the episodic engagements that I have as a teacher with students that the effects described above could actually manifest in improved student learning and behaviour in class? As a teacher, the answer is a most definite yes. But what is your opinion as an academic?*"

Dr. Lah responded, *"As to answering your question, I would genuinely hope that this would be the case. However, at this stage it is unclear whether an increase in recall of episodic details* *of learning also enhances students learning capacity (i.e., underlying cognitive skills) and has a positive effect on behavior."*

Dr. Lah's response is most noteworthy for two reasons. First, Dr. Lah and I arrived at the similar intellectual destinations: She did it from the high ground by applying scientifically valid and reliable instruments whereas I did it from the swampy lowlands with observations, statistics, critical analysis of the scientific construct of the multicomponent model of working memory and critical reflection upon my actions in the classroom. Second, she depicts the difference between academic and professional judgement: Academically, Dr. Lah is peering into the doors and windows of classrooms via theoretical constructs and scientific instruments that aim to explain the human mind, all the while hoping that her work has a place in the classroom. It is my professional judgement that turns Dr. Lah's academic hope into professional practice.

In closing the preface, I again refer to the words of John Dewey:

"The distinction between knowledge, information and understanding is **not a complicated or *philosophical matter***. *An individual* (academic) *may know all about the structure of an automobile, may be able to name all the parts of the machine and tell what they are there for. But he does not understand the machine (*classroom*) unless he knows how it works and how to work it;* ***and, if it doesn't work right, what to do in order to make it work right."*** (Dewey, 1987, p184). This is what I did ***to make it work right***.

CHAPTER 2: Introduction.

The Bios (basic input output system) pedagogy emerged as a synthesis of ideas in response to the questions, "How does the brain learn and how do I apply this knowledge to the classroom to ensure I am doing my best as a teacher?" The questions were borne of the observations that very little seemed to have changed since I (the author) was a high school student in the classroom (some 35 years ago), that it is impossible to stop students from talking (as it was then) and that scientific knowledge **must** have some relevance to how we teachers do our job[9].

The inception of the research was not cast within any theoretical framework. Rather, the professional imperative to be as inclusive as possible of student diversity to ensure all students equal as possible access to learning opportunities was the driver of this work. And because there is no academic theory addressing this teacher imperative and student right, a metatheoretical position was adopted, pragmatism. Hence, four years of observing student behaviour in the classroom and critical reflection of my practice in the classroom led to an idea being formulated about the relationship between attention and teenage socialness and its dependency upon dialogue, the three ***b***asic ***i***nput variables of classroom learning. Further, that the intersection of these three variables seemed to manifest as an overarching classroom variable referred to as engagement: An intersection that was intimately dependent upon me, the teacher in the classroom, being the active focal point in the classroom learning environment. Thus, the unification of these three facets of engagement into the professional practice of teaching should have an influence on the workings of learning in the science classroom, the ***o***utput in the

[9] The perspectives from which the work is written switch occasionally from first person to third person. As I am the teacher subjecting my professional practice to scrutiny, as well as in comparison to my colleagues, several perspectives on my professional practice and that of others is simultaneously occupied. This necessitated the adoption of both first person and third person perspectives, depending on what was being written. As the majority of this work is quantitative, writing about data was done from the third person, past tense perspective. For the less substantial qualitative component, writing about professional reflections in the workplace and classroom were written from the first person perspective.

classroom ***S***etting. Just as perception, action and cognition all unify to produce the magic of human cognition (Barsalou et al., 2007).

These three variables seemed to be reflected in the multicomponent model of working memory, that class of memory that temporarily bridges aspects of short term memory with long term memory as information is being subjected to cognitive processes (Baddeley, 2000). In working memory, the brain processes data received from internal inputs (emotional, perceptual etc.) and external inputs (environmental distractions, teacher instructions, etc.), i.e. basically anything that happens to enter one's mind, where it is matched to prior knowledge as the mind attempts to make sense of and construct knowledge from the incoming information. Consequently, the work drew extensively from working memory literature as it relates to everyday memory and student learning to focus on the role of phonological information in classroom learning: Specifically, the delivery, cultivation and management of classroom dialogue as **the** principal mechanism of learning.

For this type of research (the mutation of knowledge from multiple disciplines into a framework of professional practice that works for both the teacher and students), there is no theoretical framework to guide its formulation, implementation nor evaluation (Daniel & Chew, 2013). As such, "At the ragged edge of understanding (*the professional practice of teaching*)[10] we sometimes have to be content with statistical correlations." (Barbey & Patterson, 2011, p. 2).

Biology: the masked variable in the teacher professional practice.

Hebb, a former Canadian school principal turned neuropsychologist, formulated three propositions about how the brain stores, organises and uses information (Hebb, 1949). First, when nerve cells are close enough for a signal to be transmitted between them, repeated transmissions result in a metabolic change that increases the efficiency of signal transmission.

[10] Italics mine.

Second, groups of nerves that fire together form nerve/cognitive structures (i.e. memories) which depict the information and retain it after the stimulus has been removed. Third, thinking is the sequential firing of sets of memories. What Hebb achieved with these propositions was the centering of the brain as the organ in which stimulus and response are combined to generate thought and behaviour. Thereby, Hebb described the cellular basis of how the brain learns and responds to its environment.

Subsequently, Hebb's propositions became popularised by the saying, "Nerves that fire together wire together." Likewise, "Nerves that fire apart wire apart." These are ideas that many teachers are aware of. Indeed, they are foundational assumptions, either tacit or explicit, by which teachers conduct their professional practice. That is, by providing students with as rich a learning environment as possible, nerves would be more likely to wire together to form coherent (i.e. accurate and flexible) memories in the minds of students in response to their classroom learning.

In the period when Hebb's propositions were made, there was a growing trend to explain learning as the result of the external social environment conditioning the minds of people, viz. Watson (1913) and Skinner (1938). This was known as behaviourism and contended that learning was the result of an organism being conditioned to react in the desired manner by environmental rewards and punishments. This idea is one that many teachers comprehend and apply to their professional practice to some varying degree. For example, "If you don't settle down, I'll give you a lunchtime detention." Such maintenance of a smooth running classroom is (still and always will be) an important condition for the teacher to do their job, as well as a major concern of student teachers in their future classroom endeavours (Walkington, 2010). That is, classrooms are managed so that one may do one's job without too much effort being directed toward managing student behaviour, be it bad behaviour or incessantly chatty and off-task behaviour. As any teacher will attest, such behaving classes may impose a high tax upon the personhood of the teacher. Consequently, such relational harmony also occupies a central position in the teacher's mind about what it is that students need in order to learn: If students are well behaved then they will learn well. Unfortunately, evolution in this relational (tolerable behaviour) view of learning, as it impacts upon teaching practices **AND** student learning, has been minimal.

Alternatively, noticeable evolution has occurred in Hebbs' cellular basis of learning. That is, technology has provided more resources which teachers use to enrich the sensory experience in the classroom. For instance, the 'chalk' in 'chalk and talk' has evolved to make use of better books, videos, animations, smart boards, the internet, software programs etc. Hence, a richer sensory environment will result in nerves learning to fire together to wire together and establish coherent cognitive structures of the learning at hand. What has not co-evolved is the teachers' understanding of their role in the use of these resources. That is, the 'talk' remains the talk of reminders to 'pay attention to the app or video or animation and get back to work', with rewards and/or punishments to encourage behavioural compliance. On the part of the teacher, there is little comprehension that their talk is just as valuable a learning resource, if not more so, as the latest technological gadgetry. Or indeed, that talk is the bedrock upon which these cognitive structures are built and stored in memory. As Rodriguez (2013, p. 183) states, "We must stop believing that an iPad application, smart technology video game, or even an avatar can teach. These objects are learning tools not teachers."

Clark (2008, p.44) describes talk as a "form of mind-transforming cognitive scaffolding … whose critical role in promoting thought and reason *(i.e. learning)* remains surprisingly ill understood." Delors (1996) acknowledges the centrality of language in teacher student interactions while Perlovsky (2009) suggests that language models (how one uses language in dialogue) influences the development of cognitive models (how one thinks). That is, how one thinks depends upon the words one has available to bring forth the ideas in one's mind.

Perlovsky (2009) also suggests that the mental model of how one uses language may shadow cognitive processes from consciousness, with the consequence that cognitive content remains detached from consciousness. Hence, the co-development of cognitive skills with language skills is not a guaranteed event, and even possibly less so in response to social constructivist philosophy.

Typically, teachers employ cognitive scaffolds in manners congruent with the ‘zone of proximal development’ (Vygotsky, 1986). The ZPD represents those tasks a student is able accomplish in collaboration with the teacher (Zaretskii, 2009). Hence, tasks are devised that are just hard enough to puzzle the students but not so hard as to be unachievable. Frequently, these tasks take the form of worksheets which students work through to acquire new learning. Worksheets can take many forms: A photocopy of a page, a series of questions written on the board by the teacher, a puzzle, a question and answer session, etc. Though different in form, all worksheets are cognitive scaffolds: Structures that present knowledge in a methodical and progressive manner which, when engaged with by the student, supposedly results in the student methodologically internalising that knowledge to progressively develop more cogent, independent and critical perspectives of that knowledge.

In using worksheets, students are encouraged to socialise and share their learning on the assumption that higher levels of cognitive functioning have their origins in social interactions (Vygotsky, 1986). That is, as students grapple with the requirements of the worksheet, they ask questions of each other and thereby form a cognitive understanding of what it is the worksheet requires of the student. It is this understanding gained via these social interactions that results in students becoming conscious (albeit socially conditioned) learners, able to control and direct their mental processes to efficiently apply and solve new problems.

Intimately accompanying the concept of the ZPD is the notion that the nature of the collaboration between teacher and student involves imitation (Zaretskii, 2009)[11]. That is, the student copies the mental processes of the teacher in order to generate a response indicating that the ZPD has been extended, i.e. that learning ass occurred. For example, "Oh, I get it now. If the mother is colour blind there is no way the boy cannot be colour blind because it does not matter which X chromosome he gets from his mum, it is going to be stuffed; and dad's Y chromosome cannot compensate for mum's stuffed X chromosome!" Such an understanding is very difficult to communicate to students in the absence of verbal imitation as both the teacher and student collaborate in developing the ZPD.

Talk, logically and by necessity, therefore plays an imperative part in the use of cognitive scaffolds, insofar as it provides an opportunity for students to glimpse another's thought processes (teacher or student) in order to develop an understanding of the requirements of that particular scaffold. That is, students imitate cognitive processes as a response to talk to acquire an inkling of what is required by the cognitive scaffold and then generate some action in response to the cognitive scaffold. However, talk, in and of itself as a cognitive scaffold, is not a learning resource that is generally utilised by teachers to its fuller potential. Teachers usually take talk as far as needed to assist students to respond to the learning resource but not so far as to allow students to use talk itself as the learning device. That is, talk is typically limited to explaining and clarifying the requirements of worksheet scaffolds etc. For example, I used to respond to (and my peers continue to do so) students: "*Go back to page 56 and read section 2.3, you'll find the answer in there*" or "*It's asking you to make a connection between how fast the particles are moving and the likelihood that they will bump into each other. Can you think of a way to relate these two things*?"

[11] The extent to which students cognitively develop as a function of imitation of their peers' cognitive processes is questionable yet arguably less than that achievable via imitation of their teachers' cognitive processes.

In their review of 40 years of classroom dialogue research, Howe and Aberdeen (2013) note that the typical structure of classroom dialogue involves the teacher **i**nitiating a question, obtaining a **r**esponse which is then followed by teacher **f**eedback (i.e. the IRF cycle, Sinclair and Coulthard, 1975). Moss and Brookhart (2009) describe such teacher dialogue as 'closed questioning'; the teacher determines the nature of dialogue and any response not coherent with the teacher's perspective is wrong. Dialogue then continues until a student can utter the correct answer or until the teacher decides that the correct answer needs to be given. Such 'IRF' talk is superficial in that just enough attention and information is given by the teacher for the student to 'get the job done.' Unfortunately, Howe and Abedin's (2013) four decade review also observed that little seems to have changed regarding the IRF structure of classroom dialogue; further that a two decade pre/post perspective of classroom dialogue seems to confirm the 'little has changed' perspective of classroom dialogue.

Again, unfortunately, the cost of IRF talk seems to come at the expense of deeper engagement by the teacher with the student and vice versa. Pehmer, Gröschner and Seidel (2015) reported that secondary German teacher professional development in the use of classroom dialogue for science (and maths) classes was associated with sustained situational learning processes and cognitive elaborative strategies. That is, by teachers employing dialogical elements into their classroom practice that support higher order thinking skills, student perceptions of learning outcomes were more positive, most notably for those students experiencing a low self-concept. In the classroom, this equates to teachers challenging students to explain their thoughts in a way that promotes the student connecting new learning material with their prior knowledge to foster a deeper and more critical individual appreciation of the subject matter being taught by the teacher. Though Vygotsky was acutely aware of the imitative value of talk as a collaborative tool in promoting the cognitive development of the ZPD, it seems to have been disconnected from its function in the social constructivist understanding of the ZPD.

Arguably, the objective of such dialogue is to create a shared understanding of the knowledge the student needs to acquire to provide impetus for the student to work through the learning resources independently and generate correct and clear responses; That is, the student needs the words in their mind that will facilitate their imitation of teacher thought processes. For example, I now respond, "*Well, let's go back to page 56. Have a quick read of that section. Do you get it that as things get hotter, they move around a lot faster? Just like you will pull your hand away very fast and a long way from a hot stove if you touch it and it's hot. At which point I will give a demonstration by slowly moving my hand towards a Bunsen burner flame until it is too hot and I have to pull my hand away. How far did your hand move from the flame? A long way? Well, that's what the particles are doing. And the more of them that are doing that, the thicker the brass ball will get until it won't fit through the hoop. So see if you can figure out what will happen to an electrical wire on a hot day? Is it more likely to get shorter because the particles are pulling together to make it shorter or something else? There, do you understand that section? Can you read it out to me? So, tell me how that answers the question you are doing. OK, I am going to make up a question now and I want you to write the answer down without telling me the answer!*" Such talk whilst teaching can take some time out of the lesson and away from other students needing help but they too usually pay attention to what's happening and have their knowledge affirmed. Thus, the teacher/student engagement has created a momentarily shared cognitive structure that eases the mental demands placed upon the student by the worksheet, like reading comprehension and writing responses to the worksheet problems.

Hence, it is not unexpected that Choo, Rotgans, Yew and Schmidt (2011) reported that worksheet scaffolds may not be as significant a contributor to the learning process as thought. This group investigated learning outcomes in which worksheet scaffolds were the primary learning resource used by students. They found that there was no significant difference in learning outcomes of students who used or did not use worksheet scaffolds. Interestingly, they found that it was the ‘soft-scaffold’ of the tutor/teacher that was perceived by the students to have the greatest effect upon their learning. Choo et al. (2011) describe the soft scaffold as that effect associated with the tutor asking open-ended questions of the students to facilitate their progress through the worksheet. Chng, Yew and Schmidt (2011) refine the soft scaffold role of the tutor/teacher by emphasising the role that social congruence plays in learning, i.e. it had more influence upon student learning than did tutor/teacher content knowledge and clarity in communication of content knowledge. Schmidt and Moust (1995) describe social congruence as the ability to communicate informally and with empathy to cultivate a learning environment that encourages the open exchange of ideas. Additionally, Zhou (2012) noted that when a teacher imitated the students’ behaviour whilst learning foreign words, they achieved higher quiz scores and reported higher ratings of interpersonal rapport and satisfaction with and confidence in the teacher, as well greater satisfaction with the learning outcomes.

Kent (2013) builds on social congruence in the context of a classroom teacher to observe that effective classroom learning requires a synchronisation of human interactions amongst all members of the classroom. Further, that this synchronisation is dependent upon the teacher intuiting the needs of students and responding to those needs to create a classroom unified by the emergent rhythm of those interactions. Kent (2013) describes this process as a dynamic one that evolves out of conscious and unconscious feedback loops that constantly monitor the human interactions occurring in the classroom. Decision making on how to manage these interactions to promote and/or sustain classroom synchrony occurred almost instinctively and were mediated by actions like energising or distracting the class with movement and talking.

The synchronisation of mental processes associated with talk was reviewed by Ulm (2013). Simply, as talk is shared between the teacher and student(s), the brain regions active in processing this exchange become synchronised in both parties. This occurs via simultaneous bottom-up and top-down processing: The sounds of speech are built up (through the phonological loop of working memory) to phonologically construct and give meaning to the sound of the talk while the high level cognitive process of comprehension is constructed in advance of these lower level cognitive process. Further, this forward construction of comprehension is in advance of what the speaker is saying, allowing the listener to make predictions of upcoming dialogue. This allows the formation of a common perceptual filter in the minds of the teacher and students(s) that facilitates more efficient anticipation (or prediction) of the meaning and direction of talk and therefore, more effective cognitive processing of dialogue. Ulm (2013) indicates that the pacing of talk between two people can influence the construction of predictive comprehension: If it is too slow (or fast), the common perceptual filter evaporates and the cognitive value of the shared dialogue diminishes. To monitor the pace of the shared dialogue, close monitoring of the level of attention is required. This shared attention can thus be used by both parties to adjust the rate or topic of dialogue to create a state of sustained free flowing dialogue between the parties that is mutually agreeable. With more practice of shared speech, the neuronalcoupling becomes more tightly bound such that both parties become able to predict the nature of the upcoming exchanges, almost spontaneously.

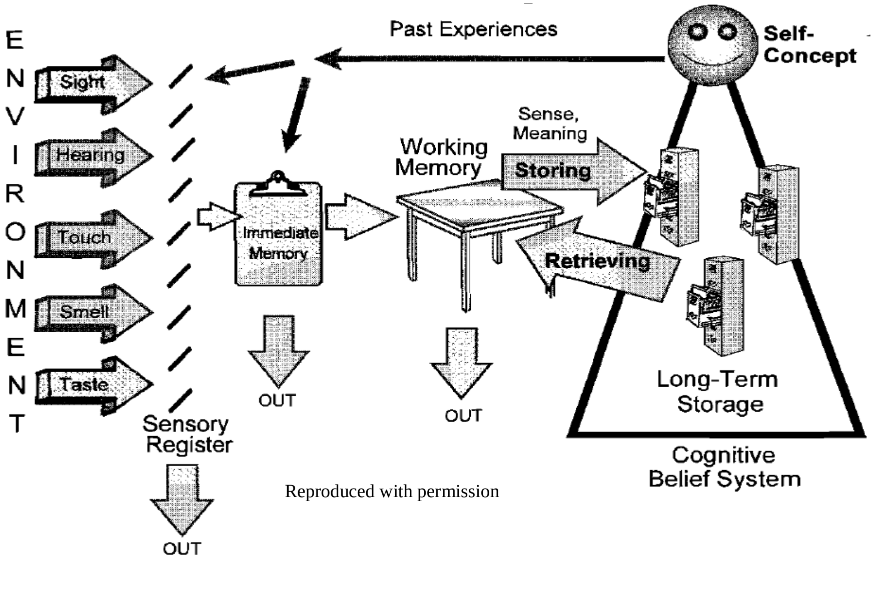
The degree to which the brain is active in response to shared speech is extensive. Ulm (2013) notes that the activities of brain regions processing speech on the left side of the brain have homologues active on the right side of the brain. This suggests that the processing of speech is being related to memories not immediately relevant to that speech. That is, the cognitive processing of speech that resulted from the focus of shared attention on that speech is more extensive than speech that results from unsynchronised speech. Additionally, Ulm (2013) notes a role for the default mode of brain activity in response to naturalistic stimuli, like shared speech. Upon watching a movie, one brain network was activated to process the external stimuli of the movie whilst another brain network, the default mode network (DM), was seemingly activated by the brains intrinsic response to that movie. The DM has been described as that mode of human thought implicated in social cognition, assisting individuals to understand themselves and their reactions in social contexts by employing the brain's metacognitive capacities. This allows the delineation of self from others and thus the interaction of self with others (Schilbach, Eickhoff, Rotarska-Jagiela, Fink & Vogeley, 2008).

In exploring the magic of human cognition, Barsalou et al. (2007) suggest that the prediction (or anticipation) of upcoming events is the core phenomenon of human cognition. In doing so, it is proposed that the social environment and the actions situated in that environment co-ordinates brain processes that manage goal management, perception, action, memory, reward, affect and learning to promote inference making about what it is that it will next experience in that moment of time. Barsalou et al., (2007) note that many of these processes are non-cognitive in origin, yet they still have a major influence on the outcome of cognition, i.e. the accurate prediction of what is next going to occur in the environment. Logically, it is the synergy of real time interactions that the brain experiences with the actions occurring in its social environment that solicits the co-ordination and emergence of human cognition. The magic arises from this interaction via facilitating the brain's reconstruction of mental states that supports behaviour to achieve its goals and social interaction across different contexts. Learning thus extends and proceeds developmentally in response to the social agents (i.e. teachers and peers in classrooms) encountered in those social environments. Hence, in their view, cognition is more about the co-ordination of non-cognitive processes within a suitable environment than it is about brute computing power of the brain.

The brain’s information processing architecture.

The Atkinson and Shiffrin (1968) information processing model of human cognition presents an architectural model of the structure of human memory. This simple model has evolved since its inception, most notably in the direction of working memory (Baddeley, 2012). Educator-friendly depictions of the cognitive architecture through which information flows from the classroom environment to long term memory storage include those by Sousa (2006) and Hardiman (2012). Figure 1 below reproduces Sousa’s (2006) depiction and indicates that working memory is a pivotal process in the formation and subsequent use of long term memory. That is, working memory binds incoming sensory information with meaning for incorporation into long term memory and from which working memory also retrieves information for current needs. Further, the architecture indicates that self-concept has a significant influence on memory processes as they pass through working memory. The significance of this is that it highlights the interactivity of biological and psychological factors (encompassed within student self-concept) with memory processes. That is, should self-concept not be healthy in its present social environment, past experiences may result in the ejection of classroom learning at several stages of information flow, leading to low quality, incoherent cognitive structures being formed in long term memory. That is, attention is not paid to learning what is occurring in the classroom with the consequence being that subsequent learning activities may be hampered because of incomplete prior knowledge.

Figure 1
The information processing model of human memory



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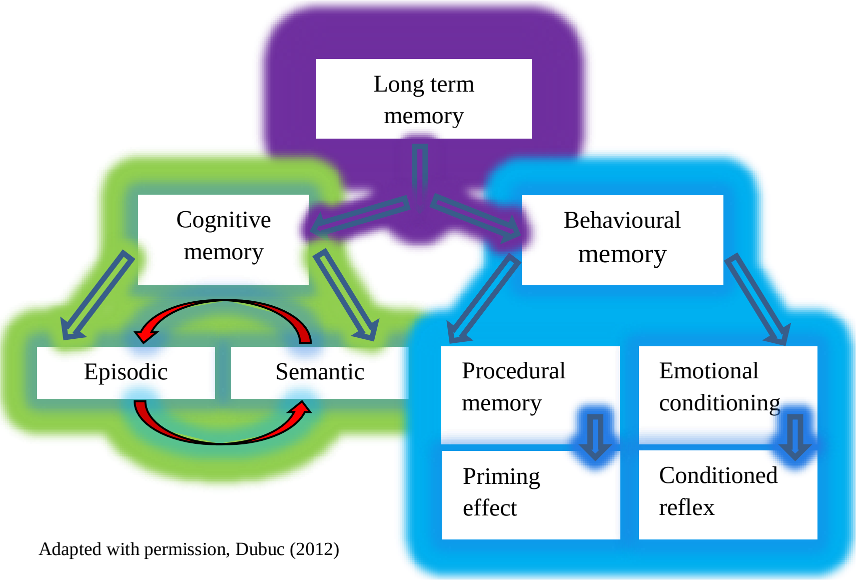
The organisation of long term memory.

The basic organisation of the different types of long term memory is depicted in Figure 2 below. The simplest distinction between these types of long term memory is whether or not the product of that act of memory can be held in mind: If it can, it can usually be verbalised and is classed as cognitive memory; if it cannot, it is usually difficult to verbalise and is classed as behavioural memory (Tulving, 2000). Cognitive (explicit) memory represents those things of which one is aware and can explain, e.g. one's name, birthday, how one felt in response to some good or bad news, the atomic symbol for hydrogen and the effect of gravity on objects. Behavioural (implicit) memory thus represents those things which one can do but not necessarily be able explain how, e.g. how to ice skate, how to drive a car, how to hit a golf ball straight or display the correct behaviour when the teacher asks you to focus on your work.

Figure 2

The structure of long term



Tulving (2000) distinguishes two types of cognitive memory, episodic and semantic. Episodic memory is that memory to which personal significance (context) has been attached, like being able to remembering the date, attendees, the meal, the weather etc. of one's marriage even though it is only one day of the past 14,000+ days since being a teenager. The function of episodic memory is thus to facilitate conscious access to the personal experience of past events. Semantic memory is that memory of facts about the world, like knowing that the faster one is going before a bicycle crash, the more likely the injuries will be worse. The function of semantic memory is thus to facilitate conscious access to and use of general knowledge about the world. The characteristics of these two types of cognitive memory are listed in Table 1 below.

Figure 2 indicate that episodic memory and semantic memory are different entities with distinct properties but which interact with each other. In this interaction, semantic memory is synthesised from episodic memory (O'Connor, Moulin & Cohen, 2008). From the semantic perspective, semantic memory extracts from the sum of episodic memory concepts that permit the generalisation of semantic knowledge beyond the world of oneself. From the episodic perspective, the concepts stored in semantic knowledge facilitate the personal understanding of events in episodic memory and thus meaning making of one's experiences. For example; When sensation becomes comprehension, it feeds back to provide greater understanding of subsequent sensations; when there is a transition of comprehension from the self to the universe, there is an increase in the inferential potential to facilitate comprehension. When memory in episodic memory is retrieved, its structure changes as concepts are extracted for fixation in semantic memory structures.

Shing and Lindenberger (2011) suggest that episodic memory is made up of two sub-components, one that serves associative functions and one that serves strategic functions. The associative function describe the binding of events in time to form personally coherent representations of events whilst the strategic function manages the cognitive processes associated with their encoding and retrieval to ensure the fidelity of these events in memory. Of these subcomponents, Shing and Lindenberger (2011) suggest that the associative function has matured by middle childhood but that the strategic function continues to mature into late adolescence and young adulthood. In conjunction, these two functions serve to facilitate the accurate contextual recall of episodic memory and consequently, more effective transfer of knowledge to semantic memory. Thus, semantic and episodic memory are concurrent and interdependent processes (Williams, Conway and Cohen, 2008). Exactly how the relationship works is not fully understood but simply encountering something in different contexts seems to facilitate the formation of semantic memory from these different episodes (O'Connor et al., 2008).

Episodic thinking.

Just as semantic memory can be used to solve technical problems, episodic memory can be used to imagine the future (Schacter & Addis, 2007). In this case, past episodes can be recalled and recombined in different combinations to construct various representations of future possible outcomes. However, recombination is not only restricted to episodic memory. Semantic memory has also been associated with imagining the future where it may facilitate in structuring imaginings against fact and thereby aid in interprability (D'Argembeau & Demblon, 2012). More broadly, Schacter et al. (2012) believe that semantic memory plays an important role in the recombination process itself.

The default mode network has also been associated with episodic future thought (Schacter et al. 2012). The DM represents a resting state of brain activity that switches on when sustained attention to the task at hand is no longer propitious (Immordino-Yang, Christodoulou & Singh, 2012). The DM has thus been implicated in social cognition, that mode of thinking which allows individuals to understand and delineate their self from others, thereby the interaction of self with others (Schilbach et al. 2008). On this interaction, the authors' note that the self is relative to a given context and that it develops within the particular contexts via reciprocal exchange.

The role that the DM plays in mental life appears to support internal mentation. Giugni, Vadala, Vincentiis, Colica and Bastianello (2010) suggest that the spontaneous, stimulus-independent thought that occurs in the DM when people are left to think for themselves allows the brain to reiterate knowledge construction processes to form more useful forward-looking memory structures. For example, the incorporation of other bits and pieces of knowledge into the knowledge currently under construction in the classroom enriches cognitive structures such that it serves purposes beyond the context of the originally encoded information. This thus allows expectations to be formed about future events which are then reconciled with their outcome, which then lead to subsequent rounds of prediction and reconciliation and so on and so forth. Bar (2009) suggests that the utility of context-specific events is that they reduce the attentional resources needed to monitor the context thus allowing the reallocation of attentional resources to explore one's environment for novelty from which we can learn and for surprises that should be avoided.

In their review of the DM and its psychosocial functioning, Immordino-Yang et al. (2012) coin the phrase 'constructive internal reflection.' This phrase describes that internal mental state associated more with the processing of abstract psychological, affective and subjective knowledge about self and others and less with the processing of factual knowledge. In the latter case, attentional resources are consciously focused on the external task at hand whilst in the former they are inwardly focused on spontaneously roaming the knowledge structures of the mind to make deep connections between the internal world and the external world, be whatever they may. To substantiate this claim, the group documents a wide range of findings in which the relationship of the DM to socioemotional and cognitive functioning is correlated. Themes of their review that are most relevant to the classroom include the following:

1. Attention is an emergent property and that internal mental processes are vulnerable to distraction by calls for outward focus attention.
2. Inward attention and outward attention co-regulate each other and predict the functioning of the other.
3. The quality of DM activity is related to the quality of neural and behavioural responses to environmental events.
4. The fluctuations between inward and outward attention is important for perception, attention and cognition associated with specific objectives.
5. Training inward attention can alter DM activity and promote sustained attention to the task at hand.
6. The efficiency with which toggling between inward and outward states occurs is associated with social and emotional health.
7. Reading, memory and attention demanding cognitive processes are associated with rest in the brain's DM.
8. Engaging the DM may promote cross-talk in the brain that results in more efficient networking of disparate pieces of knowledge and thus the construction of more personally meaningful knowledge structures.
9. The hub of the DM network is related to characteristics of self-awareness, episodic memory retrieval, day dreaming, moral judgement and empathy.
10. The DM activation represents half of the brain's mental functioning, being the processing of abstract ideas relative to the psychological, affective and subjective realms of oneself and of others.

Counterfactual thinking has been associated with episodic memory and the DM network (Van Hoeck et al. 2013). In this case, episodes from past events are remembered and recast in a manner to ponder 'what if?' imaginings of how future events may turnout. Imaginings with favourable outcomes (better than occurred in reality) are associated with regretful feelings and stronger behavioural intentions for the future whilst less favourable imaginings are associated with greater affective regulation and thankfulness that things didn't turn out as bad as they could have. De Brigard, Addis, Ford, Schacter and Giovanello (2013) also report on the counterfactual and episodic/DM relationship but additionally observed that the subjective likelihood of imaginings actually occurring altered the extent to which different components of the DM were engaged with counterfactual thinking. That is, 'I can imagine something happening but it's not very likely to occur so I won't worry about exploring it any further.'

Finally, the evolutionary function of episodic memory has been cross-linked with the development of language and intelligence in humans, viz. the cognitive niche (Pinker, 2010). As humans radiated outwards into different environments, there was a need to generate new solutions to new problems based on past knowledge. These solutions were made up as matters went along and resulted in the development of ever better tools with which to survive in new environments. Accompanying this was cooperation amongst kin and the associated transmission of knowledge required for survival, the medium for which was language. The value of language as the medium is that it is does not cost much to give away and it eliminates wasted time from the trial and error associated with the generation of new knowledge, i.e. just explain it, don't re-invent it and get on with it. As such, language is able to provide immediate answers to who, what, when, where and why questions (Pinker, 2003); presumably how as well, the single most asked question in the classroom. That is, language allows personal experience and future plans to be shared to gain the benefit of others' experiences; indeed language may have evolved specifically to permit the sharing of our episodic memory and increase the breadth of our vocabulary (Corballis, 2009). Thus, future behavioural responses may be waiting in ready should such shared experiences eventuate in one's life (Ingvar, 1979).

Pinker (2010) also suggests that it is the metaphorical abstraction of language by which humans develop their cognitive repertoire. That is, by abstracting one's intuitive understanding of biology, physics and chemistry and of social relations, humans became able to develop analogical reasoning skills that established causal relationships to explain phenomena in their environment. For example, 'If I got sick both times after eating mussels, perhaps my cows are getting sick because they are eating something different.' Pinker (2010) suggests that analogical reasoning comes naturally to the human mind and that from such reasoning, language was used to share and negotiate the exact meaning of these relationships, prompting further growth in their evolution and cognitive skills. Thus, as language skills developed, so too did intelligence co-evolve.

Autobiographical memory.

The construction of future imaginings (or counterfactual states) may occur via the self-memory system (Conway, 2005)[12]. This is a conceptual framework in which episodic memories are integrated with one's self concept to form an autobiographical knowledge of oneself. The integration of these factors is managed by the working self, which acts to process competing goals and thereby regulate behaviour. That is, it acts to minimise discrepancies between the hierarchy of desired goal states and the current state experienced by the person. Supplementing the processing of hierarchical goal states is the conceptual self. This is an abstract entity that is attached to autobiographical knowledge or episodic memories to give them context. The conceptual self is a socially constructed entity that draws upon one's culture (family, peer, school, religion, customs, media, fairy tales, etc. etc.) to help define oneself and other people

[12] At the time of submission, this was a logical inference easily drawn from the literature. Subsequently, De Brigard, Spreng, Mitchell and Schacter (2015) published work indicating that the extent to which autobiographical episodic memory was recruited into counterfactual thinking about others depended upon perceived similarity and familiarity with the subject of the counterfactual thinking, thereby providing a scientific basis for my logical assertion.

and thereby just what constitutes typical interactions with other people and of the broader surrounding world with the self.

In conjunction, the working and conceptual selves act to manage access (or deny access) to memory in order to construct, encode and consolidate long term memory. The management principle with which this occurs is that the self must be protected from change in order to sustain adherence to its goals. Conway (2005) notes that this occurs via correspondence and coherence criteria. That is, each person possesses a set of self-defining memories that specify seminal knowledge about the progress that one is making towards the achievement of long term goals, like independence, intimacy, family and even how to be a better teacher. Self-defining memories are characterised by their affective strength, extent of rehearsal, vividness, connection to similar memories and to an enduring concern. It is by these last two that self-defining memories are most strongly typified (Conway & Williams, 2008). Hence, the working self protects self-defining memories by restricting access to long term memory on the grounds of coherence. That is, to prevent knowledge construction that does not cohere with the continuity of the conceptual self and goal hierarchies, episodic and autobiographical memories are censored to ensure the integrity of self-defining memories. Similarly, the formation of episodic memory is regulated by correspondence. That is, memory formed must correspond to reality if progress toward long term goals is to be accurately tracked. Hence, the extent of internal processing given to the stimulus corresponds to the extent to which it accurately represents reality. Whether the reality associated with the stimulus is dominated by internal affective states or external social states is determined by coherence criteria. That is, stimuli that may result in the formation of episodic memory that is not coherent with one's self-defining memories will not receive as extensive attention and processing and therefore lack importance in one's world. Finally, in constructing autobiographical knowledge, people may also connect remembered with imagined experiences, adding to the richness of one's memory (but to its complexity from the perspective of the other!).

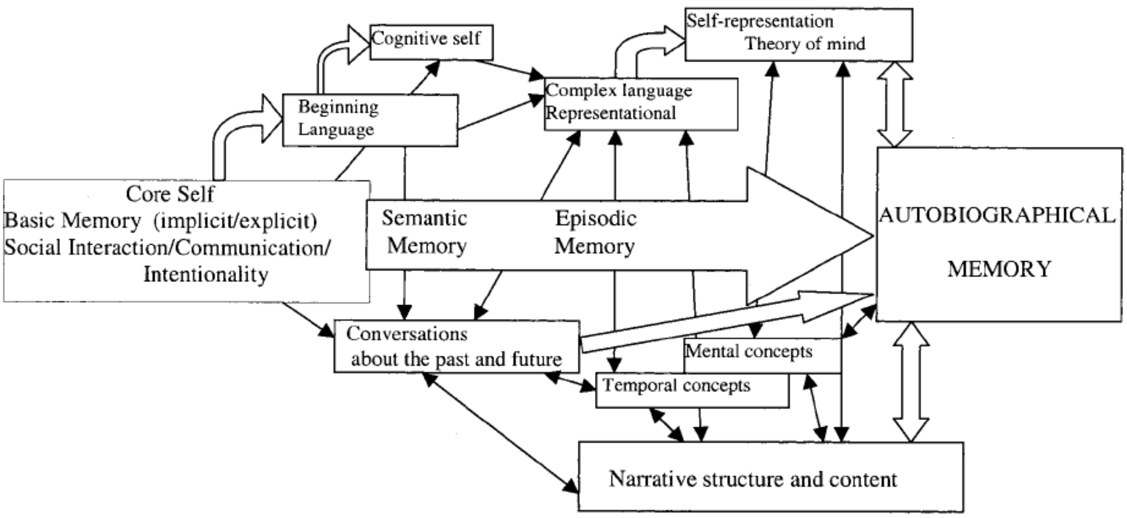
The structures in the brain that support the formation of episodic memory (upon which autobiographical knowledge is constructed) include the amygdala and the hippocampus. It is amygdala that detects and processes the emotion of incoming sensory information whilst it is the hippocampus that binds all of this information into a representation (or an episode) (Phelps, 2006). The binding of stimuli that the hippocampus does is not limited to any one type, e.g. visual and spatial information, rather it binds everything (Konkel & Cohen, 2009). Clearly, the richer the sensory experience, the more comprehensive the representation of any event becomes. Konkel and Cohen (2009) describe binding events as nodes (or co-ordinate cognitive complexes) composed of three dimensions (item, location and time) but which become multidimensional as various relations amongst the stimuli are established/mapped by the hippocampus. As other nodes become activated (on the basis of their similarity to the current stimuli) in this relational mapping process, they too may be integrated into the current binding activities to contribute to the richness of the hippocampus' multidimensional mapping of that stimuli. The hippocampus is thus a region of the brain that has been found to have extensive interconnections with other brain regions and together with the amygdala, reciprocally moderate the formation of memory as well as influence its retrieval and reconstruction as the emotional and contextual information as social situations fluctuate (Phelps, 2006, Holland & Kensinger, 2010).

Over the long term, Bartlett (1932, as cited in Ost & Costall, 2002) proposed that episodes may evolve into narrative structures. This process begins to occur as a toddler and continues through adolescence (Fivush, Habermas, Waters & Zaman, 2011), into the mid-twenties (Arnett, 2000). These narratives contribute to defining the self (viz. the working self and/or self-defining memories) by providing a scaffold according to which episodic memories may be organised;

with the organisational motif being the generation of a state of mind in which a sense and purpose to one's existence is clear to oneself and one's future.

Nelson and Fivush (2004)[13] generated a model of autobiographical memory that separates it into endogenous and exogenous influences (Figure 3 below). The exogenous influences (those below the midline) consist of the social and cultural influences as experienced with family (and other adult) interactions whilst the endogenous influences (those above the midline) consist of biological influences. On these, Fivush et al. (2011) note that the development of language (and subsequently one's narrative) is critical for the development of autobiographical memory. As such, language serves three functions; Aside from giving expression to one's memories, language provides the organisational and evaluative properties of autobiographical memory, it facilitates the construction of more organised memories of past experiences and finally, language facilitates the taking of multiple perspectives on the meaning of what one remembers.

Figure 3
A sociocultural mode of the development of autobiographical memory



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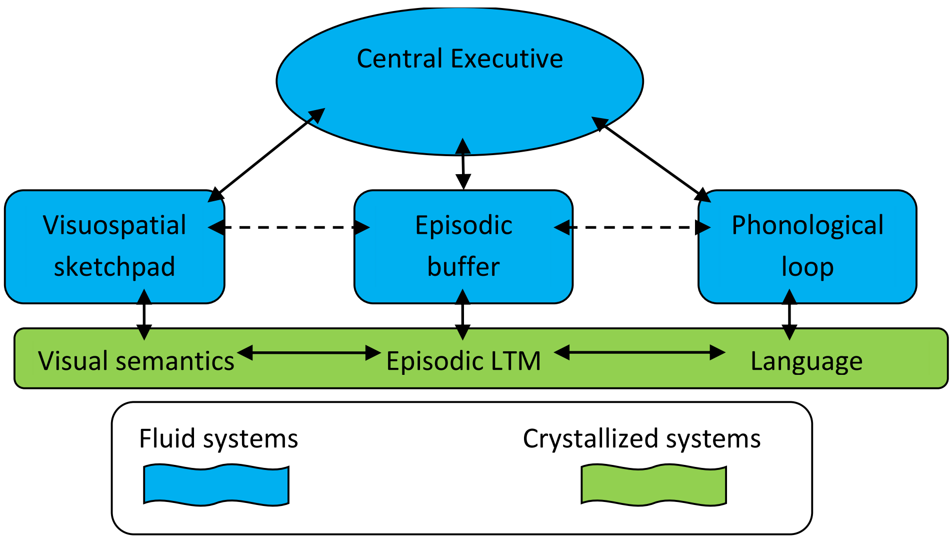
[13] This model was formulated with respect to the first five years of life. However, its structure holds for adolescent and adult autobiographical memory (personal communication, Robyn Fivush, 23rd April, 2015).

The multicomponent model of working memory.

Baddeley's (2007) multicomponent model of working memory is depicted below in Figure 4. It is in working memory that working-self processes of autobiographical memory are operationalised (Conway, 2005). As the working-self addresses actions to achieve goals, it retrieves pre-existing knowledge structures for new knowledge construction purposes and also deposits these new knowledge structures into long term memory. In facilitating these actions, working memory pulls together stimuli of various origins in order to facilitate and acts as the workbench upon which new memories are constructed. In the context of classroom learning, it is arguably the single most important type of memory process which teachers exploit (explicitly or tacitly) in their endeavours to promote student learning (Gathercole, 2008).

Figure 4

The multicomponent model of working memory



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This multicomponent model[14] of working memory has learning material entering the minds of students via the visuospatial (chalk) route and/or phonological (talk) route. The phonological loop consists of two components, a short term storage bank of incoming word sounds that quickly decay and become forgotten but which is coupled to an articulatory rehearsal mechanism. This refreshes the word sounds in the storage bank so that they are not forgotten, i.e. the mechanism recycles the pattern of nerve activity associate with words just heard. Thus, when student attention is on their own talk, the teacher's talk will 'go in one ear and out the other' because subvocal rehearsal is focused on the word sounds of their peers and not on those of the teacher. The visuospatial sketchpad acts in much the same way as the phonological loop, except that it is processing visual and spatial information. Regarding the interaction of the phonological loop with the visuospatial sketchpad, Baddeley (2007) notes that visually presented items (i.e. words written on the whiteboard) are not readily translated into phonological code. This is because visually presented information must be recoded into word sounds which subsequently results in the suppression (forgetting) of auditory information in the phonological loop dialogue and thus a reduction in the efficiency of the workings of the phonological loop. In the classroom, this relationship coincides with the frequent observation that students can recall with much more clarity something said thirty minutes ago but only

[14] Other models of working memory exist, e.g., the global workspace model Baars (1997) and the attentional model of Oberauer (2009). Baddeley's multicomponent model was applied to this work because it was more easily critically reflected upon whilst simultaneously doing the work of teaching in the classroom. For example, teachers talk and write things on the board (amongst other activities), actions which align with the operations of the phonological loop and visuospatial sketchpad. So, it was simple enough to hold those aspects of WM in mind whilst observing for student reactions to what I was doing at that moment relative to those aspects of WM. Teachers also cultivate good relations with students, an operation that aligns with the workings of the episodic buffer and central executive. To my being, such teacher actions do not easily align with the workings of the spotlight of attention on the stage of working memory nor do I not consider myself an actor in the life of my students. Additionally, it was difficult to hold declarative WM and procedural WM in mind and concurrently reflect upon student reactions to these concepts. Thus, in my professional judgement, Baddeley's multicomponent model of working memory is the simpler and more productive framework to hold in mind and critically reflect upon my learning and teaching practices as they are occurring in the moment with my students. But this situation may equally represent a limitation in my knowledge of these models and their potential utility in the classroom; nonetheless, both models do have concepts that are very useful.

vaguely recall something written on the whiteboard ten minutes ago and then, only after referring back to their notes.

Such observations allude to the limits of working memory. That is, it is a limited capacity memory system. For instance, it is easier to remember short number sequences (2453) than longer sequences (001116132554773), but which can be remembered if chunked (0011) (1) (613) (255) (4773). Likewise, it is easier to remember a short instruction to think about how to do it than it is to remember a whole sequence of instructions before then thinking about how to do it. Finally, it is easier to say the word than it is the say the colour of the word (viz. the Stroop test).

Once information enters working memory, it can move between the different components depending upon processing needs. From the crystallised systems and/or fluid aspects of long term memory of language, events and images can enter the phonological loop, the visuospatial sketchpad and the episodic buffer for subsequent use by the central executive. Here, they are manipulated and integrated with information currently occupying those subcomponents. It is the central executive that manages conscious attention directed to each of these subcomponents via the actions of four processes. First is the process of maintaining attentional control, i.e. focus during complex tasks. That is, when doing a task composed of several small sub-tasks, attention must be maintained to ensure the sub-tasks are completed in order to achieve the overall goal. Accompanying attentional control is the ability to inhibit distractions, external and internal, to ensure that what is being held in working memory remains in working memory and is not accidentally booted out to preferentially process the information associated with the distractions. Updating highlights the process in which new and relevant information is brought into working memory as it is needed to facilitate its processes without ejecting what is currently being processed. Lastly, shifting describes the redirecting of working memory onto other matters and then back to the original matter.

It is in the episodic buffer that different chunks of memory converge for processing in working memory. The episodic buffer itself is limited in the amount of information it can handle and is envisaged as having four slots into which chunked information can be placed for working memory processes. The importance of the buffer is that it serves as a platform upon which the converged memory can be evaluated for its usefulness in providing a solution to the problem at hand (Baddeley, 2012).

Working memory and problem solving.

Baddeley (2012) describes the episodic buffer as something that is able to take in information from several disparate sources and bind these to be a creative and perceptible new memory structure. In the episodic buffer, Baddeley (2012) notes that there is a limited number of slots, somewhere in the region of four but maybe a few more, into which memory is recruited and subjected to working memory processes. It is into these slots that activated memory (memory recalled from long term memory that is needed to fulfil the processing needs of working-self goals) is deposited and examined for its compatibility with needs of the events currently at hand. If the matching is near enough, then a solution is generated. If a match is not generated, other memories associated with those previously activated are cycled through the slots to generate next best matches and thus different perspectives to the problem at-hand. These next best matches may then go on to be stored in memory and later activated for use in subsequent memory recombinations. Thus, it is the constant cycling of activated memory into the episodic buffer that allows the imagining of new things and different solutions to the problem at hand.

Attention is also brought to bear in the episodic buffer as working memory processes churn activated memory to generate solutions. Cowan et al. (2005) described attention as something that could can just as easily focus in on the contents of one of those slots or pull out to get a broad view of the contents of all four slots. Oberauer and Klein (2012) suggest that the function of the focused in attention is to single out information that is critical to working memory processes whilst the function of the broad view attention is to facilitate the binding of multiple representations to generate a common cognitive coordinate system. By this, it is meant that a complex cognitive structure is built that incorporates spatial as well as non-spatial components (time) so that every aspect is in some way related to another. This permits the binding of context with content and the highlighting of arbitrary associations as these cognitive structures are compared and contrasted. From this, subsequent inductive or deductive analogical reasoning may proceed to generate a best fit solution (Oberauer, 2009).

Representation of knowledge.

As semantic and episodic memory is built up into knowledge, it may be envisioned as a conceptual hierarchy or as a relational network (Cohen, 2008). Conceptual hierarchies proceed according to logical rules and emulate the complexity of memory by ever increasingly finer distinctions amongst the rules, i.e. memory is rational. However, as described by Nickerson (1977), human memory in the real world is anything but the consequence of the application of precise logical operations to an unquantifiable database to inevitably arrive at a definitive memory recollection; it is fuzzy and almost always closer to a best guess than the recall of an exact fact. Hence, relational networks work by permitting fuzzy connections amongst general associations of memories. Such fuzzy connections, logically, represent cognitive structures bound by the broad view of attention of activated memory subjected to working self-processes in the episodic buffer of working memory. From these associations, relational knowledge is generated that fulfils processing needs at that moment in time.

Indeed, Halford, Wilson and Phillips (2010) describe such relational knowledge as the foundation upon which higher cognitive functioning is built. The role that relational knowledge plays in higher cognitive functioning includes reasoning, categorisation, planning, quantification and language. Underpinning these characteristics are three core properties that relational knowledge needs to possess to come to fruition. These include structurally consistent mappings, compositionality and systematicity. The mapping refers to the need for memory structures to correspond to the event being represented in the mind. That is, a group of restaurants may be represented as a combination of dots on a grid as long as the relationships between those dots corresponds to the restaurants in reality. Compositionality refers to the need for those restaurants to retain the details of their identity in their mapping. That is, restaurant A is located on a corner next to a hardware store and has bright pink neon lights above the door. Systematicity refers to details that are intrinsically connected to the restaurant. That is, 99 Spices is an Indian restaurant so a good portion of their dishes will be heavily spiced with chilli.

With these properties, it is in working memory that such aspects of memory may brought together to generate relational representations (or cognitive coordinate complexes) for use in the formulation of relational knowledge. Halford et al. (2010) describe this as resulting from the integration of heuristic and cognitive analyses. Gauffroy and Barrouillet (2009) described heuristic analysis as a more or less reflex cognitive complex representation of an event as it is triggered by prior knowledge that is constrained by current context and processing goals, i.e. it is a thought that comes to mind. These heuristic models (which contain default states of mind for responses, decisions and inferences) serve as the initial learning resources against which further, more conscious (analytical) models are juxtaposed. Whether or not these analytical models, which are slower to arise and more deliberate, considered and sequential in nature (being dependent upon working memory) alter the initial heuristic model is optional: Should the initial heuristic model prove an adequate template upon which to satisfy processing needs, it is unlikely to be enriched by further conscious processing. However, if the option is taken, the analytical model acts to inhibit, revise or replace the initial heuristic model.

Thus, implicit inferences are drawn from the representations based upon association (or heuristic models), e.g. beef madras curry was hot so fish madras curry will be just as hot.

Explicit inferences are made by logically reasoning about pertinent relationships (analytical models), e.g. that dish has a 5 chilli rating whilst the other has a 2 chilli rating, so the first dish must be much spicier. These inferences are transitory and change as working memory reconfigures the representations but they may also be influenced by beliefs. For example, green chillies are hotter than red chillies so the 5 red chilli rating isn't really that hot. Finally, a major role for working memory may be determining the degree of structural correspondence of representations. That is, the mapping of implicit and explicit inferences is done automatically, which perhaps is achieved via correspondence being attained between mapping and the needs of the working-self. Is some such manner, relational knowledge may create novelty because it uses real world knowledge to generate mental models that represent the logical outcomes of imaginings which then need words created for expression to others and negotiation about their meanings.

Attention, affect and cognition.

Phelps (2006) notes that emotion and cognition interact from the point of early perception to reasoning and decision making. In other words, emotion influences memory encoding, consolidation, recall and construction. As such, emotion is embedded with memory of the circumstances surrounding that emotion. In so doing, emotion may be detected automatically (before conscious awareness) and subsequently influence the perception of and attention given to an event, irrespective of one's interest in that event. That is, one has a favourable affect toward something that is of interest to oneself. The exemplar of this is the cocktail-party effect (Cherry, 1953). This describes the ability of a person to pick out of the surrounding noise words that are meaningful to oneself, for example one's name, and focus more intently on the events surrounding one's new focus of attention (i.e. what are they saying about me?). In addition to this automatic detection of emotionally salient information, Phelps (2004) describes how verbal descriptions of emotional events by others may equally draw one's attention, without the need for direct experience of that event, i.e. one can develop a feeling of empathy for another simply by hearing about their story. The function of emotion hence appears to be something that facilitates the bringing to conscious awareness of personally relevant stimuli (that would otherwise go unattended) so that events surrounding that episode are more vivid and easily recalled at a later date.

Regarding the role of attention in cognition, too much focus on one event may result in a lack of attention being given to one’s general environment, viz. inattentional blindness. Simons and Chabris (1999) illustrated inattentional blindness by having people count the number of times a ball was passed amongst a group of people, through which another person dressed as a gorilla walked. It was reported that about half the people did not notice the gorilla walk through the scene. The explanation given was that half the participants were simply paying too much attention to counting the number of ball passes that they did not notice anything else, i.e. their focus of attention was zoomed in on the ball.

Dewey (1899) proposed the idea that different types of attention may have a major influence on learning. He distinguished divided attention from undivided attention and associated an affective state with each type of attention (Dewey, 1913). In the former case, divided attention is a state characterised by a lack of interest and effort with the result that intelligence and cognition is disengaged from the learning experience. This is because the learning environment in the classroom lacks purpose to the individual and so one simply shuts down the mind. Alternatively, the presence of purpose in the classroom cultivates personal interest and effort, which results in the class being more affectively disposed to deep learning about the subject and not just the accumulation of knowledge for the sake of doing so.

Dewey (1899) depicted these two types of classrooms as being either work focused or play focused. The work focused classroom was characterised by the use of stimuli (the variety of learning resources employed by the teacher) to solicit student attention and/or the demand (explicitly or tacitly) that students ‘pay attention’ to what the teacher is teaching. This is the ‘work classroom’, one in which attention is consciously and resolutely focused on the task at hand yet is associated with a lack of interest and effort. It is a classroom that excludes a sense of playfulness with the result that there is a lack of interest and effort given by students to their learning. Alternatively, the same classroom may be managed by the teacher to have a sense of playfulness. The outcome being a more diffuse attention to the classroom, one characterised by personal interest and effort being voluntarily given by students to their learning.

Long and Hoy (2006) explore the relationship of interest and effort from the student perspective. Specifically, whether or not the individual interest possessed by a teacher is related to student perceptions of teacher effectiveness. They defined a teacher with individual interest as one who has knowledge of their subject matter that is aligned with a personal interest in the subject matter, i.e. the teacher has an interest in the subject (science) that extends beyond the classroom but which also feeds back into the classroom. Long and Hoy (2006) suggest that for such interested teachers, their classroom behaviour may generate cognitive, affective and conative associations with the subject. Cognitively, a teacher’s interest in a subject may stimulate students to engage their intelligence with a sense of purpose and interest, making it more likely that one will connect one’s cognitive abilities associated with knowledge already possessed to the knowledge being learned. This contributes to deeper learning (Schiefele, 1998) and enhanced recall of knowledge (Shirey & Reynolds, 1988). On affect, interested teachers may foster within students a ‘like’ for their subject. This may be an individual interest in which a student associates with the subject and is identified by the subject (Renninger, 2000). For example, Jake loves science and is really good at it but not so with English. Or it may be situational interest in which a student’s attention is brought to bear on something colourful in a textbook or worksheet etc. (Ainley, Hidi, & Berndorff, 2002) Finally, a conative effect represents a state in which one initiates purposeful action and sustains that to achieve a goal (Snow, Corno & Jackson, 1996). Such motivated students display persistence in their work efforts (Renninger & Wozniak, 1985), self-esteem and belief in the abilities of their skills (Schiefele & Csikszentmihalyi, 1994). This conative effect may also synergise with other, deeper aspects of voluntary motivation, like goal achievement (Schiefele, 1996). In short, the sum of these three teacher interest effects is probably operating at the level of autobiographical memory, specifically the development of self-concept: People develop interests in things to help build their own identity to subsequently present to the world the skills acquired from the mastery of that interest (Hannover, 1998).

Processing language in the mind.

In the classroom, cognitive (academic) development is assessed foremost by the written output of students. This may be in the form of test answers, essays, completion of worksheets etc. etc. Preceding this is teaching, those actions that a teacher employs in the classroom to facilitate the learning and cognitive development of one's students. Inevitably, these actions will, to some extent or other, rely upon verbal communication and the taking down of notes in student workbooks. From investigating dyslexia that occurred in families (children and parents), Berninger et al. (2006) found that the three forms words may take (its phonological sound, its morphological structure and its orthographic symbols) were each able to predict reading and writing difficulties, i.e. the cognitive processing of sound, structure and symbol cross over with each other as they are processed (Richards et al., 2006). Additionally phonological components of working memory and central executive that rely upon phonological processing were also found to predict reading and writing difficulties. However, it was the interaction of all these factors that was found to be the most effective predictor of these difficulties. Most importantly, Berninger et al. (2006) reported that individual differences existed amongst children and parents about the extent to which any one factor of working memory and/or word form fell outside the normal range and contributed to reading and writing difficulties. Or expressed another way, the same reading and writing difficulty may be arrived at but by different working memory and/or word form deficiencies. In simple terms, the sounds, shapes and symbols of words blurred with deficits in working memory processes result in cognitive difficulties in reading and writing.

The formation of cognitive structures in the classroom.

In the classroom, the relational network concept of memory reconciles most accurately with classroom on-goings and the program of learning that students must complete before entering senior high school. That is, junior high school emphasises the relational aspects of curriculum in its attempt to develop as broad an understanding of science content knowledge so that it serves as prior learning should students want to specialise in the curriculum associated with physics, chemistry or biology. The junior high school curriculum also places an emphasis on cross-curricula relationships, e.g. how the science of sound relates to different types of musical instrument or how the composition of drill bits determines into which type of material it can drill. Later in senior high school, the curricula is focused onto the topics of biology, chemistry and physics etc. to develop conceptual hierarchies, which will be assessed for competitive entrance to tertiary institutions. Additionally, students at this age, 15 to 16 years old, are in a stage of exploring and building up their understanding of the world in general, i.e. they're not really interested in the precise mechanics of how things work. They're more intrigued by the novelty of things and what that novelty can explain to them and how they can use that to explain phenomena of interest to themselves. Thus, they are busy developing self-defining memories, their working-self and their autobiographical knowledge of their place in the world.

On the whole, it is logical to suggest that the most common and wide ranging means of human interaction, talk (amongst all members of the classroom), is a critical factor in effective student learning. It is probably the synchronisation of classroom talk and its subsequent relational networking of memories across the brain that is acting as the 'cognitive architect' in the minds of students as nerve structures fire together and wire together during classroom learning. More specifically, it is the fuzzy exchange of language between the teacher and students minds that lends inferential scope and negotiated meaning to the cognitive structures occupying the two minds (teacher and student) as the novelty and personal meaning of learning material is engaged with in the classroom. As Ausubel (1963) noted, it is the interaction of cognitive structures (between teacher and students/student and students/teacher) and subsequently their meaningful alteration that is at the heart of the educative process.

Ausubel (1963) described the cognitive structure of an individual's knowledge according to its state of organisation, stability and clarity. If the structure is coherent, further learning of that subject is facilitated because it can easily absorb the new material due to prior learning. That is, something exists in common between the activated cognitive structure and the new material that permits its processing to generate an updated cognitive structure for storage in long term memory. Thus, prior learning has provided an 'ideational anchorage' point for the development of more complex and abstract knowledge. But if the scaffold is incoherent, learning is hindered due to a lack of prior learning and/or no ideational anchorage, i.e. the new learning lacks the ability to attach to prior learning, leaving it an isolated and unconnected piece of memory that may be difficult to later attach new learning or recall for use in problem solving.

In developing prior knowledge, Ausubel (2000) describes two properties for new material and relates them to the use of language to facilitate the meaningful alteration of cognitive structures. First, new material must be non-verbally anchored, i.e. it must be very difficult to simply recite it in one's mind a few times for commitment to memory, and second it must be non-arbitrarily anchored, i.e. the new learning material must be directly relevant to the learning at hand if it is to have relevance to prior knowledge structures. Hence, when new learning material is presented, the talk that surrounds the new material needs to facilitate its meaningful reception and insertion into current cognitive structures. So, words must be used in such a way that they permit increasing manipulation of concepts and inferences drawn from the new material. This permits the clarification of the meaning of new learning material, making it more precise and transferable to and from cognitive structures as they are created and retrieved from memory. The interplay between the properties of new material and the use of language ought to result in meaningful learning, i.e. the evolution of one's cognitive structures in response to learning, not just the rote learning and over rehearsal of knowledge into arbitrary cognitive structures that offer poor ideational anchorage for future use.

Language, in Ausubel's view and that of the many others cited, plays an integral, if not the foundational role, in the process of thinking; a role that is infinitely more important than its communicative function alone. Hence, Ausubel (2000) was an advocate of expository verbal instruction. This is a form of learning in which the material to be learned is presented as verbal language to the learners in a form that is 'more or less' already in its final form. But, in a form that still requires students to think about what they have heard to make sense of it so that it can be efficiently anchored to their prior knowledge. In this way, the student assimilates correct knowledge to produce high quality cognitive structures and reduces the likelihood of developing low quality (and later confusing or incorrect) cognitive structures.

As a pedagogical mechanism, expository learning has been disparaged by educational theorists (Ausubel, 2000). It is claimed that verbal learning promotes rote learning because students simply parrot what the teacher is saying. This has seen the rise of constructivist teaching practices with the suppositions that learning can only be achieved as a result of problem solving activities and that language is useless unless one has concrete, real-world experience with the language underpinning that subject matter.

Kirschner et al. (2006) address the fallacy of these suppositions. Their primary argument is that constructivist teaching practices are not compatible with human cognitive architecture, namely the role of working memory in learning. They note that constructivist practices, which have labels like experiential learning, problem-based learning, inquiry learning and constructivist instruction techniques, aim to immerse a student in the processes of that subject by which knowledge of that subject has been acquired. Accordingly, students will come to think of that subject in the same way that the experts think of their subject and thereby become masters of that subject. However, experts also have expertise in the methods by which their subject matter generates its knowledge, an expertise that is not acquired simply by convincingly parroting the words of that subject. To this end, Kirschner et al. (2006) observe that the practice of a profession is not the same as learning the theory of that profession, echoing Dewey's distinction of knowledge and understanding.

To substantiate their point, Kirschner et al. (2006) focus on the effectiveness of problem-based learning in the education of medical students. In short, they concluded that empirical data demonstrates that no overall benefit was gained by medical students taught by problem-based learning relative to conventionally trained medical students. Indeed, negative impacts on student learning were noted, being lower basic science exam scores, more study hours and the use of unnecessary pathology tests. Onyon (2012) reflects these findings on the efficacy of problem-based learning by medical students. She notes that despite their being an overwhelmingly sound theoretical basis for the use of problem-based learning in the education of medical students, no difference exists in the exam scores of so taught medical students. Given such disappointment, Onyon (2012) suggests that the uncoupling of the theoretical benefits of problem-based learning from its real world outcomes may be due to the imperfect world in which practising doctor's work, i.e. the real world tends to reveal theoretical deficiencies.

Kirschner et al. (2006) have a similar pondering about the hegemony of constructivist practices in teaching; why is it so pervasive when the empirical data strongly supports guided (expository) instruction over constructivist instruction? Their answer is simply that the assumptions of constructivist instruction seemed to cohere with the philosophy of how science works and the psychology of how knowledge is constructed, irrespective of cognitive science's bourgeoning empirical understanding of the biological processes underpinning knowledge construction. Rowe (2006) is equally sceptical of constructivist practices, noting that they are inadequate for the learning of students with and without learning difficulties (learning in the present as well as for the future), despite the wealth of empirical evidence indicating just that.

Working memory and the classroom.

In the classroom, working memory describes the ability of students to hold something in memory and manipulate it to find an answer to the problem at hand (Gathercole, et al., 2008). The absence of this ability is synonymous with teacher statements like, 'Get back to work' and 'Focus on the task at hand'. As information presented to the working memory of students is more under the control of the teacher than any other variable, i.e. the teacher controls the quality, the quantity, the when, the how, the why and the affect with which information is presented to students for processing and learning, it is the teacher's treatment of this single variable that is pivotal to the immediate educational achievement of students and also the development of their general cognitive attributes. If the teacher can generate a positive affect within the self-concept of the student and thus with the new learning material, the student is more apt to comprehend and subsequently learn the new material. Can talk play a part in generating affect AND learning?

Research into the role of working memory in learning has largely taken the form of statistical analyses. The methodology relies upon making correlations between tests of working memory and school achievement. As a general rule, statistically significant correlations are routinely demonstrated between working memory and school achievement (Al-Ahmadi & Oraif, 2009). Gathercole et al. (2008) and Alloway and Alloway (2010) note that working memory skills are closely related to student progression in reading and mathematics and those children with poor working memory skills have specific learning difficulties with reading and mathematics. Gathercole et al. (2008) examined the attentional behaviour and other executive functions of children with low working memory capacity in classes of 5/6 and 9/10 year old UK students. They reported that children with low working memory scores were distinctly over-represented in their teachers' ratings of students exhibiting cognitive problems and inattentiveness, i.e. they exhibited short periods of attention, were easily distracted, had difficulty in monitoring the quality of their work and creating solutions to problems. St. Clair-Thompson and Gathercole (2006) investigated the contribution that executive function and working memory played in school achievement of 11/12 year old UK students in English, mathematics and science. They also found that working memory capacity was closely linked with achievement in English and mathematics. More precisely, the central executive function of inhibition (the ability to consciously block out distractions) was linked to achievement in English, mathematics and science, that verbal working memory was correlated to achievement in English while visuospatial working memory was correlated to achievement in all three topics. Finally, Hussein and Reid (2009) reported that learning material modified to avoid overloading (i.e. making too much information available to) working memory while teaching chemistry to 15 year old Emirates students increased achievement by an average 13%.

In a different approach to correlating working memory to student achievement, Alloway, Gathercole, Kirkwood and Elliott (2009) first identified five to eleven year old students with low working memory capacity and then monitored their classroom progress within a range of rural and urban schools in North-East England. Alloway et al. (2009) reported that the majority of these students had a very high likelihood of not making adequate academic progress at school. They noted that this risk was accompanied by a distinctive behaviour pattern of inattention and forgetfulness. This resulted in frequent and unexpected interruption to classroom practices. The risk to academic performance was most pronounced in cognitive skills associated with reading and mathematics. Alloway et al. (2009) further note that after statistically controlling for the influence of general ability associated with reading and maths, working memory skills still predicted reading and maths scores. This is an important perspective for teachers to appreciate. It suggests that another learning pathway exists within every students' brain and one that may not necessarily being utilised in the classroom, viz. working memory difficulties may result in learning difficulties that are independent of cognitive skills (Alloway et al., 2009). Additionally, as classroom forgetfulness may obscure underlying failures in attention (Gathercole, 2008), of which a student may well be aware and of which the teacher may be unaware, perhaps deficits in classroom attention cascade into deficits in working memory and subsequently into disruptive classroom behaviour?

On working memory as an independent pathway in student learning in the classroom, Alloway and Alloway (2010) determined that it was a better predictor of literacy and numeracy skills than IQ over a six year period as children were educated to the age of eleven. Indeed, working memory has been proposed to be a more genuine measure of a child's learning abilities than IQ, which essentially measures knowledge already constructed, not how a child constructs knowledge (Alloway & Alloway, 2010). These authors also noted that measures of working memory were not significantly associated with socioeconomic measures, i.e. maternal education level, years in preschool and economic background, and that deficits in working memory cannot be made up over time.

Managing working memory in the classroom.

On the whole, the literature pertaining to working memory and school achievement indicates that working memory and conscious control of attention/effortful cognitive effort are pivotal processes in effective classroom learning. In line with this, strategies have been developed for teachers to implement into their L&T practices that reduce the impact of low working memory capacity on academic progression. For example, Gathercole, Lamont and Alloway (2006) note that the teacher needs to avoid overloading the working memory of students in order for them to complete the task at hand. The inability of the teacher to do this results in errorful learning and describes events such as losing track of the task at hand, forgetting what the task is about and losing track of instructions associated with the task. Recommendations thus include keeping instructions short and linguistically simple (common instead of jargonistic words and direct, “Do this…”, instead of relative, “Look at how Sarah did it”), having students repeat crucial task information in order to prevent forgetting, reducing the processing demands of tasks to avoid overtaxing working memory, taking instruction notes while listening to the instructions and using external memory aids to trigger recall of task-related information. Gathercole and Alloway (2007) also suggest that monitoring the work of students will facilitate the teacher identifying when tasks may be overtaxing working memory and thus indicate which of the preceding suggestions may need to be more explicitly addressed in the teacher’s professional practice. Possibly the most significant of the recommended teacher monitoring activities is that of asking the student directly in the course of the task what one is currently doing, why one is currently doing it and what one will do next. Thus, the overarching suggestion of Gathercole et al. (2006) and Gathercole and Alloway (2007) is to alter the format of learning resources to ease the student interaction with its cognitive structure to facilitate student learning.

The utility of the Gathercole et al. (2006) and Gathercole and Alloway (2007) suggestions must be balanced against their observation that the working memory age range of students in any class can vary by several years and that it pertains to research conducted mainly on primary school age children. Further, the efficiency of other learning pathways may themselves be compromised by such practices. Thus, in a class of 15 year old students, an age range of working memory capacities of 12-13 year olds to beyond 15 year olds and beyond may exist. As such, the described classroom recommendations are not likely to be warmly received by teenage students on the grounds that the teacher would be 'treating them like an idiot'. Or it could be that the teacher would be signalling to classroom peers that little *Tommy* is special and needs special attention, which would have a negative impact upon little *Tommy's* social identity and his peer identity. Nonetheless, there is no reason to suspect that adopting pedagogical principles derived from working memory would not have the desired effect of improving learning in this highly socially aware age group, especially those practices that ask direct questions of students.

Shell et al. (2010) formulated a model of learning that aims to 'subsume' all other models of learning by placing working memory at the core of the learning process. Their model, the 'Unified Learning Model' (ULM) derives 5 general rules of learning from the 'micro context of the neurobiology of learning' and applies those to the 'macro context of the classroom'. These 5 rules include: 1) New learning requires attention; 2) Learning requires repetition; 3) Learning is about connections; 4) Some learning is effortless, some requires effort; and 5), learning is learning (irrespective of how it is taught).

Ironically, many of these practices already reflect what it is that teachers do in the classroom. For example: feedback and assessment is a task routinely performed whilst teaching for no other reason than it helps the student learn from their mistakes; classrooms are routinely managed according to expected behaviours to encourage self-regulation; tasks are set that have several levels of achievement in them to ensure that a sense of self efficacy can be derived by completion of each level; Teaching is done in a scaffolded manner that aims to reduce cognitive load and sustain attention to the task at hand and goals are set for the student to achieve. Hence, the ULM is of intellectual (informational) interest because it does not really have anything new or innovative to say about classroom learning (knowledge of teaching). The work of Shell et al.

(2010) is not original in its content (scientific or professional) as far as the classroom teacher is concerned.

Three other authors provide useful teacher-friendly recommendations on how to use cognitive neuroscience in the classroom. Sousa's (2006) book, 'How the brain learns', Hardiman's (2012) book, 'The brain targeted teaching model' and Carraway's (2014) book, 'Transforming your teaching: Practical classroom strategies informed by cognitive neuroscience', provide excellent information on how to apply science to classroom practice. This is done via a series of 'practitioner's corner' sections, 'checklists' and other such cognitive organisers that permit one to audit one's classroom actions against actions aligned with the cognitive architecture of the brain. What these books do not do is give adequate recognition to the role of the teacher in influencing student learning; they present scientific information as a series of 'tick the boxes' and you will achieve this outcome. However, the distinction that must be made about the extent to which such checklists etc. actually become internalised by the teacher to become a deeper guiding principle in the moment to moment classroom interactions that result in student learning. They are also onerous in the amount of preparation required to fulfil all requirements and unfortunately, time is in short supply for the fulltime teacher. Battro et al. (2013) make a similar observation, noting that the vast quantity of cognitive neuroscience literature has been generated from the perspective of learning in the student brain that has come at the expense of the other side of the equation, teaching in the teacher brain[15]. What none of these books adequately address (in my professional judgement) is the role of language in learning, which is the crux of this thesis.

Hardiman (2012) notes that teacher are bombarded with initiatives from well-meaning education aficionados that have very little relevance to their classroom work. Consequently,

[15] Just to be clear, this work is about the teaching brain and what I as the teacher did to make it work better for the student brain.

they have developed a ‘sit and wait this fad out’ perspective to education initiatives[16]. Hence, though the work in the books is very interesting, the uptake of their recommendations would be patchy at best. Suffice it is to say that there is a mountain of literature on how teachers can improve their professional practice that for the most part, just does not gain traction in the professional practice of teachers (because we are forever told this is best how to do it, only to be told later that this is now best how to do it and so on, *ad infinitum*).

Working memory training.

Given that working memory deficits are associated with reduced student achievement at school, a lot of effort has been directed at correcting these deficits in order to improve student learning outcomes at school. Examples of such efforts include CogMed (http://www.cogmed.com.au/), Jungle Memory (http://junglememory.com/) and CogniFit (https://www.cognifit.com/). Such interventions exercise the different components of working memory with the anticipated effect that any improvements in working memory processes will be transferred to skills needed to enhance, say, school achievement. However, Melby-Lervåg and Hulme (2013), via a meta-analysis of 23 studies investigating working memory interventions, found little evidence that the benefits of working memory training were generalisable to other cognitive domains in typically developing children. Hence, their usefulness for improving school achievement is doubtful. This point is acknowledged by Cogmed (circa 2013), whose corporate caveats include that training gains will not last forever, that higher IQ scores will not be attained, that inhibition control and reasoning or long term memory will not be improved and finally, that it will not generate better grades at school. Despite Cogmed and Shell et al. (2010) relying upon almost identical scientific foundations to justify their claims, the Cogmed caveats also apply to the grandiose claims made of the ULM. *Ipso facto*, there is no reason to suppose that the work

[16] Just as I am sitting and waiting out a fad aimed at promoting teacher inquiry (the professional learning community concept) and for which its university education academic has acknowledged (personal communication, June, 2015) as not possessing any evidence that it will work in secondary schools.

of Shell et al. (2010) has any validity in the professional workplace of the teacher. Thereby indicating that the process of learning involves a lot more than proficiency in primary cognitive processes associated with memory (being possibly the human element that does not exist with these computer programmes).

The teacher, the classroom, language and cognitive development.

In the classroom, teacher professional judgement about the biological variables underpinning knowledge construction are not generally considered for their applicability to how they may promote learning. This is not due to a lack of professionalism or goodwill toward the learning of students on the part of the teacher. It is the absence of teacher knowledge about the biological basis of learning that fogs its significance to the professional practice of teachers; especially about the role of language in cognition.

For example: If teachers viewed talk as a motor nerve event akin to the catching of a ball and for which practice makes perfect, would the report by Adank, Hagoort and Bekkering (2010) that vocal imitation of an artificial language is essential to comprehension of that language find classroom application? Even if that were backed up with the report by Ramsden, Richardson, Josse and Price (2011) that verbal and non-verbal intelligence were co-located in an area of the brain where sensorimotor skills (like catching and throwing a ball) are processed? That tasks involving language skills (naming things, reading and counting aloud) more strongly activate the motor speech area than do tasks requiring finger press responses and finally, that the sensorimotor area contributes in some way to cognitive intelligence? Even if teachers knew that when students learn a new topic, it is like learning a new language? That, as a typical speaker of English can understand 1,000,000,000,000,000,000,000 sentences (Miller, 1950), there is plenty of scope for a student to not understand something the teacher said? That making sense of that sentence involved the workings of 100,000,000,000 nerve cells, with each nerve cell possessing 10,000 nerve input connections and a few nerve output connections, with the workings of these structures being largely unconscious (Baars, 1997). That the sound and sequence of language itself may provide a mental scaffold upon which cognitive processes later develop or, that as new classroom learning material is presented in a sequentially and scaffolded manner, sound may be superior to tactile and visual means for the encoding of temporal and sequential information of that new material (Conway, Pisoni & Kronenberger, 2009). And if language worked by facilitating the brain's predictive capacity to acquire the meaning of words and the manipulation of their inferences (Barsalou et al., 2007), would teachers refine their talk to make it a more effective learning resource for students in the classroom? And if deductive inference making and higher cognitive process (like reasoning) rely upon language as the bedrock upon which subsequent cognitive processes build (Barbey & Barsalou, 2009), would all of this help students to catch a deeper glimpse of the teachers' thought processes through shared dialogue and thus propel students become independent learners?

The notion that language is an important pedagogical tool and that language does not necessarily correspond with cognition has a long history (Hendrix, 1961). Indeed, it is arguable that this relationship did not garner adequate academic recognition until Gertrude Hendrix, a mathematics teacher cum teacher instructor, connected her observations of horse behaviour with student learning. Hendrix subsequently formulated a pedagogical method, teaching for unverbalised awareness, which suggested (more observationally than quantitatively) a fundamentally different type of learning occurred in response to her teaching method versus two other conventional teaching methods. Hendrix (1961) describes this method as one in which considerable effort is given by the teacher to set the stage such that when the penny drops, it can be applied without further teaching and before any conscious verbalisation of what has just been learned. Thus, the teacher teaches with the objective of producing better intuitions by students. The teacher's task in using language is thus to avoid the conscious, verbal coaching of students about how to apply the learning (the other two types of conventional teaching methods) and focus on communicating with students so that they pick up the patterning (i.e. the secondary labelling functions of language that serves as the mental scaffold for cognitive learning) of the learning at-hand (Hendrix, 1947).

The interactivist-constructivist approach to intelligence and learning (Christensen & Hooker, 2000) is a more formal expression of Hendrix's teaching to develop intuition. They have a holistic view of this process in which systems are distributed within the environment and within individuals that need to be integrated if that individual is to survive in that environment. An individual thus develops a model of what to anticipate in the environment under different environmental conditions. This may be managed in two ways, low order management and high order management. The former occurs in mosquitos; the female mosquito simply follows the carbon dioxide concentration gradient (as well as other odours produced by the attractor) to identify its food source. From these simple chemical cues, the mosquito does not anticipate that its buzzing sound nor its sting will result its being swatted and eliminated from the environment. Alternatively, a cheetah hunting its prey is an example of high order management. The cheetah must be aware of its environment in order to successfully stalk its prey to get close enough before pouncing. Then, the cheetah must anticipate that the prey will take evasive action and it must react in time with its prey, changing direction and speed to match. In this manner, the cheetah must use anticipation (intuition, prediction) to achieve a successful hunt, i.e. no hunt is ever the same other than the need for the cheetah to integrate environmental and bodily reactions to anticipate the next move so that it has a better chance of proving a successful hunt.

And this is what it is like with students in the classroom; students enter the classroom in a state of mind that forms the stage upon which learning will progress during the lesson. By using language to re-orient that state of mind, the teacher engages in a 'hunt' with the class/individuals to help the class anticipate a new state of mind that is conducive to the teacher's expectations and also classroom learning. In this new state, classroom learning then progresses with some altered but hopefully favourable state of affect that is mutually reciprocated, within the individual and at the class level, with students and teacher alike. Hence, a teacher is reflecting upon one's actions as they are occurring and adapting to student responses as needed to ensure that the hunt for learning progresses during the class. Or, a teacher is holding one's ground, expecting the students to follow the behavioural gradient defined by the presence of the teacher and adjust their state of mind to the teacher's expectations for the duration of the lesson.

The teacher's autobiographical self.

A teacher's autobiographical self can be described as that amalgam of formal and informal knowledge according to which they direct their classroom practices, consciously and/or unconsciously. Thus, the experience of their formal university education to qualify as a teacher forms, in some part large or small, a portion of their autobiographical self. Regarding the change in thinking experienced by student teachers in response to their education, Walker, Brownlee, Whiteford, Exley and Woods (2012) reported that all but one belief evolved over the three year course of a tertiary teaching qualification at an Australian university; that belief being that knowledge construction is not grounded in personal construction processes. That is, knowledge is constructed independent of the influence of the working self, self-defining memories and working memory. This view of knowledge construction, something that occurs passively yet optimally in the minds of the students as an exclusive function of the social milieu in the classroom, is a scientifically shallow and naïve understanding of the human mind. For the author, it was my prior learning about brain plasticity, working memory and epilepsy research experience that allowed me to have a greater appreciation of the contribution that biology plays in personal knowledge construction processes. It was also an understanding that was not received well by my teacher qualification lecturers. It was this understanding and its peremptory rejection from having any relevance to classroom learning that form the premise of the two most-human characteristics of my self-defining memories; connection to similar memories (i.e.

knowledge construction is a personal process that is still not adequately understood by education academics and teachers) and to an enduring concern (that the exclusion of this biological view of knowledge construction from the education of student teachers can only be to the detriment of the learning of their future students).

In Australia, teacher qualification programs are dominated by constructivism (Rowe, 2003, 2006 and 2007). Rowe (2007) observed that this had been the case since 1998 and I observe that it is still the case in 2015. Rowe distinguishes constructivism as a theory of knowledge construction that has little to offer the practice of how to teach. In doing this, Rowe outlines the assumptions upon which constructivism is supposed to work in the classroom; that students are intrinsically motivated to be actively engaged with classroom learning and that classrooms need to be authentic (i.e., it should replicate how that subject works in the 'real world'). In classroom practice, constructivism permits the justification of minimal teacher intervention in the student learning process on the grounds it is the child's responsibility to construct one's own knowledge if one is to successfully make one's own way in life, irrespective of whether or not the knowledge constructed is correct and suitable for subsequent learning. Constructivist practices, as enacted by the teacher in the classroom, thus decompose into prioritising teacher-student positivity and harmony in order to boost student self-concept and presumably, student learning efficacy. As Dinham (2014) indicates, constructivist practices are associated with unbridled positive reinforcement to cultivate such harmony. Students are 'pumped up' to believe their skills are exemplary yet rarely get a reality check on just how good their skills really are; consequently, student self-concept and achievement are artificially inflated at the cost of future achievement and self-concept. Though student self-concept has been identified as having a beneficial effect upon student learning, it pales in comparison to authentic achievement (Hattie, 2009); hard work and effort by the student supplemented with corrective yet supportive feedback from the teacher, is a more genuine way to promote student self-concept and affect toward future learning, “no matter how small” such authentic achievement may seem (Dinham, 2014, p.8).

Rowe thus characterises constructivism as an ideology that has little empirical evidence to justify its use as a teaching strategy. Further, he expressed dismay about the extent to which teachers, administrators and especially education academics that provide teacher qualifications accepted ideology as the basis for their teaching practices at the expense of empirical data. Indeed, Sasson (2001) has described constructivism as postmodern ideology masquerading as an educational theory of everything that shuns any sort of evidence to justify its mutation from a theory of knowledge construction that occurs in the mind of individuals to its real-world use as an effective method of teaching. It is this unquestioned confusion of theory (and one that is devoid of any consistent theoretical underpinnings to justify its movement from the philosophical workbench of academia onto the classroom teachers’ desk) with classroom teaching practices for which Rowe is most damming of Australian education academics.

Indeed, constructivism itself has been described as educations ‘grand unifying theory’ (Matthews, 2002). Consequently, constructivism is supposedly a caring, people-centred philosophy, in which individual ideas, personal theories, self and professional esteem and human development are sacrosanct (Watts, 1994). That is, as it is a philosophical view that meshes with a variety of educational agendas like multiculturalism, feminism and other such reformist initiatives, it is perceived as an educational panacea by which such social discrimination can be eliminated. So, constructivism is seen as being a morally superior pedagogical practice with which to educate and emancipate the next generation.

However, as Matthews (1992, 2002 and in Yalaki and Çakmakcı 2010) and Suchting (1992) have pointed out, constructivism is inherently relativistic (seeks coherence) in what it accepts as being considered knowledge. Hence, according to constructivism, knowledge cannot be imparted, it can only be socially constructed by the student at that moment in time (for better or worse). Matthews, in Yalaki & Çakmakcı (2010), recounts a 1992 seminar on constructivist learning and teaching practices that highlights the downfall of constructivism in science education (and more broadly with other topics) in the 'real world' of the classroom. Nails were placed in different chemical environments and students had to monitor the rate of rusting. Though the results were obvious, the underlying scientific principle was impenetrable to the student mind: "The theory that rusting is a chemical reaction between iron, oxygen and water, resulting in the formation of a new substance, is not one that students are likely to generate for themselves." (Scott et al., 1994, as cited in Yalaki & Çakmakcı, 2010, p.302). Subsequently, the authors state that though such a lesson may stimulate students to contemplate and question their own personal theories, it is unlikely to lead to the development of a scientific understanding of rusting (nor contribute to the development of a scientific understanding of the natural world).

It is this disconnection between the purpose of (science) education and the pedagogical means by which it is achieved that Matthews identifies as the fundamental problem of constructivism (as cited in Yalaki & Çakmakcı, 2010). Simply, students do not have enough of a scientific understanding of the material they are going to encounter in their classroom lesson in order to attempt to construct scientific explanations for what it is they are learning about; scientific explanations that have taken the collective minds of very knowledgeable adults hundreds of years to formulate. So, Matthews asks, "Why not just explain (*impart)* these ideas to students, and do it in such a way that they understand them?" (Matthews, 2002, p.130). Doing so would allow students to personally construct their own learning of the science being learned in the classroom but this would at least be done so upon a scientifically valid explanation provided by the teacher. So, it is unsurprising that Mayer (1999) concluded that constructivist pedagogy did not work and that if it did, it was only because constructivist principles were ignored, i.e. that knowledge can be imparted and does not have to be constructed anew by each and every student upon encountering new learning material. Matthews consequently observes that constructivism has not offered anything educationally useful in terms of classroom pedagogical practices for some 2,500 years, i.e. since Socrates' dialogue with Meno, and that the recommendations of constructivist pedagogy is essentially old wine in new skins (as cited in Yalaki & Çakmakcı, 2010).

Nonetheless, constructivism, as described by Vygotsky (1986), is the bedrock upon which classroom teaching practices are organised and justified. Vygotsky observed that language is a (if not the) central tool by which knowledge is transmitted through culture to facilitate learning; Vygotsky is, ironically, very much about the imparting of knowledge by language. Human culture itself is a product of the exchange of human language, which both co-evolve to influence each other and permit the generation of cognitive niches (viz, Pinker, 2010). Wheeler and Clark (2008) describe this interaction of culture, language and biology as the triple helix, an interaction that occurs between language and culture in the space of the person to create new ideas and ways of using language by that person for sharing with other people. Yet in the classroom, the importance of language as a means of imparting knowledge has been forgotten, to be replaced by an emphasis on the processes by which knowledge may be created.

Gee (2004) describes how this space may operate. Gee observed that children from socioeconomically disadvantaged backgrounds possessed comparable linguistic skills as those from non-disadvantaged backgrounds. This was based upon the comparability of knowledge that both sets of children acquired from their interaction with the Pokémon game world; a linguistic world in which technical detail about Pokémon skills permits children to engage in battle and trading activities to establish Pokémon supremacy. In learning the rules associated with Pokémon battles and trading, Gee (2004) noted that the learning was not acquired by studying the accompanying Pokémon fact sheets but rather by interacting with other Pokémon players from whom the children acquire and develop their language skills.

At around 4th grade in primary school, this equality in linguistic skills deteriorated and children from non-disadvantaged backgrounds started to accelerate in their learning whilst the disadvantaged students began lagging. Gee (2004) identified that the former students possessed a prototype academic language skill that facilitated their learning as school learning material became more complex, which became especially pronounced as reading became a more heavily relied upon as resource for student learning. This prototype academic language skill had its origins traced back to the family environment where rich and challenging dialogue was exchanged between the parents and/or significant other adults/siblings/relatives.

Reflecting upon his own learning experiences by reading the instructions of real time strategy games versus actually playing the games, Gee (2004) observed that the mind needs to run mental simulations of what it is encountering in order to comprehend it. In this way, spoken language and written language (words with different formats) are given meaning via previous experiences being 'relived' within the new context surrounding the new language. In the context of schooling (and specialist subjects like science), Gee (2004) argues that students can understand content, be it a comic or physics text, when that content is related to activities that allow them to talk and make decisions about how it relates to their experienced world. In this regard, Gee (2004) indicates that learning new words and ideas at school (or in the family for that matter) is dependent upon the student being able to experience the 'world' to which content specific words are associated. Thus, Gee (2004) recommends that to develop reading skills, students (and people in general) be allowed to 'play' with content specific words in a way that allows student to attach content specific meaning to the way that language is used in specialist areas. In developing such content specific meaning, Gee (2004) is clear in his statement that the development of language ability is dependent upon the intense engagement between the teacher and more advanced students such that they experience cognitively challenging talk. So, student vocabulary is expanded by the teacher and their ability to run mental simulations is enriched, giving broader meaning to words and one's ability to read. Thus, according to Gee (2004), the teacher as the significant adult in the classroom is the affective focal point of spoken and written words from which students run simulations to experience the 'world' of that subject (science) as they learn in the classroom and develop their knowledge.

Conventionally, the teaching of reading skills proceeds independent of the teacher as the affective focal point. Ken Rowe, the Chair for the Australian Government report, 'Teaching Reading: National Inquiry into the Teaching of Literacy' (DEST, 2005), noted two methods by which literacy was taught to primary school-aged students, the whole language approach and the phonics approach. The whole language approach is akin to a teacher immersing students in language who subsequently pick up on how the language works to become literate. On the other hand, the phonics-based approach requires the "explicit teaching of the structure and function of written and oral language in ways that allow children, regardless of their backgrounds, to reflect on and consciously manipulate the language" (DEST, 2005, p28). The report notes that the whole language approach is underpinned by constructivist philosophy in which "children are viewed as inherently active, self-regulating learners who construct knowledge for themselves, with little or no explicit *language* decoding instructions" (DEST, 2005, p.28).

In the whole-language classroom, Daniels (2001) describes the role of the teacher as that of facilitator, orchestrating the social milieu of the classroom. In this case, the teacher aims to ensure that students develop their own meaning of learning goals as it is constructed through their interaction whilst engaging in activities that promote interaction, discussion and reflection with their peers whilst foregoing correction by the teacher. This is in contrast to the role of the teacher in the phonics-based classroom. Here, the teacher is the director, providing explicit direction about the correct way to sound-out, pronounce, spell and use words in appropriate contexts. In neither case, whole language or phonics-based, is the teacher an ‘actor’ in the developing cognitive niche of students.

Westwood (1999) hints to the extent to which the role of the teacher is skewed from that of director to that of facilitator (but ultimately away from actor). It was noted that 79% of teachers in South Australia were strongly encouraged to apply constructivist philosophy in their initial teacher training and subsequently in their professional development, with 67% of trainee teachers indicating that they were not aware of any other approach to teaching other than constructivism as it was presented by their university. As of April 2015, this state of affairs has been conserved: Both Canberra University and the University of New England do not provide any teacher qualification that addresses the cognitive architecture through which learning occurs. Consequently teachers graduate form these two institutions without an iota of understanding about how and/or why students construct their personal knowledge of the topic they are studying. Let alone the importance of language in cognitive development.

In exploring classroom language, Anderson (2004) found that as far back as the ‘60s, teachers did most of the talking. Topping and Trickey’s (2014) review of this area and the results of their intervention suggest that not very much has changed. In response to their dialogue-rich intervention, which aimed to promote reciprocal teacher/student and student/student questioning, they reported a 25% increase in the ratio of student/teacher dialogue. In doing so, they also noted that changing teacher and/or student verbal behaviour is very difficult; it is akin changing one’s attitudes and way of thinking about education. Nonetheless and more broadly, Trickey and Toppings (2004) metareview of such intervention strategies for primary and secondary school students found an average effect size of d =.43 for outcomes that included reading, reasoning, self-esteem and improved behaviour.

The upshot of constructivist philosophy upon teacher education is that the autobiographical self of the teacher acquires an understanding that individual student differences arise exclusively because of differences in their social backgrounds. Apparently, these differences do not stem from individual differences in the level of working memory maturity, from gene expression differences nor language usage by teachers or from any other biological root. Individual differences are solely the result of social factors! So according to social constructivist doctrine, the multitude of underpinning biological processes upon which learning depends will be automatically synchronised and learning optimised in response to the ideal classroom social environment. Hence, student learning occurs via student behaviour being normalised to the teachers' behavioural expectations of what constitutes the perfect social environment of the classroom. Consequently, teachers focus on generating the optimal social environment for students to interact and learn because it is that which will naturally result in student learning and do not consider themselves an integral variable in how that social world works.

Yet there is no good reason to suspect that the social world of the classroom will achieve this effect. In attempting to dispel the notion that the environment is the 'be all and end all' of human differences, insofar as it pertains to individual reading differences and teacher quality in the classroom, Olson, Keenan, Byrne and Samuelsson (2014) note that classroom effects are consistently small; accounting for variances from 4% (Byrne et al., 2010, cited in Olson et al., 2014) to 7% (Nye, Konstantopoulos & Hedges, 2004, cited in Olson et., 2014) and to 10% (Kovas, Haworth, Dale & Plomin, 2007, cited in Olson et al., 2014). Though these studies were conducted on children in grades 1 to 2, Olson et al. (2014) also note that after a year of formal school reading instruction, what is secondary education if not more formal instruction in reading?: The 'bottom line' is that individual differences in spelling, reading and reading comprehension are still extensively influenced by gene expression (more so than environmental classroom factors may account for).

In practice, that is in the classroom where teaching and learning occurs, the influence social constructivism has acquired is of a deity-like status. Its catch cry is that student diversity must be identified and appropriately diagnosed so that student learning needs can be differentiated and catered to. That is, different students have different learning styles, so the teacher just has to figure out the learning styles of students Jack, Jacqui and Jonah and conduct their professional practice accordingly. Pashler, McDaniel, Rohrer and Bjork (2008) reviewed the mountain of literature pertaining to learning styles and concluded that the evidence to justify it as a professional practice was, at best, scant. Indeed, the core evidence needed to scientifically justify the use of learning styles as a professional way of thinking about student learning needs is missing. Consequently, the biological role of language in promoting learning and thought is not adequately exploited by social constructivist teaching practices because the social constructivist philosophy masks the role of biology and its individual variability from teachers' professional thinking.

Conventional (counterfactual) learning and teaching practices.

Classrooms are diverse environments of student capacities. This diversity is foremost a function of the social world from which the students originate and therefore, this social diversity needs to be catered to in order for the students to learn. Consequently, Conventional teaching practices rely upon a range of tools with which students are to engage to facilitate their learning process. This involves, but is not limited to, group work (peer selected or teacher assigned), note taking, the modelling of quality work by the use of scaffolds and reading books, along with some talk with the teacher. Typically, the use of such tools requires only that the teacher administers the use of and monitor the progress made with these learning resources. Hence, the teacher is removed as the principal learning tool for the students and remains a critical observer (not active participant) in the process of student learning. Underpinning this deflation of the teacher as the primary learning tool in the classroom is the assumption that learning is constrained by the social world of the student. Ipso facto, it is the student's responsibility to wholly engage with and struggle with the provided learning resources if one is to learn, achieve and develop lifelong learning skills.

This learning environment manifests itself in the teacher with a conception of the student mind as, above all, something that only requires behavioural guidance. Thus, an effective classroom is one in which students are wholly engaged with the use of these learning tools, are focused on the task at hand, are not distracting other students and/or the teacher and are generally well behaved young people. Unfortunately, such a behaviourally-based teacher conception of the student mind leads the teacher to underestimate the potential of the student mind for learning by not paying due consideration to how the student mind processes language as it is learning and in response to the classroom practices of the teacher.

The propositions of the Conventional classroom learning.

Emerging from the behavioural conception of the student mind are five propositions that guide the routines of professional practice in the Conventional classroom. It is proposed that these dampen the contribution the contribution that language may make to student learning.

Proposition 1: Select a resource that meets learning needs and which is located in the classes ZPD.

Proposition 2: Deliver the learning resource to the class and bring it into their ZPD by introducing the topic and calling for thoughts on the topic.

Proposition 3: Allow students to work through the resource, offering minimal assistance so that it is the students who extend and develop their own ZPD at their own pace, not the teacher.

Proposition 4: Control the class's behaviour to ensure that students give their attention to the learning resource and thus engage with and learn from the provided resource, not socialise with each other.

Proposition 5: Request that those students who have not completed the task complete it for homework.

Bios learning and teaching practices.

Alternatively, classrooms are diverse environments of student capacities. This diversity is foremost a function of the brain's predictive activity of the moment in the classroom. The brain is, at its core, an information processor constantly engaged in making predictions within and between its biological, psychological and social realms, and most likely not about events pertaining to classroom learning (Karli, 2008). Thus, learning is a complicated, highly individual process that is nonetheless underpinned by common biological processes. The brain has evolved to process language data with greater attention than visuospatial data. This is due to the information density of phonological data providing a greater array of predictions because of the evolutionary immediacy of sound to survival. Predictive creativity and evaluation is a function of data stored in long term memory. All long term memory passes through working memory where it is encoded with events associated (relevant or irrelevant) with the learning of the moment. The key aspect to working memory associating relevant events for more efficient long term storage, retrieval and manipulation back in working memory is real time shared attentional engagement with the teacher's mind. Thus, the assumption is that the mind is programmed to learn and this is only constrained by the conception of mind that the teacher brings into the learning environment.

A human being is a social creature that needs social interaction as an essential experience in its development throughout life. In making its way through life, Karli (2008) proposed that the brain acts to integrate, mediate and unify life's experiences. He espouses viewing the human being as a trinity composed of a biological individual, a social actor and a self-conscious, reflective and deliberating psychological subject. These three identities are in dialogue with their own respective environment, being the living organism's material world, the actor's social milieu and the subject's inner world. Further, each source of dialogue is in a constant two-way exchange of new information with its counterparts. Karli (2008) suggests that this flow of dialogue is teleological in nature and as such, the brain is concerned only with the means by which goals can be attained. Thus, much of the brain's dialogue is dedicated to constantly evaluating/predicting the efficiency of goal attainment within/between these three identities, both before and after action. Finally, the nature of this tripartite dialogue is temporally dependent upon the momentary functioning of the brain in response to its environment. Hence, the software of accumulated experiences influences the physical structure of the brain which in turn alters the way the brain processes information. Simply, the brain is formulating its own potential futures as it imagines them in response to the moment. In the classroom, it is the memory embedded within the brain's structure that is being challenged with alternative cognitive structures being presented in the class. What can a teacher do to make this challenge have a greater educational influence?

Bar (2009) also suggests that the brain proactively generates predictions in anticipation of future events. He suggests that this occurs via an analogy→associations→predictions mechanism. That is, as information enters the brain, its processing begins with the question, "Is this input similar to anything already experienced?" in order to find an analogous memory that would speed up understanding of the new information. Once a match is found, it triggers the rapid spreading activation of those memories and from which subsequent predictions are generated about what is probably likely to be next encountered. It is most likely that numerous matches will be found for any single input, that these may be perceptual, conceptual, semantic, functional and episodic (i.e. whatever type of memory serves to be predictively productive) and that they would be processed in parallel to generate complex predictions beyond the immediate input context, if needs be. For example, predictive events may be as simple as figuring out whether or not a branch will hold one's weight to complex predictive events like the mood of a crowd and one's safety in that crowd. Such predictive activity of the brain has been termed 'memory for the future' (Eichenbaum & Fortin, 2009) and has been suggested by Bar (2007) as being an off-line (i.e. non-attention requiring cognitive task) property of the declarative memory system from which future possibilities may be harmlessly explored relative to their current situation.

This simultaneous conception of the student and teacher minds alike manifests as a learning environment dominated by dialogue that may or may not be on content task. In either case, the natural prediction-making activity of the student mind is engaged with by the teacher, in real-time interaction, to sustain general attention and thus provide sustained exercise in the prediction making activities. In the context of science, this requires the teacher to think aloud to model the cognitive processes associated with establishing cause and effect relationships about natural phenomena (but also with whatever is occupying the mind of the student at the time). Attention therefore is given by the mind of the student in the classroom and the student mind is more fully engaged in its learning. Thus, the teacher is the primary learning resources with which the student engages in the process of learning.

Hence, an interesting question to explore would be, "Can teacher talk provide some breathing space between the past and future cognitive structures to help students engage more consciously and rationally with the dynamic interaction of different cognitive structures of teachers, themselves and their peers alike to become more efficient and effective learners?"

The propositions of the Bios classroom learning.

Emerging from the cognitive conception of the student mind are five propositions that guide the routine of professional practice. It is proposed that this results in richer and more extensive teacher/student and student/student dialogue to facilitate student efforts in the construction of their own cognitive niche as it relates to science.

Proposition 1: Students are given the latitude to ask what seem like obtuse questions about what it is that interests their minds in the moment in relation to what is being discussed in the class. This permits connections to be formed between the topic at hand and the memory structures of individual students. In this way, student socialness and its dependency upon dialogue are brought forth into the classroom as a means of establishing interpersonal rapport.

Proposition 2: Dialogical exchanges are engaged in with the aim of keeping students thinking laterally from their initial question. This sustains the prediction making activity of the mind and the engagement of the central executive and language processing via the phonological loop. Thus, by soliciting from students their own thoughts and subsequently, the evaluation of their thoughts through shared teacher dialogue, students fine tune their thinking skills and associated cognitive scaffolds against those of the teacher (foremost) and their peers.

Proposition 3: Learning material is chunked and consolidated into small pieces, reiterated numerous times (as needed) and reinforced once with simple diagrams and/or short passages of whiteboard text. This facilitates generally the networking of working memory processes as knowledge is constructed.

Proposition 4: Textbooks are used sparingly as a teaching tool. This draws upon executive functions of working memory by promoting self-directed refocusing of attention onto classroom learning and sustained student engagement with classroom ongoings. That is, students are not sent off into the solitary world of text within which they may not have adequate reading skills to construct their knowledge.

Proposition 5: Disruptive behaviour, i.e. social interaction independent of the learning of the topic-at-hand, is accepted as a normal aspect of teenagers and downplayed. This draws upon student desire to maintain a socially and talk-rich learning environment in which students exercise attentional control over the course of their learning.

The five bios propositions as they are routinely enacted in the classroom.

The duration of a Science class lesson in my school is 50 minutes. Usual opening and closing routines eliminates 5 to 10 minutes from the lesson, leaving 40 to 45 minutes for teaching. Each lesson begins in a welcoming and relaxed manner. The lesson topic is informally introduced to lead the students into a settled and attentive state of mind. At this point, when a general level of group attention is evident, a few key words of the topic at hand are spoken and explained in very simple language and a very casual manner. Almost inevitably, at least one student will have some perspective on that dialogue which they then contribute to the class. This triggers input from the teacher and other students and dialogue is continued on this basis. Throughout this process, minimal attempt is made to control the direction of the dialogue, other than it is appropriate and in some round-about way relevant to the topic. This is the first key distinguishing feature of the Bios lesson: Students are given the latitude to ask what seem like obtuse questions about what it is that interests their mind in the moment in relation to what is being discussed in the class. This permits connections to be formed between the topic at hand and the memory structures of individual students. In this way, student socialness and its dependency upon dialogue are brought forth into the classroom as a means of establishing interpersonal rapport. On many occasions, great patience is needed to allow such dialogue to run its natural course and for students to realise when they have digressed for long enough and get back to work (usually three to four minutes).

Subsequently, focused questions about the topic at hand are then asked to stimulate greater critical and personal engagement with classroom dialogue. Such questions involve requesting students to make predictions about events and then working backwards, with guided dialogue, to figure out whether their prediction is logical. This is the second key distinguishing feature of the Bios lesson: Dialogical exchanges are engaged in with the aim of keeping students thinking laterally from their initial question. This sustains the activity of the central executive and language processing via the phonological loop. Thus, by soliciting from students their own thoughts and consequently, the evaluation of their thoughts through shared teacher dialogue, students fine tune their thinking skills and associated cognitive scaffolds against those of the teacher and their peers.

When it seems that students have adequate dialogue and are comfortable enough with the topic at hand, a diagram will usually be drawn on the whiteboard and labelled with the language used in the discussion. Alternatively, a few sentences of dictation will be given in which the words and ideas of the students are used to record the learning that has just occurred. If knowledge essential to understanding is to be learned, it will be written on the whiteboard in scientific terms for students to copy down. Subsequently, teaching switches back to discussion and the whole process is continually layered so that a pedagogical pattern emerges in which cycling between talk, visual reinforcement and to finish the topic off, a chalk and talk session is presented in which talk is concurrent with drawing. This is the third key distinguishing feature of Bios lessons: Learning is chunked and consolidated into small pieces, reiterated several times and reinforced once with simple diagrams and/or short passages of whiteboard text. This facilitates generally the networking of working memory processes as knowledge is constructed.

As a rule, textbooks are used sparingly as a teaching tool, the fourth key distinguishing feature of Bios lessons. This draws upon executive functions of working memory by promoting self-directed refocusing of attention onto classroom learning. Additionally, textbooks may be used for students to read a brief section about essential knowledge of the topic at hand. In this case, the textbook is simply used as a means to provide a reading consolidation of the learning that has already occurred via dialogue. In either case, the reading of textbooks is minimised in favour of scientific dialogue as it is harder for students to feign attentiveness to talk during learning than it is whilst simply copy out textbook notes.

In the event of unruly classroom behaviour, disruptive behaviour is accepted as a normal aspect of teenagers. As such, the class is asked to be quiet as the teacher maintains a patient pause until after the message has spread, more often than not via students asking their peers to quieten down. Then, calmly but with great authority, indicating that such disruption is unfair and must be toned down because it is preventing the teacher from doing the best job possible. A continually disruptive student would be spoken to quietly and/or offered a rest period outside for a few minutes to regain their composure. "Right then, let's get back to it!" This is the fifth key distinguishing feature of Bios lessons: Disruptive behaviour is accepted as a normal aspect of teenagers and downplayed. This draws upon student desire to maintain a dialogically rich and accepting learning environment in which students exercise control over the course of their learning.

Science classroom lessons were 50 minutes with seven lessons per fortnight. Each term was about 10 weeks with four terms per year. This totalled to a maximum of 116 hours of science classroom lesson time (less time lost for assemblies, excursions, illness, etc.). In this time, every student, to some degree or other, would actively participate in sharing their ideas about science.

The core neuroscience concepts that inform L&T practices.

Dubinsky, Roehrig and Varma (2013) presented a case study where they investigated whether or not an understanding of cognitive neuroscience by the teacher impacted upon classroom teaching practices. Participating teachers attended 'Brain U' workshops to learn how the core neuroscience concepts aligned with L&T practices (Society for Neuroscience, 2008, as cited in Dubinsky et al. 2013). These were presented in two weak intensive professional development session to teachers over a three year period. The eight core neuroscience concepts included:

1. Learning strengthens a set of electrical and chemical events at the level of individual neurons that, over time, result in functional associations distributed throughout the brain. The act of remembering opens up this synaptic set for further plasticity.
2. Behaviours, thoughts, and memories result from activation of different sets of associated synapses and neural pathways. Partial activation of a synaptic set subserving a specific memory can result in reconstruction of that memory with reasonable but variable fidelity.
3. Synaptic pathways are loosely grouped into sensory, motor, emotive, homeostatic, attentional, and decision making systems, among others, within the central nervous system.
4. Experiences during early childhood development in conjunction with genetically determined development shape these pathways. They continue to change throughout life in response to every interaction. Mastery involves changing the brain system used for executing a task from deliberative to automatic through rehearsal, application, and self-evaluation.
5. Repeated behaviors or salient experiences influence synaptic and circuit development more than single or irrelevant ones. Only experiences with an emotional stamp become committed to memory; decisions require operational emotional circuits.
6. Because there are so many neurons (>100,000,000,000) and so many more synapses (~1,000,000,000,000,000) in the human brain, the activation patterns producing similar behaviours in different brains can be largely comparable yet decidedly unique and individual.
7. Physiological status, e.g., nutritional and hormonal state, stress, availability of oxygen at high altitudes, and adequate sleep, will influence one's ability to learn, remember, and make appropriate decisions. Emotional status implies a specific physiological state.

8. The complexity of the nervous system endows us with powerful reasoning and communication skills and curiosity about ourselves and our environment. Structured learning environments provide opportunities for building these skill sets.

In general, Dubinsky et al. (2013) concluded that teachers participating in 'Brain U' were significantly more knowledgeable ($p \leq .05$) in their understanding of cognitive neuroscience and its role in the classroom. By the end of the third year of 'Brain U' professional development, observations of the teachers' classroom practices compared to control teachers' classrooms revealed increases in effect sizes of $d = 1.8\text{-}2.2$ ($p < .001$). The parameters of student learning assessed included higher order thinking skills, deep knowledge, substantive conversations and connections to worlds. In short, knowledge of the core neuroscience concepts that underpin L&T had a positive effect upon the classroom environment; arguably being principally mediated by the exchange of dialogue (substantive conversations) between the student(s) and teacher. As core neuroscience principles, they are open to appropriation, mutation and adaptation to what works for each individual teacher in their classroom. Hence, the next stage for this research would be for the Brain U teachers to reflect on their new mode of professional practice to identify their pedagogical propositions and whether or not these translate into cognitive gains in student achievement.

Comparatively, Bios L&T practices are reflective of the L&T practices of the core neuroscience concepts. However, Bios L&T practices build upon these by proposing the behavioural actions with which a teacher may engage students to facilitate memory formation and cognitive development. Comparable effects may thus be fairly expected of Bios L&T practices.

The professional and academic context.

At present, there is little, if any, empirical research that investigates the effect of working memory on student learning and achievement when the teacher embodies working memory as a pedagogical process in the natural setting of a classroom composed of 15/16 year old students.

Though the field of cognitive neuroscience has enormous potential to improve student learning, the focus of this work has been squarely placed upon how students learn: It has not equally addressed the other side of the equation, the cognitive neuroscience of the 'teaching brain' (Battro et al., 2013). In the studies cited, the measurements of working memory are performed independently of the pedagogical processes that contributed to the item of school achievement being examined for its correlation to working memory. So the question arises, "*Is language something that I can manipulate in myself, my teaching brain, to facilitate working memory knowledge construction processes and bind teenage socialness and attention via the use of dialogue into their classroom L&T practices to facilitate student engagement with classroom learning?*"

Aim.

The aim of this research is investigate whether or not the application of cognitive neuroscience information to classroom L&T practices has practical value in student learning.

CHAPTER 3: Methodological framework.

Nature of the study.

The research in this study is *ex post facto*, being of a causal comparative nature. Cohen, Manion and Morrison (2007) describe this design as one that seeks to retrospectively clarify the relationships between variables in pre-existing data sets by comparing one data set to another in order to identify and quantify cause and effect relationships. As such, the study is inherently counterfactual in analysis and reasoning. Roese (1997) defines counterfactual thinking as that which is contrary to the facts. To be a meaningful counterfactual state, it must be possible that the variable manipulated in one state must also be able to be manipulated in the other, viz. all things are equal except that variable being manipulated (Winship & Morgan, 1999). Consequently, the causal factor is that factor without which the effect in the treatment state could not exist (Höfler, 2005), which in this work is hypothesised to be Bios L&T practices.

In counterfactual thinking, the one criterion about which its credibility revolves is temporal direction, i.e. the intervention must come before the effect (Höfler, 2005). Temporal direction is the pivotal criteria because a causal effect is defined as the difference in outcomes between the treatment and control states; $t \neq c$ (Herman, 2004), i.e. $t - c > 0$. In this study, the control state was the learning of science in other classes according to Conv. L&T practices, i.e. the control Conv. L&T practices represent the counterfactual state. The treatment state was the learning of science in my classes according to my Bios L&T practices. It is against these counterfactual control classes that reasoning was applied to determine the nature and mechanism of whatever Bios causal effect may be detected. Ipso facto, that of Conv. L&T practices.

That the treatment preceded the effect was a workplace necessity. I had to have taught my students before their Science tests otherwise I would not have been doing my job (and would not have a job) and my students would not have passed their exams. Additionally, the fidelity with which I adhered to Bios L&T practices was unencumbered by a sneak peek at its results, something that may have altered the ‘naturalness’ of the study environment. This state was necessitated by the need to have time to teach myself how to conduct and interpret the statistical analyses, something that only became available upon completion of the study.

As causal effect studies typically occur in natural settings, i.e. the classroom, it is impossible to scientifically control variables by randomly assigning students to treatment and control conditions. Doing so may present ethical issues. For example, if a group of students were assigned to one teacher to be taught in one manner and another group assigned to another teacher to be taught in a different manner, and the learning of one of those groups did not equal the other, all manner of objections could be made by parents, teachers, bureaucrats, etc. etc. For this reason, variables are statistically controlled in causal effects studies. Hence, groups of students with similar learning characteristics were identified and used as the control groups. By focusing the study on comparable groups, analysis of the data is thus focused on the process of learning; not the outcome.

Höfler (2005) also notes a single caveat for causal effect studies, that it is not possible to have 100% evidence of causality. It is simply a matter of how much evidence can be collected in practice and the types of statistical models that can be used to accumulate evidence. In this work, regression analyses in different forms, bivariate, multivariate and multiple mediation, were used to progressively explore in finer detail student learning outcomes in response to different L&T practices. The bivariate and multivariate regressions examine the direct effects that different L&T practices may have upon student learning. For example, a variable may be more strongly associated with one set of L&T practices than another.

Alternatively, a causal effect may have an indirect origin because many causal factors may coalesce to generate a direct effect. By referring to the manner in which prescribed drugs influence disease states, Höfler (2005) notes that they may trigger a cascade of effects (of biological, psychological, pharmacological and/or social origin) that then lead to the desired direct effect outcome. That is, variable *a* causes affect *b* because it has an effect on variable *c* that then affects *b*. This can be investigated by multiple mediation modelling (Hayes & Preacher, 2014).

In the classroom setting, it is entirely feasible that multiple causal effects may co-exist; indeed it is only to be expected given the complexity of the environment. This is a state untenable to laboratory based researchers whose focus is on individual variables, not the plurality and interactivity of variables in their natural setting. Causal effects and counterfactual thinking is thus pragmatic; evidence is drawn from practical situations for quantitative analysis and contrasted to provide rich insight into the workings of natural systems.

Cohen et al. (2007) document the advantages of ex post facto research. They include that such research:

1. Meets an important need of the researcher where the more rigorous experimental approach is not possible.
2. Yields useful information concerning the nature of phenomenon.
3. Is more defensible due to improved statistical methods.
4. Can be more useful than experimental methods because no artificial control is introduced into research process.
5. Is particularly appropriate when simple cause and effect relationships are being explored.

6. Can provide a sense of direction and alternative models to which experimental methods can be applied for more stringent investigation.

Indeed, the causal comparative design is most useful in educational research precisely because of its inability to scientifically control variables. First, as the independent variable cannot be artificially manipulated to solicit the expected effect from an experimental group, knowledge that is obtained is more reflective of natural classroom processes and whole school practices. Thus, such knowledge is more generalizable to the professional practices of other teachers because it was probably derived from natural conditions reminiscent of their own classrooms. This also means that the causal comparative design lends itself to pragmatic (not academic) empirical model-making about events in their natural (not laboratory) setting. Consequently, improved models of classroom practices can be formulated from pragmatic analyses of quantitative data that may then lead to shared theories of practice. The causal comparative design is thus quasi-scientific: It attempts to reconcile the multifaceted propositions of different pedagogical practices with statistical measurement of their influences on student learning using statistically identified controls.

Before proceeding, I must emphasise that Bios L&T practices originated from workplace counterfactual thinking and which resulted in the a priori formulation of the five Bios propositions. The counterfactual trigger was my realisation that my own professional experience (and more significantly, the university qualification I completed to become a teacher) possessed little scientific foundation; which for a scientist was disconcerting. Conventional classroom lessons could be summed up simply by five propositions that were repeated day after day after whole school year, irrespective of the year group being taught. So, whilst I was a science education lecturer at a local university in 2007, I imagined an alternate future, "What would my teaching be like if I mutated science to fit in with the classroom environment?" I mapped out this mutation and formulated a series of propositions, implemented these actions into my classroom practice. I measured its effect at the end of the journey to figure out if an imaginary reality had indeed been arrived at.

Justification for the statistical methods of the study.

Sophisticated regression methods could have been applied to this data to determine if $t \neq c$; specifically, value added models (VAMs) and structural equation models (SEMs). These are topical techniques in quantitative educational research because they aim to fractionate out from the myriad of variables influencing the classroom that effect solely attributed to the influence of the teacher on individual students in the classroom. However, VAM methods are still experimental (Wainer, 2011). And so, how they achieve this fractionation is of concern. Hubbard et al. (2010) note that mixed models (like VAMs) rely on assumptions about the underlying structure of the data, assumptions which cannot be tested. Hence, VAMs rely on the modeller's discretion to correctly specify the equation by which the fixed effect (that effect attributable to the teacher) and the indirect effects (the assumptions about how all the other random effects are distributed in the data but in unknown quantities and/or relationships) are estimated. It is these indirect effects, social support and peer relationships and teacher relationships, which defy laboratory manipulation because they are so hard to observe outside their natural setting, i.e. in the classroom (Höfler, 2005). The consequence of this is that the interpretation of VAMs may be complicated by model parameters and susceptible to erroneous assumptions made about the natural setting it is trying to represent.

Wainer (2011) raises additional concerns about the utility of VAMs. That is, their ability to assign precise measurements to the extent to which a teacher has changed the person of the student. He notes that almost half the measured teacher effect derived from VAMs can be dependent upon the type of VAM applied (which is a function of modeller preferences). Further, as the end-user of VAMs, the teacher, has little to no input into the specification of the regression equation, VAMs become more of a cognitive artefact of the modeller's judgement rather than a tool into which conscious mental effort has been invested by the teacher. Without this intellectual ownership, such 'data tools' are not favourable to professional ownership and manipulation in the classroom reality to improve the professional practice of teachers. Still further, VAMs do not incorporate any latent affective component of the teachers' professional practice. That is, that part of teaching that *turns on* a students' interest to ask questions about a topic but which is not captured in a data set though has life changing potential further down the track: "I really liked maths/science/geography even though I hated it or wasn't any good at it. But I'll give it another go and see how I go…"

Höfler (2005) raises similar and other concerns about SEMs. For instance, that model assumptions are not fully justified (McDonald & Ringo Ho, 2002) and alternative assumptions are avoided (McCallum & Austin, 2000), making SEM results problematic to interpret because there is no way to model the impact of these assumptions upon the model itself (Stefanski, 2001). Additionally, SEMs have been found to generate results that are not reproduced in experimental settings (Lalonde, 1986). Finally, from my direct experience in working with SEM's and VAM's, modellers try to compress too much information into a single equation, viz. all the interactions stratified and nested etc. so that they become almost invisible to the mind. The consequence of this is that it is very difficult to focus on one single variable and think about its role in the classroom. Thus, Hubbard et al. (2010) state that multivariate regressions are better than VAMs because they probably provide a truer representation (but not 100% knowable) of the phenomena being studied. Also, Höfler (2005) recommends that caution be exercised in the use of SEMs.

On the matter of group versus individual data analyses, Cohen, Sandborn and Shiffrin (2008) investigated the statistical outcomes of several modelling procedures in response to grouped and individual data sets. They note that grouped data analysis findings, as employed in the current work, are prone to distortion as a sub-group of individuals within any one group may represent distinct subpopulations (which in this study is controlled), hence restricting the extrapolation of findings to that subgroup to the exclusion of the broader population. Cohen et al. (2008) concluded, foremost, that neither group nor individual data analyses can be recommended as a universal practice. However, under certain data conditions, such as when the number of data per individual diminishes, grouped data analysis provides an advantage over individual analysis. That is, when little data per individual is available, individual data analysis methods may generate ‘noise’ in the statistical analysis, leading to findings that likewise cannot be extrapolated to the broader population. Hence, grouped data analysis, as is employed in this work, is the least bad strategy (Cohen et al., 2008) with which to seek causal patterns in data structures that have only few data points per individual.

Considering the above, bivariate, multivariate and multiple mediation regressions were the preferred statistical methods to analyse the data of this project for the following reasons. They:

1. Are robust techniques that require minimal data conditioning.
2. Can be performed without expert statistical knowledge.
3. Are established and widely used statistical methods.
4. Do not require assumptions about the nature of the data to be made on the behalf of those involved in the study.
5. Possess underpinning concepts that can be easily explained to teachers.
6. Permit straight forward interpretation of results.
7. Are easily accessible in software for which there is a substantial amount of supporting documentation.

Finally, it should be noted that the methods applied in this study emulate those employed in fMRI studies (the gold standard) of human brain studies; regression analyses (Webber, Mangus & Huskey, 2015). In these studies, a base state of brain activity (the control) is subtracted from its experimentally induced state of brain activity (the treatment). The difference between these two states is then examined at some confidence interval to determine whether or not the strength of correlation induced by the experimental condition is adequately different from zero to justify subsequent claims of causality, i.e. $t \neq c$. fMRI studies ask basic yet very specific questions; typically to do with the localisation of brain activity in response to stimuli. These studies do not (cannot?) address the psychological processes like affect, behaviour and cognition associated with the localisation of brain activity to particular geometrical co-ordinates within particular brain structures (Cacioppo et al., 2003). It should also be noted that no fMRI studies exist in which whole classes of students have been examined for their brain activity in response to different L&T practices. It is fairly expected that such an activity would generate so much noise in the resting state (given that the resting state in a classroom can be anything from dead silence to a murmur to very noisy, depending upon circumstances) that it would be extremely difficult to identify any teacher induced brain activity as playing a causal role in student learning. Besides, what would be the experimental cognitive neuroscience paradigm by which naturalistic classroom memory reconstruction was investigated? A case of '*confabricor ad absurdum*'*?* Hence, the value of statistically controlled, natural and ecologically valid classroom studies.

Sequence of the study.

In this study, evidence for causal effects was accumulated from science exam scores of Year 10 students (average age of 15.5 years, equal distribution of male and female students) completing their Stage 5 Science program of the NSW School Certificate (SC) qualification. Over the course of the study, 2003 to 2010, all teachers followed a common science program that remained unchanged in the content that was to be taught (as prescribed the NSW Dept. Education). The common science program was defined as that body of semantic knowledge that students must learn to complete their course. Students thus form cognitive structures of course content as a function of the classroom L&T practices to which they were exposed. In any one year, students form these cognitive structures over a period of three 10-week terms. At the beginning of Term 4, students completed a School-administered Trial science exam as a measure of their learning and which contributed to their final science grade. About four weeks later, students completed a New South Wales Department of Education and Training SC science exam, from which a grade was awarded relative to the rest of the students in the State in that year.

Correspondence criteria for assigning a causal effect.

The process by which a causal effect will be ascribed to L&T practices will be determined according to the following schema.

Statistical control over variables that may influence these science exam scores was achieved by using Mahalanobis distance (Md) measures (Stuart & Rubin, 2007). The Md measure itself can be considered a proxy trial exam score in its own right as it is a composite of two other trial exams. Hence, the Md captures a raft of unobserved variables that may exist in the natural environment of the school and its classrooms. By identifying those classes with the most comparable proxy trial exam scores, group heterogeneity was minimised to ensure that 'apples were compared to apples' and thus the validity of counterfactual state. This is a significant consideration as the veracity of counterfactual reasoning requires that the probability of an outcome be equal in both the treatment and control conditions; thus by identifying 'outlier' classes, group heterogeneity was minimised and the more likely it becomes that the counterfactual control state would generate the same result as the treatment state. Such matching also enhances the reliability and accuracy of effect measurements, i.e. all things being equal, the effect that $t \neq c$.

In this work, trial English and geography exam scores were used to generate Md scores. These exam scores were outside the scope of the study but which covary with those variables being studied. English scores were used because English is the thinking and communication medium common to all subjects and geography because it is similar to science in the demands it makes upon student learning (and also it was the only other data set available that covered the whole time period of the study). Thus, the identification of similar groups according to the Md ought to capture unobserved variables that may influence student learning in the broader natural setting of the school. Hence, heterogeneity amongst all groups used in the study would be comparable, lending accuracy and reliability to effect measurements.

On accuracy and reliability, Stuart and Rubin (2007) note that matched groups increase the robustness of causal comparative studies. That is, group heterogeneity is minimised, thus reducing the reliance upon the assumptions of data normality which regression modelling depends as a quality control mechanism. Additionally, bootstrapping may be applied during regression analyses to generate coefficients that are not dependent upon assumptions of data normality (Efron & Tibshirani, 1993). Simply, the regression analysis is repeated, say 2000 times, but on each occasion a sample is randomly selected from the data set for each individual analysis. In this manner, the natural variability within the data set is used to establish robust confidence intervals of coefficients that are more like the coefficients of the whole population under study. This therefore generates more reliable modelling of proposed cause and effect relationships and aids their generalisation to the broader study population.

Psychometrically, the Md measure can be considered for its discriminant validity. This describes the ability of different instrument to discriminate between two states that may be measuring outcomes that potentially overlap. In this case, the extent to which the Md covaries with the Trial science exam score but which is not actually emulating the Trial science exam score. March, Parker, Sullivan, Stallings, and Conners (1997) determined that adequate discriminate validity was characterised by a correlation of .63 at $p < .01$. In this work, the Md measure itself could not be assessed for its correlation to the Trial science exam score, instead the correlation of English and geography trial exam scores is used as a proxy measure of discriminant validity. Additionally, a test for comparable heterogeneity of matched groups is whether or not their mean Trial science exam scores differ at the 95% confidence interval; there were no differences indicating that matched groups were comparable in unobserved covariates and general learning abilities and thus qualify as counterfactual control groups.

Of the five groups used in this study, four were identified as control groups and one as the intervention group. Two of the four control groups were Conv. G1 and Conv. G2, which represent students that received Conv. L&T practices from different teachers at different times, being the years 2003 to 2006 and 2008 to 2010, respectively. Thus, the Conv. G1 and Conv. G2 groups represent a longitudinal perspective of student learning in response to Conv. L&T practices. The third control group, Conv. G3, represents students that received Conv. L&T practices but from the intervention teacher only in the years 2003 to 2006. This group represents a cross sectional and longitudinal perspective of student learning in response to Conv. L&T practices. These three groups (G1, G2 and G3) thus capture the extent of heterogeneity with which Conv. L&T practices are applied in the classroom to generate results from individual or groups of teachers across the entire period of the study. The fourth control group, G4, represents the average of these three groups and establishes a baseline of student learning in response to Conv. L&T practices. The fifth group, Bios, represents students that received Bios L&T practices from the intervention teacher in the years 2008 to 2010[17]. It is the Conv. L&T practices that serve as the counterfactual control against which Bios L&T practices are contrasted to isolate any difference in learning responses associated with different L&T practices.

[17] The year 2007 was omitted from the study because I, the intervention teacher, took a job as a science education lecturer at a local University.

It is from these matched groups that the test-retest setting of the study is positioned and from which the primary measure of the effect of different L&T practices is drawn via bivariate regression. On the psychometric validity of such test-retest situations, correlations in the order of .85 are to be expected with an intervening period of 12 weeks and of .75 with an intervening period of 10 months (Funderburk, Eyberg, Rich, & Behar, 2003). Additional statistical criteria are outlined in Collins, Onwuegbuzie and Jiao (2007). In reliably determining that $t \neq c$ in causal comparative studies, the sample size of c and t each require a minimum of 64 participants for two tailed hypothesis testing at the *p* .05 level of significance. This would correspond to the detection of a small to moderate effect size (r =.15) [18] with statistical power of .80. Additionally, the 95% confidence interval of the effect size ought not to include zero, thus providing a very strong indicator that $t \neq c$ (Field, 2013). Please note that a priori power analysis is not suited to this work: Attempting to prescribe the number of students assigned to 'elective choice' subjects so that science classes were known ahead of time was not feasible. It may have interfered with the desired educational outcomes for those assigned students and this would represent an unacceptable conditioning of students and also not be ecologically representative of the student population.

Supplementing the Conv. G2 and Bios test-retest groups were NAPLAN scores for the period 2008 to 2010. These are Australia-wide measurements of student skill levels in reading, writing, literacy and numeracy, as well as growth in these scores. Such testing data was administered by the NSW Department of Education and Training and has been declared to be psychometrically reliable and valid (ACARA, 2012). For 2008 data, measurements were taken one year earlier than the 2009 and 2010 measurements and no growth in these scores is available. However, the 2008 data was psychometrically moderated by the NSW Department

[18] Collins et al. (2007) specify d =.3. This d effect size was converted to its equivalent r in which $r = (d^2/d^2 + 4)^{1/2}$ (Ferguson, 2009).

of Education and mapped onto NAPLAN scales (personal communication with psychometrician, Department of Education, 2009). Whether the one year time difference in acquiring 2008 NAPLAN data may be significant or not would be indicated by significant contributions of the 2009/2010 growth scores to science exam scores; the absence of which would indicate that growth in NAPLAN parameters is not a classroom variable that plays a substantial role in classroom learning.

With respect to the test-retest regime, NAPLAN data was used to provide greater insight into the cognitive processes that may have contributed to differences in structure of prior learning derived from different classroom L&T practices. By increasing the number of independent variables from one (the Trial exam) to nine (reading, writing, literacy, numeracy and growth in these scores), patterns in the data may be revealed that lend inferential specificity to the nature of the treatment (Rosenbaum, 2005).

The bivariate regressions thus evolved into multivariate regressions. In these models, the effect size of interest was still based upon the correlation coefficient *r*, but was refined to the partial squared correlation, pr^2, as recommended for multiple regressions (Cohen, 1988). This effect measures the unique contribution that each variable makes to the independent variable, after the contribution of all other variables has been accounted (Field, 2013). Whether the pr^2 effect represents a $t \neq c$ state was determined by its 95% confidence interval. For any pair of variables, if one confidence interval included zero and the other excluded zero, a $t \neq c$ condition existed and deemed a substantive response to those L&T practices. If the confidence interval of both variables excluded zero, an analogous response was deemed to have occurred in response to both sets of L&T practices. In this case, the ratio of effects may be used to gauge a causal effect (Höfler, 2005). A 1:1 ratio for any pair of variables would indicate an equal effect occurred response to both sets of L&T practices, i.e. $t = c$. A ratio of a higher magnitude, say >2:1, may indicate a causal effect in response to that particular L&T practice, i.e. $t \neq c$, and likewise deemed a substantive response to those L&T practices. If the confidence interval of both variables included zero, no effect was deemed to have occurred in response to either type of L&T practices.

Should a $t \neq c$ be detected, multiple mediation analysis would be warranted. As the classroom is a complex systems of interactions, it is entirely feasible that one variable may be having more than one effect, i.e. it may be cascading into another variable which then causes the effect. Subtler interactions may also be highlighted by contrasting the multiple mediators with each other. As for other coefficients, a $t \neq c$ can be ascribed to any pair of variables whose 95% confidence intervals do not include zero or differ in their magnitude.

Patterns in t vs. c variable pairings may lend credence to the assigning of causal effects to regression models. Rosenbaum (2005) describes three data patterns indicative of causal effects. First, two or more control groups that had not received treatment but that differ in terms of scope of the unobserved covariates should be included for comparison. The Conv. G1, G2 and G3 groups all differ in the teachers, the cohorts of students and did not receive Bios L&T practices. Second, coherent patterns of associations within the data act as indicators of proposed cause and effect relationships; specifically, that two or more variables ought to be illuminated in response to a causal effect. For example, Bios L&T practices may illuminate writing and numeracy as significant variables whilst Conv. L&T practices may illuminate literacy as a significant variable. Third, certain variables should not be affected by the treatment. For example, reading may be illuminated as a significant variable in response to both Bios and Conv. L&T practices and/or all growth measurements likewise failed to be illuminated. Taken together, such data patterns provide adequate justification to infer that the proposed causal effect is discriminating in the mechanism by which it exerts its effect and therefore, generally less likely to represent a correlation-only effect. Consequently, the weaker the counterfactual or the treatment state becomes should data patterns not be observed (Rosenbaum, 2005).

Hence, some data patterns represent cause and effect as they would be encountered in scientific laboratories while others do not (Hill, 1965). Ipso facto, a t ≠ c state can more reliably be assigned to particular L&T practices.

A summary of causal effects criteria.

Correspondence to the following quantitative criteria would provide a solid psychometric platform upon which fair inferences may be drawn about student learning in response to different L&T practices, as they occur in the natural setting of the classroom. The conditions are generally depicted in Figure 5 below.

For the bivariate regression modelling:

1. All four matched groups should possess trial English/geography/science exam score correlations of approximately .6, no difference in the mean Trial science exam score at the 95% confidence interval and should possess n ≥64. This would indicate effective group matching for statistical comparison purposes and that there was adequate discrimination between the tests to minimise the effect of covariance upon the science test scores.
2. All test-retest correlations should be r ≥ .75; indicating psychometric validity of the testing instruments.
3. All coefficient comparisons of the control groups G1, G2 and G3 should have an effect of r <.15 and include zero in their 95% confidence intervals, with all groups having power ≥.8; indicating that the learning of response of all students who received Conv. L&T was comparable, despite the range of unobserved covariates captured by the different groups, and that the size of the groups was adequate to reliably detect effects.
4. The comparison of the control group G4 to the Bios treatment group should have an effect of r =.15, that does not include zero in its 95% confidence interval, and has a power of ≥ .8; indicating that psychometrically distinct learning of science occurred in

response to Bios L&T practices and that the size of the groups was adequate to reliably detect effects.

For the multivariate regression modelling:

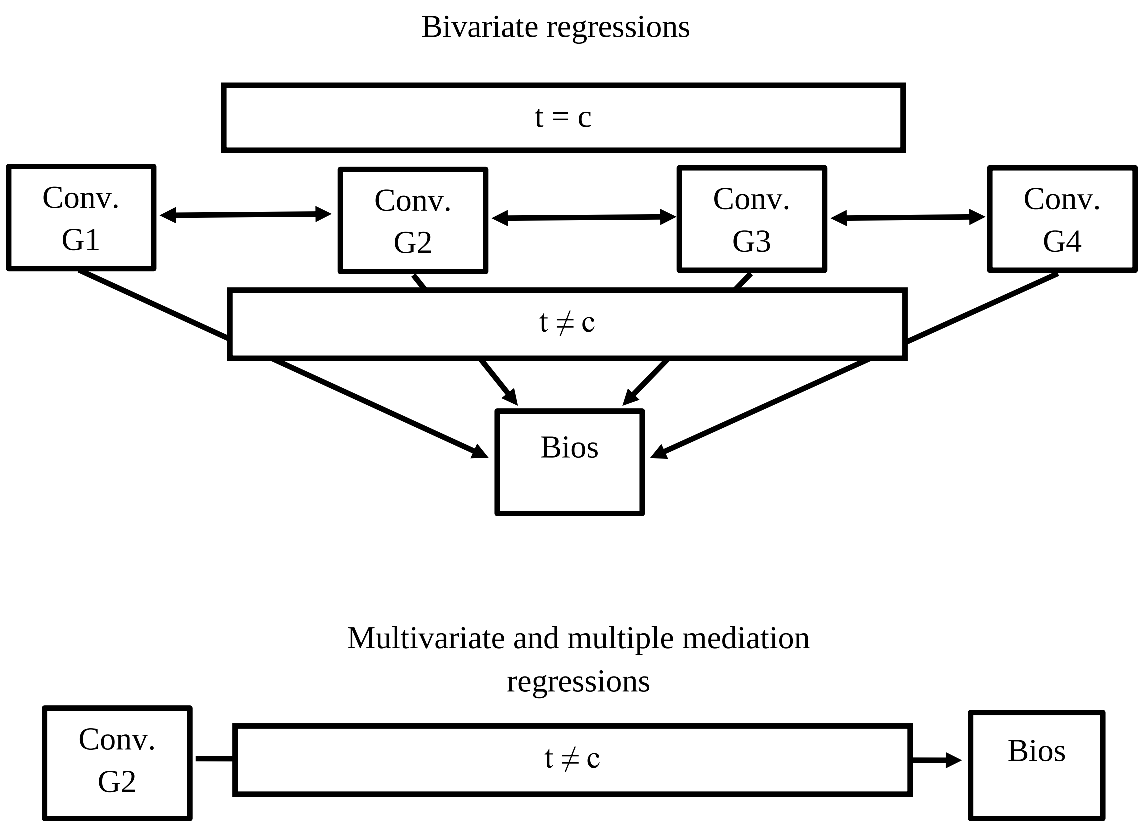
1. Both matched groups should have no difference in the mean reading, writing, literacy and numeracy NAPLAN measurements and their accompanying growth measurements at the 95% confidence interval with $n \geq 64$ and power of $\geq .8$; indicating effective group and psychometric matching and that the size of the groups was adequate to reliably detect effects.
2. Substantive variables should have coefficients whose 95% confidence intervals do not include zero whilst its counterfactual variable does include zero; indicating that $t \neq c$ and is thus a causal effect associated particular L&T practices.
3. Analogous variables should have confidence intervals that exclude zero but which differ in the magnitude of their ratio compared to other indeterminate variables; indicating that $t \neq c$ and is thus a causal effect associated particular L&T practices.
4. Pairs of unaffected variables should have 95% confidence intervals including zero; indicating that $t = c$ and thus the presence of a discriminating mechanism by which causal effect(s) occurred.
5. Growth scores should have 95% confidence intervals that include zero; indicating that $t = c$ and thus validate the use of 2008 NAPLAN data.

For the multiple mediation modelling:

1. The substantive variables from the multivariate regression should have coefficients whose 95% confidence interval do and do not include zero with $n \geq 64$; indicating that $t \neq c$, implicating that variable as being pivotal in the causal effect pathway.

2. Unaffected variables should sustain their multivariate relationship and possess 95% confidence intervals that exclude zero.
3. Contrasted indirect effects should be flagged as significant should have 95% confidence intervals that do not include zero; indicating the possibility that other mediated interactions may exist.

Figure 5
<u>Results criteria</u>



CHAPTER 4: Methods.

Demographic profile of school.

The demographic profile of the school to which the methods were applied is described in two ways, the Index of Community and Socio-educational Advantage (ICSEA) score and the University Admissions Centre (UAC) disadvantage score. The ICSEA score is a composite formulated to facilitate the comparison of NAPLAN scores of Australian schools so that the influence of socioeconomic factors upon NAPLAN scores can be controlled (ACARA, 2015). The score is determined via a multilevel regression model using the equation;

ICSEA (student) = SEA (student) + student Indigenous status + SEA (school cohort) + Percent Indigenous student enrolment + Remoteness (ACARA, 2013)

The score has a national average set at 1000 and ranges from 800 to 1200. The average ICSEA score of the school from 2008 to 2010, the period in which the multivariate data resides, was 1035. In this period, the school also had an average; 711 students (from Yr. 7 to 12), 95% attendance rate, 2.7% Indigenous enrolment, 5.5% household language other than English enrolment and a 1:1.04 male to female enrolment ratio. The difference in distribution of students across disadvantaged to advantaged quartiles from the National quartiles was negligible, being 2% more in the top quartile and 2% less in the middle quartiles.

The UAC disadvantage score is SO1E (UAC, 2015). This describes a school that has been identified by the NSW Catholic Education Commission as being comparable to the most socioeconomically disadvantaged schools in the Government sector. This means that students of the School are eligible for top-up points (1 to 10) to increase their competitiveness in entrance to tertiary education institutions.

For all intents and purposes, the school is country school that draws its students from a large farming area. Hence, there are around 170 weekly boarding students mixed in with around 550 or so day students. On the whole, the student population is comparable to mainstream Australian city schools, it is just located quite some a distance from a major population.

The Science programme used by all science teachers remained the same during the course of the study. The programme included a range of scientific disciplines, being biology, physics and chemistry. The number of classes in any one year is routinely six. The classes were not streamed and composed more or less equal numbers of male and female students, depending on how many boys or girls chose certain other subjects on other competing timetabling options. The total number of teachers in the study was 12 of whom 4 were male and eight were female, with all having minimum of four years teaching experience; except for myself who had two years teaching experience before the beginning of the study. Of the teachers in the study, four have classes in both the before and after phases of the study. The number of students in Yr. 10 in any one year varied from 107 to 138, averaging approximately 123 students per annum.

Classroom practice.

Bios (treatment) and counterfactual Conv. control classes were taught and managed according to the following propositions over the school year.

Bios:

Proposition 1: *Students are given the latitude to ask what seem like obtuse questions about what it is that interests their minds in the moment in relation to what is being discussed in the class.*

Proposition 2: *Dialogical exchanges are engaged in with the aim of keeping students thinking laterally from their initial question.*

Proposition 3: *Learning material is chunked and consolidated small pieces, reiterated numerous times (as needed) and reinforced once with simple diagrams and/or short passages of whiteboard text.*

Proposition 4: *Textbooks are used sparingly as a teaching tool.*

Proposition 5: *Disruptive behaviour, i.e. social interaction independent of the learning of the topic-at-hand, is accepted as a normal aspect of teenagers and downplayed.*

Conv. propositions:

Proposition 1: *Select a resource that meets learning needs and which is located in the classes ZPD.*

Proposition 2: *Deliver the learning resource to the class and bring it into their ZPD by introducing the topic and calling for thoughts on the topic.*

Proposition 3: *Allow students to work through the resource, offering minimal assistance in order to promote the student-driven development of their ZPD.*

Proposition 4: *Control the class's behaviour to ensure that students give their attention to the learning resource and thus engage with and learn from the provided resource, not socialise with each other*.

Proposition 5: *Request that those students who have not completed the task complete it for homework.*

At the beginning of Term 4, all students completed a Trial science exam that was followed three to four weeks later by a SC science exam. All Trial science exams were purchased from external suppliers and marked by class teachers. All SC science exams were provided by the NSW Department of Education and marked by the Department. All NAPLAN exams were administered by the Department of Education and marked by the Department.

Data entry.

Trial exam scores for English, geography and science were imported into a Microsoft excel spread sheet and then organised according to their Science classes. Corresponding School Certificate (SC) science exam scores were then manually entered. Scores for reading, writing, literacy, numeracy and growth in these scores were exported from a PDF file into the spread sheet where they were matched to their Trial and SC science exam scores. All data was then cross referenced twice with paper copy to ensure data integrity. The experimental teacher was coded as Teacher 1 while other teachers were randomly assigned a number from 1 to 13 for every year group (the conventional teachers).

Exploratory plots.

An excel spread sheet containing the Trial English and geography exam scores was imported into the R statistical software package. An exploratory scatter plot was generated with the Trial science exam score as the independent variable and the SC science exam score as the dependent variable.

Matching of classes.

The Mahalanobis distance (Md) profile of individual Science classes was determined using the Trial English and geography exam scores. The Md was determined using the R statistical software package and defined as $d(x_i) = (\mathbf{x}_i - \mu)'\Sigma^{-1}(\mathbf{x}_i - \mu)$ where $\mathbf{x}_i$ represents the vector English and geography scores for student *i*, Σ^{-1} is the covariance matrix for the English and geography scores and μ is the bivariate mean of English and geography scores (Gelman & Hill, 2006). Classes comparable to those of the Bios teacher were then identified on the basis of exhibiting a fairly good overlap in the resultant dot plots (Stuart & Rubin, 2007). This required that the dot plots demonstrated a similar distance from the axis to the first data point, a similar clustering of the mass of data points and a similar stretch in the tail of data points. Such matching focuses the statistical analyses on the effect of different L&T practices upon the process of student learning and less upon the learning prowess of students. Consequently, ‘smarter’ outlier classes will be eliminated from the study so that any differences detected via regression analysis may fairly be inferred to result from L&T practices (not student capacity for learning).

Data grouping.

Classes identified as possessing comparable Md profiles to those of Teacher 1 were grouped and entered in to a new spread sheet. This was then cross referenced with the paper data to ensure the integrity of data structure. The discriminant validity of the Md matching was examined by averaging the bivariate correlation of English and geography scores to the Trial science exam score using SPSS (Version 22). The correlation was set for two tailed significance at the 95% confidence interval with 2000 bootstraps (bias corrected and accelerated). The equivalence of the matched data groups was examined by comparing mean Trial science exam scores. Differences in the mean were examined for at the 95% CI using the '*Confidence Interval for Two Means, Without Assuming Equal Variance*' function in ESCI software (Cumming, 2011).

Regression analysis.

Data was imported into SPSS (Version 22) from the data grouping spreadsheet, assigned variable names and subjected to regression analysis (Field, 2013). All regressions had settings of two-tailed α = .05, the prediction interval for the mean was set at 95%, the stepping probability criteria for data entry was F = .05 and F = .10 for data removal. Regression and residual diagnostics for outliers was set at 3 standard deviations. Bootstrapping with simple sampling set at 2000, bias corrected and accelerated (BCa), was subsequently used to generate robust 95% confidence intervals. All regressions were performed with the enter function. Regression analysis was dealt with in the following order.

- Data normality was examined using scatter plots to inspect for a linear pattern in the distribution of data. The Shapiro-Wilk statistic was used to highlight possible outliers which were subsequently inspected via box plots, with those identified as abnormal data being trimmed.
- Bivariate regressions were performed on all models. The normality of residuals was examined via normal pp plots, standardised scatter plots and the Durbin-Watson statistic. The regressions were then repeated with bootstrapping. Subsequently, differences in the correlation coefficient (*r*) of the Trial and SC science exam score

relationships between each of the groups was examined at the 95% CI using the '*Two Correlations*' function in ESCI software (Cumming, 2011). Effect sizes were described as small ($r \approx .1$), medium ($r \approx .3$) and large ($r > .5$), (Cohen, 1988).

- Multivariate regressions were performed on the Conv. G2 and Bios models. Initially, all nine independent variables, the Trial science exam score and the eight NAPLAN scores (reading, writing, literacy and numeracy scores and their growth counterparts), were entered for analysis as the 'whole class' model. The normality of residuals was again examined via normal pp plots, standardised scatter plots and the Durbin-Watson statistic. Additionally, the variance inflation factor was inspected to gauge the extent to which colinearity existed amongst NAPLAN scores. The regressions were then repeated with bootstrapping.
- The preceding whole class learning model was then separated into cognitive and growth variables and the multivariate regressions repeated with each individual variable withheld for entrance until step 2. Subsequently, the squared partial correlation effect size (pr^2) and its 95% CI was determined for each variable via the non-central F distribution script in SPSS (Smithson, 2001). Effect sizes were described as small ($pr^2 \leq .04$), medium ($pr^2 \leq .25$) and large ($pr^2 > .64$) (Ferguson, 2009).

Mediation analysis.

Mediation was examined using Hays' PROCESS macro in SPSS (Field, 2013). Multiple mediation, using model 4 and bootstrapping with simple sampling set at 2000, bias corrected and accelerated (BCa). The independent variable was the Trial exam, the dependent variable was the SC exam and the mediators were reading, writing, literacy and numeracy or their growth scores. The κ^2 effect size of noteworthy mediators was determined by entering only that variable as the mediator. Effect sizes are described as small ($\kappa^2 = .01$), medium ($\kappa^2 = .09$) and large ($\kappa^2 = .25$) (Preacher & Kelly, 2011).

Power analysis.

The achieved post-hoc power (difference in slopes) for the comparison of bivariate regression slope coefficients was determined using the '*Linear bivariate regression: Two groups, difference between slopes*' function in G*Power (Faul, Erdfelder, Buchner, & Lang, 2009). The input mode was '*residual σ and slope*' with two tail testing at p =.05. The power of the bivariate and multivariate regressions was determined using a non-central F distribution script in SPSS (Smithson, 2001).

CHAPTER 5: Results.

"**We can only study something if we treat it as a variable, comparing its presence to its absence**." (Baars, 1997, p. 11).

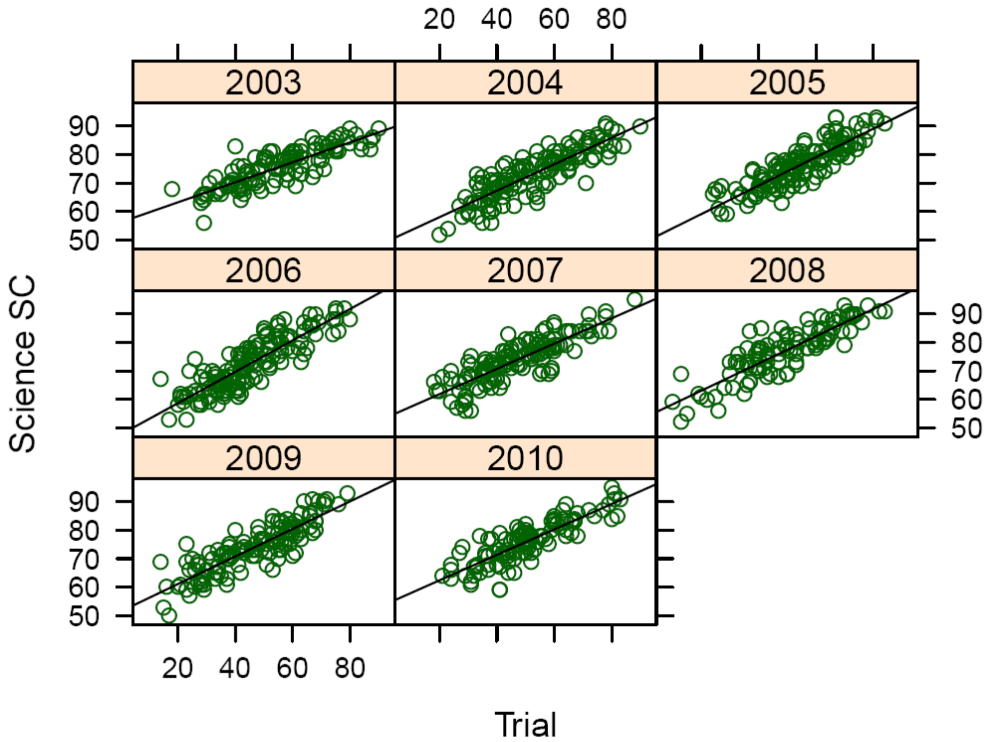
Introduction.

The results demonstrate that a difference exists between student learning in response to Conv. L&T practices and Bios L&T practices. The differences comply with criteria identified as being indicative of cause and effect relationships (Rosenbaum, 2005), of possessing psychometric reliability (Dunlap, Cortina, Vaslow and Burke, 1996) and of adequate power for matched group studies (Onwuegbuzie & Collins, 2007).

- First, all three control groups of Conv. L&T practices show no significant difference in student achievement from a cross sectional and longitudinal perspective but from which the Bios intervention group is significantly different.
- Second, all correlation coefficients are of an order indicating discriminant and psychometric reliability.
- Third, the difference of the Bios bivariate slope coefficient from all Conv. slope coefficients has adequate power.
- Fourth, the difference in slope is associated with the identification of reading as a unique response to Bios L&T practices, with which is associated a prior learning response that is much greater than its control.
- Fifth, other variables (numeracy and writing) were comparable in their lack of response to either type L&T practice.
- Sixth, reading skills mediated an indirect effect upon student learning.
- Seventh, the classroom behaviour of Bios students was distinctly more mature and responsible than those experienced with Conv. students.

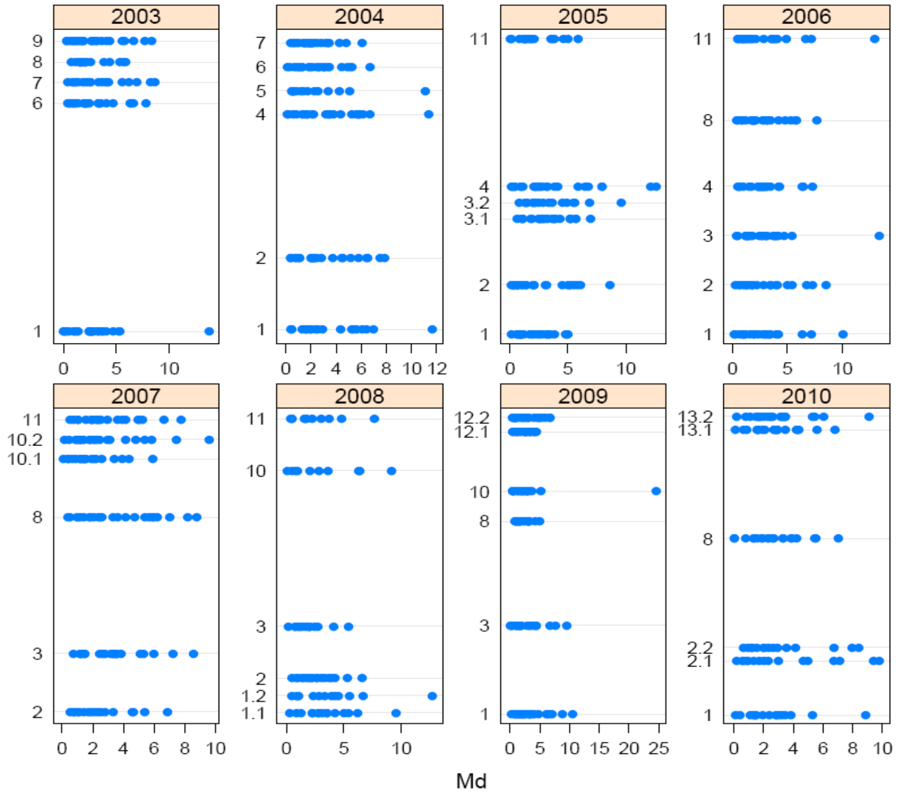
Is the data normal?

Figure 6
Scatter plots of yearly Trial and SC exam scores



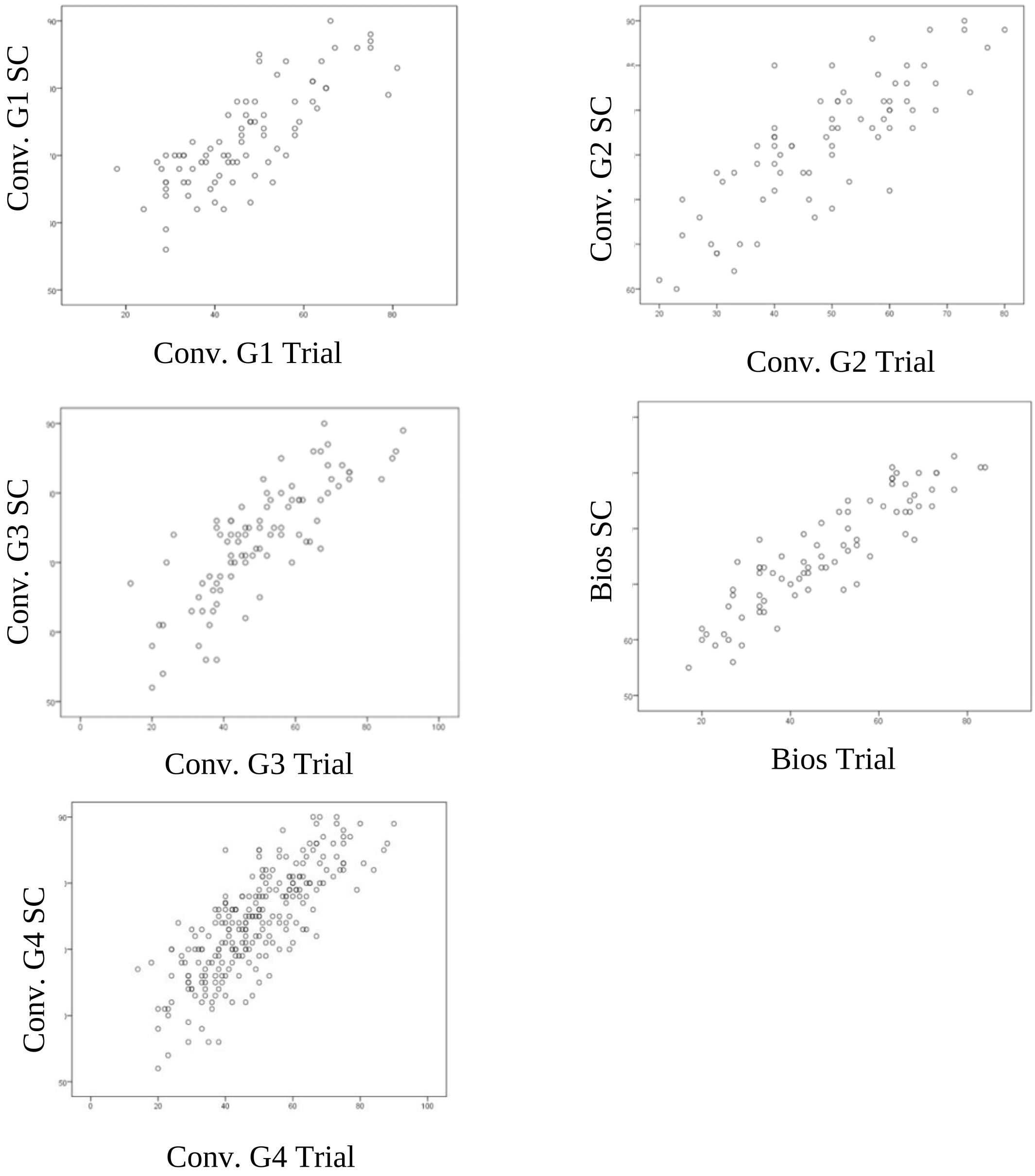
The scatter plots in Figure 6 examine the presence of a linear relationships between Trial and SC science exam scores. The range of Trial scores is from approximately 15 to 85 with a corresponding range of SC scores from approximately 50 to 95. Some minor fluctuation in the slope of the relationship exists across years, likewise the distribution of scores about the data axis. The plot also indicates that the characteristics of any year group are comparable to any other year group across the period of the study, 2003 to 2010. Finally, a linear relationship exists between achievement in the Trial exam and achievement in the SC exam in each year of the plot. Thus, the Trial science exam is a fair predictor of the SC science exam and suitable for further statistical analysis.

Figure 7
The Mahalanobis distance profiles of individual science classes.



The Mahalanobis distance (Md) plots in Figure 7 presents a proxy measure of Science class achievement. It aims to identify classes with comparable learning and achievement characteristics on the basis of achievement in other subjects. The new variable was derived from student achievement in two independent assessment tasks, being the Trial English and Trial geography exam scores. Figure 8 indicates that classes comparable to the Bios teacher's classes (1), located on the vertical scale, include: Class 8 in 2003, Class 4 in 2004, Class 11 in 2005, Class 2 in 2006, Classes 2 and 10 in 2008, Class 3 in 2009 and Class 8 in 2010. These plots also indicate the number of classes (and hence teachers) teaching in any one year, with each dot indicating the number of students in that class.

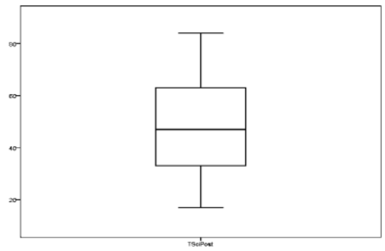
Figure 8
Exploratory scatterplots of grouped data



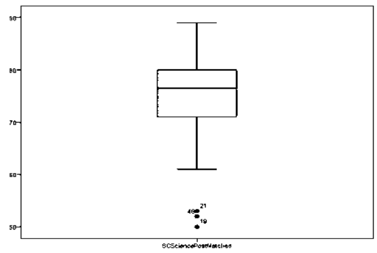
The scatterplots in Figure 8 examine for the presence of linear relationships between the independent (Trial science exam) and the dependent (SC science exam) variables in the grouped data. It indicates that all the scatterplots display a linear relationship and that linear regression is an appropriate method with which to analyse the Trial and SC science exam score relationship; so grouping the data has not affected its structure.

Table 1			
Shapiro-Wilk statistic of regression data			
Bivariate data	Statistic	df	Significance
Conv. G1 Trial	.97	.82	.08
Conv. G1 SC	.97	.82	.06
Conv. G2 Trial	.99	74	.53
Conv. G2 SC	.98	74	.21
Conv. G3 Trial	.99	90	.42
Conv. G3 SC	.98	90	.26
Conv. G4 Trial	.99	246	.09
Conv. G4 SC	.99	246	.14
Bios Trial	.97	79	.06
Bios SC	.97	79	.09
Multivariate data (Conv.)			
Conv. G2 Trial	.99	74	.53
Conv. G2 SC	.97	74	.21
Reading	.99	66	.87
Writing	.97	66	.95
Literacy	.99	65	.7
Numeracy	.99	68	.74
Reading growth	.99	31	.64
Writing growth	.96	35	.21
Literacy growth	.94	35	.04
Numeracy growth	.98	33	.75
Multivariate data (Bios)			
Bios Trial	.99	74	.53
Bios SC	.97	74	.21
Reading	.99	66	.87
Writing	.97	66	.95
Literacy	.99	65	.7
Numeracy	.99	68	.74
Reading growth	.97	31	.64
Writing growth	.96	35	.21
Literacy growth	.94	35	.04
Numeracy growth	.98	33	.75

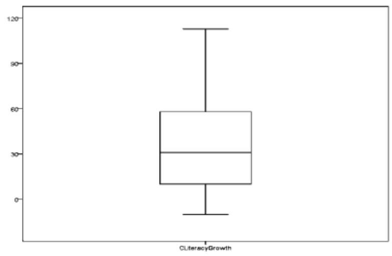
Figure 9
Box plots of possible non-normal data.



Bios Trial



Conv. G2 SC



Conv. G2 literacy growth

Table 1 presents the Shapiro-Wilk statistic, which was used as the primary gauge of data normality. In the event of possibly non-normal data, box plots were used to investigate the deviation. For the Bios Trial and Conv. literacy growth data, the statistic initially suggested that data was not normal whilst the boxplots did not identify any outliers. Hence, the data was used as is. For the Conv. G2 SC, the statistic also indicated abnormal data and the box plot identified three outliers (see Figure 9)[19]. Consequently, this data was trimmed by removing these outliers and the statistic again indicated data normality.

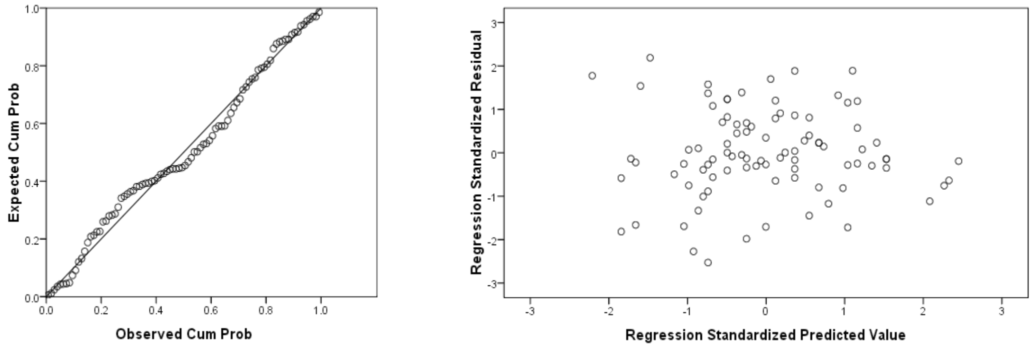
[19] The three student cut from the data were identified as students with special needs. Such students who did not identify as outliers were retained in the data. For the Bios group, six of six special needs students were retained while for the Conv. G2 group two of five students were retained.

Figure 10

<u>Bivariate residuals</u>

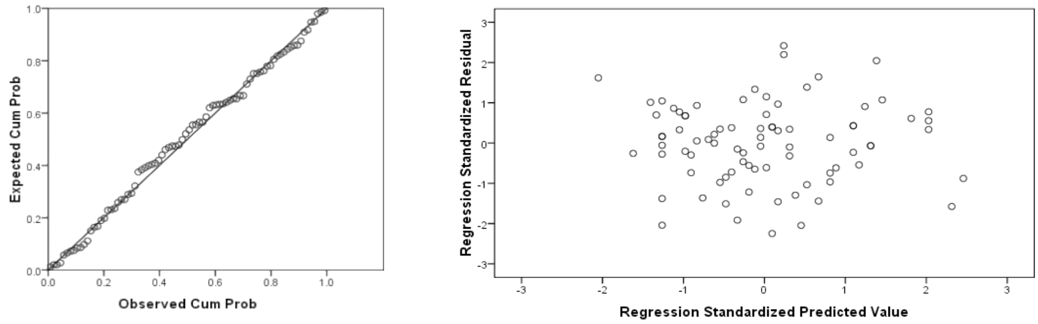
Conv. G1

Normal PP plot Dependent variable: SC Standardised scatter plot



Conv. G2

Normal PP plot Dependent variable: SC Standardised scatter plot



Conv. G3

Normal PP plot Dependent variable: SC Standardised scatter plot

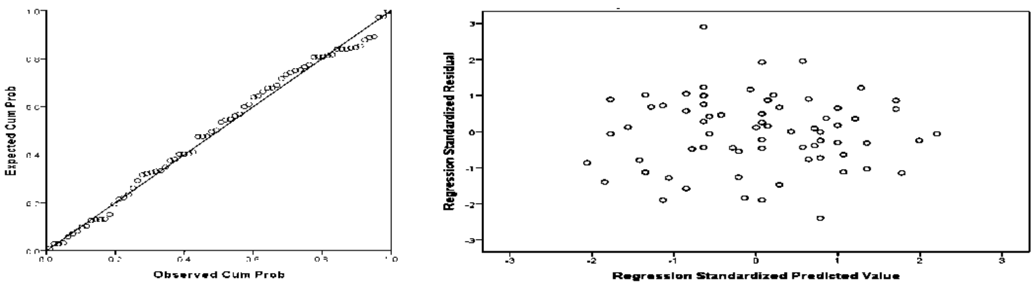
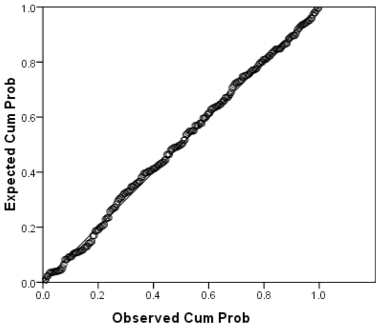
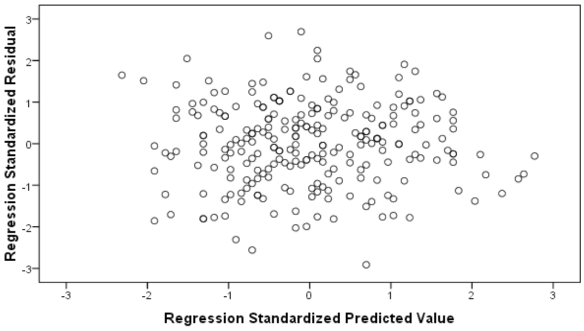


Figure 10 cont'd

Conv. G4

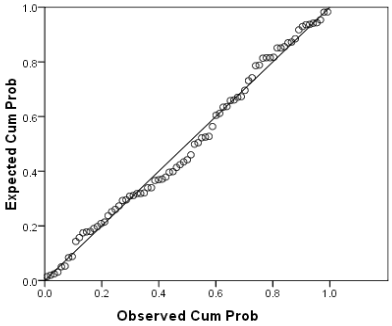
Normal PP plot Dependent variable: SC Standardised scatter plot





Bios

Normal PP plot Dependent variable: SC Standardised scatter plot



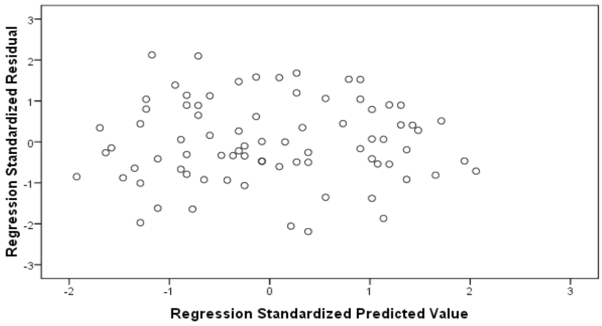
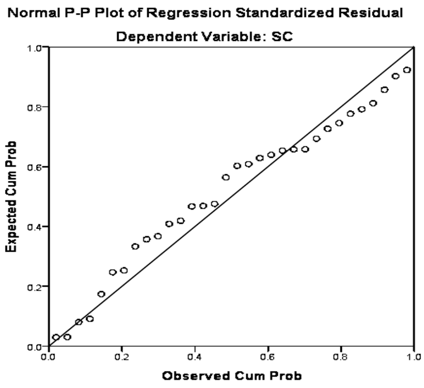
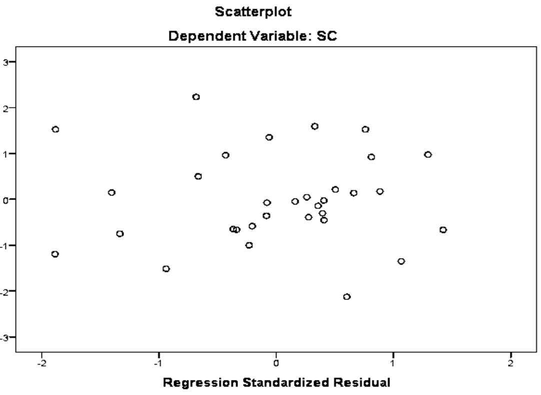


Figure 11

Multivariate residuals

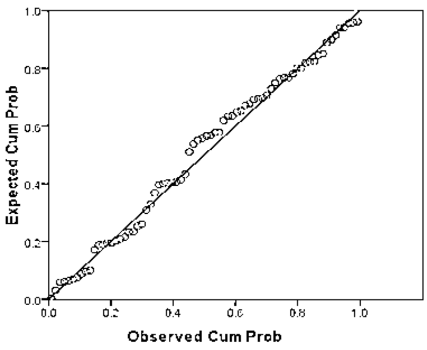
Bios whole class residuals

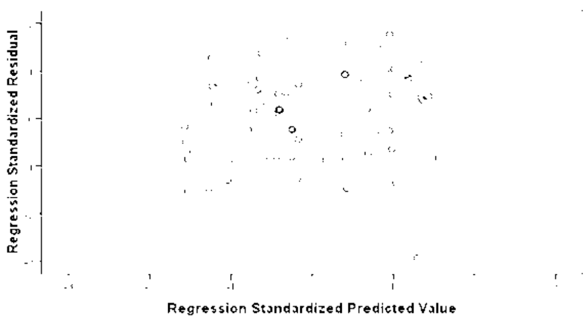




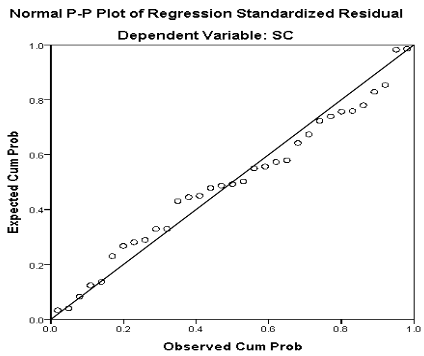
Bios cognitive residuals

Normal PP plot   Dependent variable: SC   Standardised scatter plot





Bios growth residuals



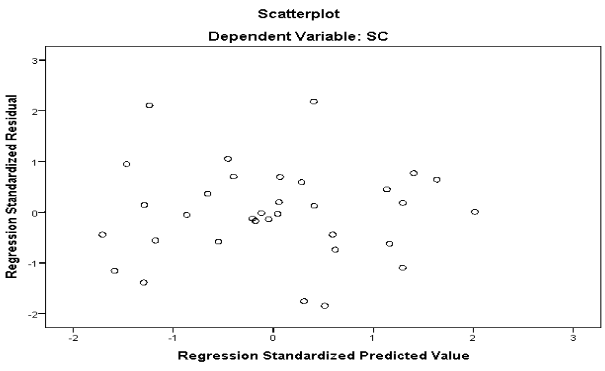
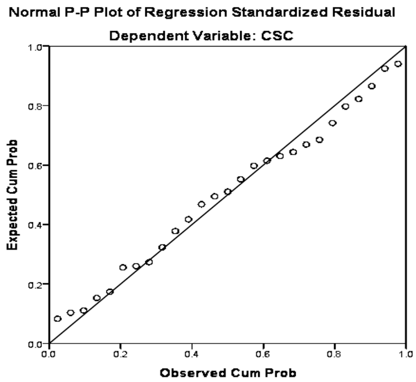
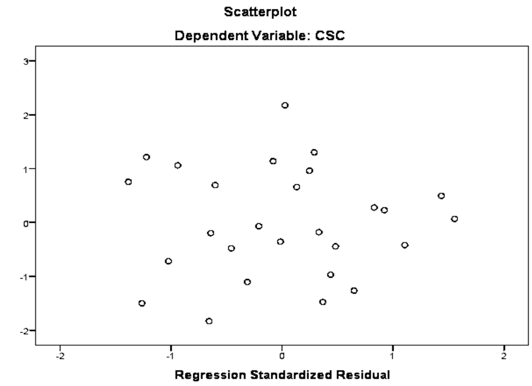


Figure 11 cont'd

<u>Multivariate residuals</u>

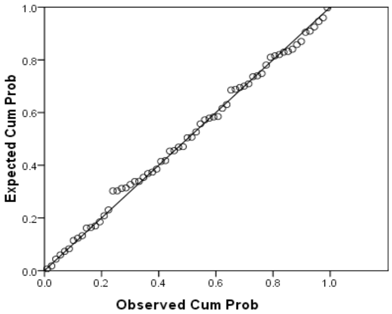
Conv. G2 whole class residuals

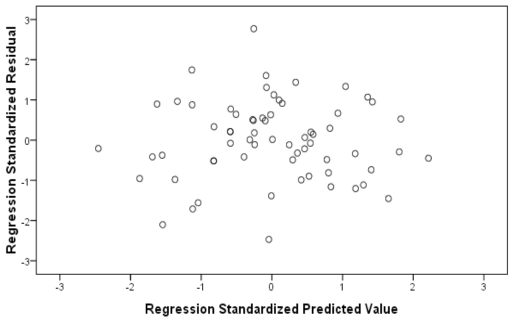




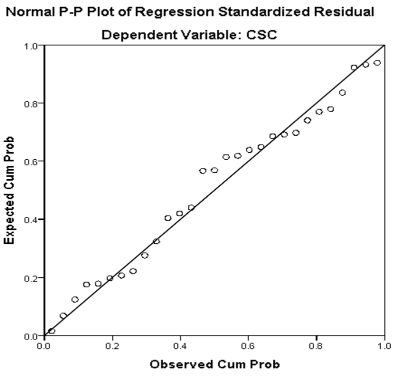
Conv. G2 cognitive residuals

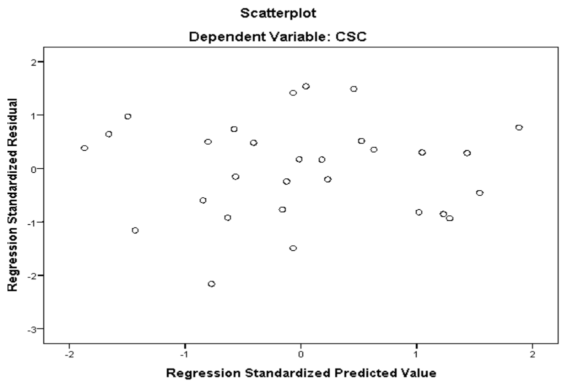
Normal PP plot   Dependent variable: SC   Standardised scatter plot





Conv. G2 growth residuals





The residual plots in Figures 10 and 11 above indicate whether there may have been an underlying pattern in the residual data that may hinder the fair interpretation of the data. The normal PP plots indicate whether the regression residuals were normally distributed relative to their theoretical distribution. In all of these residual Figures, a more or less straight line of residual values overlays the theoretical line of residuals, indicating normal data. The standardised scatterplot indicates whether the variance in the residuals was constant. In all of these plots, the distribution of residuals is random, showing no bowing or clustering in any one area. This indicates that it is not likely for an underlying non-linear relationship to exist within the residuals that would compromise the assumptions underpinning linear regressions. Nonetheless, bootstrapping was subsequently applied to these regressions to minimise the effect of any possible violations of data normality and most importantly, enhance the robustness of the 95% CIs of coefficients.

Table 2

<u>The Durbin-Watson statistics of regressed data</u>

Regression model	Conv. G1	Conv. G2	Conv. G3	Conv. G4	Bios
Bivariate	1.6	2	1.7	1.6	2.2
Multivariate whole class		2.5			1.8
Multivariate cognitive		2.3			2.2
Multivariate growth		2.2			2.3

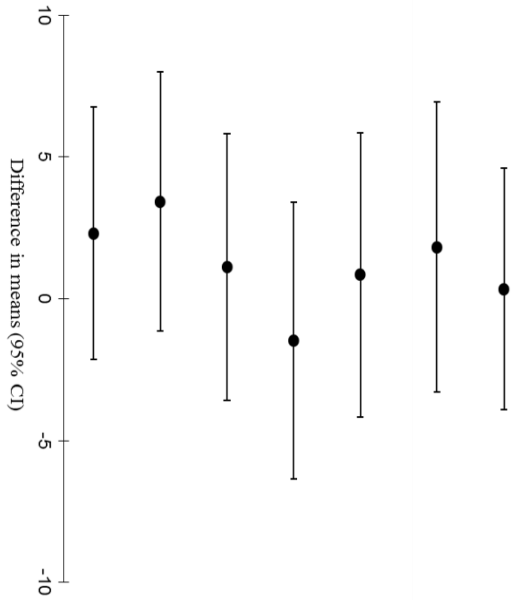
The Durbin-Watson statistic in Table 2 examine for the possibility of correlations amongst the residuals that may diminish the interpretive validity of the data. The statistic examines for the absence of an underlying pattern in the distribution of the residuals, indicating a possible correlation within the residuals. The Table indicates that all Durbin-Watson statistics fall within a range (<1.5 x >2.5) indicative of the absence of worrying correlational pattern within the residuals, supporting the assumption of independence of errors (Field, 2013).

On the whole, the assumptions upon which linear regression depend for generating reliable results have been met. These include: The assumption of linearity, as indicated by the exploratory scatter plots, the Shapiro-Wilk statistic and the box plots, the assumption of independence in the errors, indicated by the standardised scatter plots and the Durbin-Watson statistic and finally, the assumption of normality of residuals, indicated by the normal PP plots.

Is there a difference in the influence of different L&T practices upon student learning?

Figure 12

<u>Difference in mean Trial science exam scores of matched groups</u>

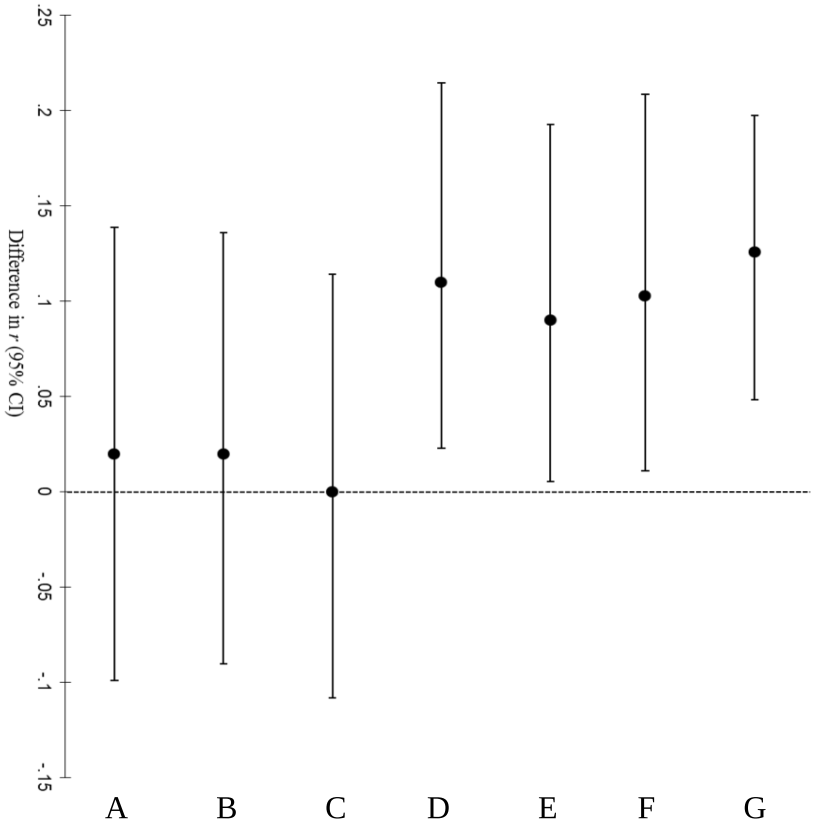


A: Conv. G1 vs. Conv. G2 **B**: Conv. G1 vs. Conv.G3 **C**: Conv. G2. vs. Conv. G3

D: Conv. G1 vs. Bios. **E**: Conv. G2 vs. Bios **F**: Conv. G3 vs. Bios **G**: Conv. G4 vs. Bios

Figure 12 compares the Trial science exam scores of all groups identified as being comparable in the learning and exam achievement profiles. As all comparisons include zero in the 95% CI, no significant difference existed between any of the Md matched groups. On the discriminant validity of these matchings, the average correlation of trial English and geography exam scores to the trial science score was; Conv. G1 =.63, Conv. G2 =.66, Conv. G3 =.64, Conv. G4 =.61 and Bios =.73; all within the range indicating that adequate discriminant validity between the proxy Md trial exam score and the trial Science exam. Thus, like groups were matched for subsequent comparison of learning responses.

Figure 13
Difference in *r* of bivariate models



A: Conv. G1 vs. Conv. G2 B: Conv. G1 vs. Conv.G3

C: Conv. G2. vs. Conv. G3 D: Conv. G1 vs. Bios.

E: Conv. G2 vs. Bios F: Conv. G3 vs. Bios

G: Conv. G4 vs. Bios

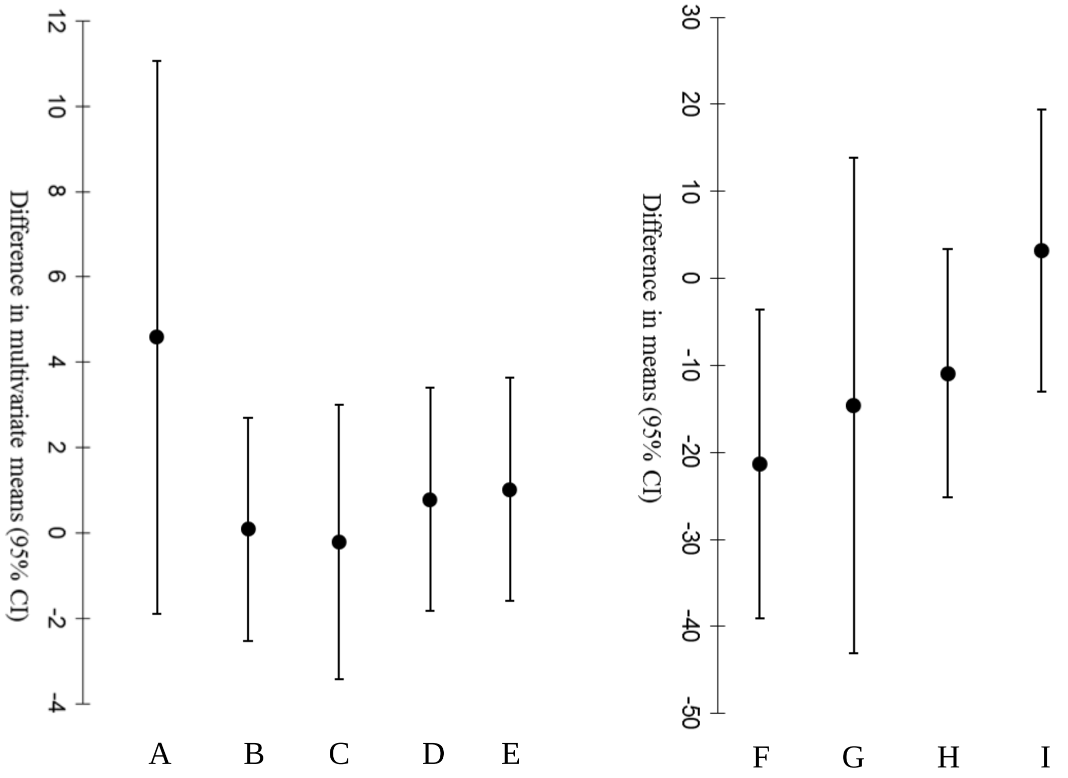
The difference in correlation between bivariate regressions in Figure 13 examines the effectiveness of the Trial science exam serving as a prior learning experience for the SC science exam. Differences between these correlations indicate the influence that different L&T practices had upon the memory formed of science relative to their classroom learning environment. Figure 13 indicates that none of the confidence intervals of the Bios comparisons crossed zero whilst all the Conv. comparisons crossed zero. In the latter case, this indicates that teacher practices and/or student response to Conv. L&T practices did not change over the course of the study, 2003 to 2005 and 2008 to 2010. Further, that student learning is more a function of L&T practices than it is of the individual teacher i.e., whether or not students were taught by the single Conv. G3 teacher or group of teachers (Conv. G1 & G2), the outcome was the same. Alternatively, Bios L&T practices resulted in students developing a significantly different learning of science from their classroom experiences. As the Conv. G3 teacher was the same as the Bios teacher, this difference in learning can be directly attributed to Bios L&T practices altering the learning environment so that students developed a different memory of the science they learned in the classroom.

The general effect of Bios L&T practices upon Conv. L&T practices is illustrated by the Conv. G4 comparison (which is the average of all the Conv. models). The difference in r =.11[.042, .17], which corresponds to a small effect (Field, 2013), and for which the power was .81, indicating that the scope of the study was adequate to detect any such effect that might have resulted from different L&T practices (Field, 2013). Although this effect is slightly less than the r =.15 specified by Collins, Onwuegbuzie and Jiao (2007), it is of a comparable magnitude, does not include zero in its 95% CI and possesses adequate power. Hence, the trial Science exam served as a significantly better contributor to the School Certificate Science exam in response to Bios L&T practices than did Conv. L&T practices.

For the individual regression models, the Conv. G1 model accounted for 62% of variance ($R^2_{adj.}$), $F(1, 80) = 134$, $p < .001$, the Conv. G2 model accounted for 66% of variance ($R^2_{adj.}$), $F(1, 72) = 139$, $p < .001$, the Conv. G3 model accounted for 65% variance ($R^2_{adj.}$), $F(1, 88) = 168$, $p < .001$. These three independent models cross validate each other to indicate that comparable classes were matched to ensure fair comparisons and that no change occurred in the Conv. L&T practices and/or the student learning response over the course of the study, 2003 to 2010. Additionally, as the individual correlation coefficients of all Conv. L&T regressions were of an order ≥.75, the psychometric reliability of these tests-retests lends credence to the inferences that may be drawn from the data about the impact of different L&T practices upon student learning in the classroom. This therefore qualifies their grouping into the Conv. G4 model, which accounted for 62% of variance ($R^2_{adj.}$), $F(1, 244) = 405$ at $p < .001$. Alternatively, the Bios model accounted for 80% of variance ($R^2_{adj.}$), $F(1, 77) = 320$ at $p < .001$, or 18% more classroom variance than is accounted for by Conv. L&T practices.

Is there a difference in the cognitive processes underpinning different L&T practices?

Figure 14
Difference in multivariate means



A: Trial exam. B: Reading. C: Writing. D: Literacy E: Numeracy.

F: Reading growth. G: Writing growth. H: Literacy growth. I: Numeracy growth.

The descriptive statistics indicate whether there is any difference between the mean predictor score that may complicate claims of causal inference associated with L&T practices. Figure 14 indicates that the 95% CIs of all but one predictor include zero, being reading growth in favour of the Bios group. On the whole, the Figure indicates that no systematic difference exists in the cognitive skills of the Conv. G2 and Bios groups, whilst noting the caveat of reading growth. Generally, this reinforces the efficacy of the Md matching in identifying comparable classes.

Table 3				
Predictors of SC exam achievement				
	Bios model		Conv. G2 model	
Variables	B	95% CI	B	95% CI
Constant	21.3	[-9.1, 52.5]	20.8	[-26.1, 62.6]
Trial exam	.24*	[.05, .47]	.15	[-.12, .4]
Reading	.017	[-.07, .12]	.023	[-.07, .12]
Writing	-.035	[-.13, .06]	-.017	[-.11, .11]
Literacy	.084	[-.02, .19]	.041	[-.19, .2]
Numeracy	.006	[-.05, .07]	.097	[-.03, .15]
Reading growth	.024	[-.04, .08]	.002	[-.14, .1]
Writing growth	.054	[-.02, .15]	.006	[-.09, .07]
Literacy growth	-.089	[-.25, .05]	-.008	[-.19, .25]
Numeracy growth	-.028	[-.1, .04]	-.012	[-.06, .02]
R^2 (adj.)	.8		.75	
F	14.3***		9.7***	
Note: *N* (Bios) = 36, *N* (Conv.) = 30, CI = confidence interval. These numbers differ in subsequent regressions as growth data was only available for the years 2009 and 2010.				
*$p < .05$, **$p < .01$, ***$p < .001$				

Table 3 examines the contribution that all nine available NAPLAN variables may be making to achievement in the SC science exam. It is this model that is most representative of naturalistic classroom learning because of the range of variables represented. It indicates that the only variable that does not include zero in its 95% CI is the Trial science exam in response to Bios L&T practices. This suggests that Bios L&T practices have their primary effect upon memory formation, i.e. the establishment of prior learning that serves as an effective experience for use in subsequent needs, the SC science exam. All other variables included zero in their 95% CI, irrespective of L&T practices, indicating that neither set of L&T practices has any effect upon the cognitive processes of reading, writing, literacy and numeracy or that they co-opt growth in these processes into classroom learning. An emphasis must be made regarding the lack of effect that reading growth contributed to Bios L&T practices, though it was significantly different from the Conv. G2 group, just as in that group it did not contribute to Bios L&T outcomes.

For the individual models, the Bios model accounted for 80% of variance ($R^2_{adj.}$), with $F(9, 26) = 14.3$ at $p<.001$ whilst the Conv. G2 model accounted for 75% of variance ($R^2_{adj.}$), with $F(9, 20) = 9.7$ at $p<.001$. Both models had power >.8.

Table 4				
The contribution of growth in cognitive variables to SC exam achievement				
	Bios model		Conv. G2 model	
Variables	B	95% CI	B	95% CI
Constant	53.74**	[48.9, 60.1]	57.69**	[52.6, 62.6]
Trial	.42***	[.29, .51]	.36**	[.26, .46]
Reading growth	0	[-.034, .066]	-.022	[-.096, .083]
Writing growth	.012	[-.01, .083]	-.037	[-.079, .026]
Literacy growth	-.003	[-.16, .06]	.099	[-.058, .18]
Numeracy growth	.004	[-.075, .079]	-.011	[-.063, .01]
R^2 (adj.)	.73		.68	
F	17.9***		13***	
Note: *N* (Bios) = 37, *N* (Conv.) = 32, CI = confidence interval (2000 bootstraps, BCa)				
*p < .05, **p < .01, ***p < .001				

Table 4 presents the contribution that growth in the cognitive variables made to SC science exam achievement. For both models, all the 95% CIs of the growth variables included zero, indicating these variables have little bearing upon classroom learning. Noteworthy is that even though the mean score for reading growth in the Bios group was significantly different from the Conv. group, this difference was not carried over into the regression analysis. Thus, growth in the skills due to whatever influence, be it natural ability, peer and social influences etc. has little effect upon student learning in the classroom. The Bios model accounted for 73% of variance ($R^2_{adj.}$), with $F(5, 31) = 17.9$ at $p < .001$ and the Conv. G2 model accounted for 68% of variance ($R^2_{adj.}$), with $F(5, 26) = 13$ at $p < .001$, with power > .8 for both models.

Table 5				
The contribution of cognitive variables to SC science exam achievement				
	Bios model		Conv. G2 model	
Variables	B	95% CI	B	95% CI
Constant	23.4**	[12.6, 31.3]	25.3**	[10.8, 39.9]
Trial exam	.31***	[.24, .37]	.21**	[.075, .33]
Reading	.048*	[.008, .089]	.011	[-.027, .046]
Writing	.008	[-.027, .046]	-.013	[-.042, .019]
Literacy	-.017	[-.086, .045]	.045	[-.021, .11]
Numeracy	.023*	[.002, .041]	.01*	[0, .055]
R^2 (adj.)	.88		.74	
F	101***		37.5***	
Note: *N* (Bios) = 72, *N* (Conv.) = 64, CI = confidence interval (2000 bootstraps, BCa)				
**p* < .05, ***p* < .01, ****p* < .001				

Table 5 presents the contribution of the cognitive variables to SC science exam achievement[20]. It indicates that both sets of L&T practices had comparable effects associated with the trial exam and numeracy, though of slightly larger magnitudes in the Bios model. However, the Bios model is distinguished from the Conv. G2 model by the reading variable, which does not incorporate zero in its 95% CIs. The absence of an effect upon literacy in the Conv. G2 model is noteworthy because it is to this skill that Conv. L&T practices are targeted. Together, this indicates that Conv. L&T practices do not seem to promote the integration of language-based cognitive skills with the subject matter of the science being learned in the classroom. Alternatively, Bios L&T practices seem to co-develop the cognitive skill of reading with

[20] Appendix 1 presents a regression that uses 2009-2010 NAPLAN data. This generated results comparable with these 2008-2010 NAPLAN regressions. The only difference being that numeracy for both the Bios and Conv. G2 models included zero in their 95% Cis but which has no bearing upon the findings of the work. This indicates that the data structure of these two sets of NAPLAN numbers is equivalent and that the inclusion of the 2008 data simply increased the sample size to make it more representative of the student population.

subject matter. The Bios model accounted for 88% of variance ($R^2_{adj.}$), with $F(5, 66) = 101$ at $p < .001$ and the Conv. G2 model accounted for 74% of variance ($R^2_{adj.}$), with $F(5, 58) = 37.5$ at $p < .001$, with power > .8 for both models.

Table 6

The partial correlation of individual cognitive variables.

Bios model	Trial			Reading			Writing			Literacy			Numeracy		
Variables	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI
Controls	.772			.866			.877			.877			.869		
Predictor	.876	.31***	[.23, .38]	.876	.048*	[.01, .091]	.876	.008	[-.027, .047]	.876	-.017	[-.085, .046]	.876	.023*	[.001, .04]
Total $R^2_{(adj.)}$	.876			.876			.876			.876			.876		
pr^2	**.46**		**[.28, .59]**	**.091**		**[.004, .23]**	**.003**		**[0, .077]**	**.077**		**[0, .079]**	**.064**		**[0, .2]**
n	72			72			72			72			72		

Table 6 (Cont'd)

G2 model	Trial			Reading			Writing			Literacy			Numeracy		
Variables	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI	$\Delta R^2_{(adj.)}$	B	95% CI
Controls	.691			.747			.746			.741			.726		
Predictor	.744	.21**	[.086, .32]	.747	.011	[-.028, .046]	.744	-.013	[-.043, .017]	.744	-.045	[-.025, .11]	.744	.027*	[.001, .057]
Total $R^2_{(adj.)}$	.744			.744			.744			.744			.744		
pr^2	**.18**		**[.038, .35]**	**.0055**		**[0, .095]**	**.0087**		**[0, .11]**	**.027**		**[0, .15]**	**.079**		**[0, .23]**
n	64			64			64			64			64		

Note: Control variables include School Certificate exam (constant), Trial exam, reading, writing, literacy and numeracy, minus that predictor. CI = confidence interval (2000 bootstraps, BCa).

*$p < .05$, **$p < .01$, ***$p < .001$

Table 6 presents the partial correlation of all variables in the cognitive models. Comparatively, the Bios trial exam made a 2.6x greater contribution to SC science exam achievement than the Conv. G2 Trial exam, pr^2 =.46 vs. .18 respectively, of which both sets of 95% CI did not include zero. The Bios reading effect did not include zero in its CI and had a small effect at pr^2 =.09 and for which there was no equivalent effect in the Conv. G2 model. All other effects included zero in their 95% CI, indicating generally that neither set of L&T practice had any influence upon these cognitive skills (writing, literacy or numeracy). On the whole, this suggests that the other effects are specific to the different L&T practices.

The mediated effect of reading upon exam achievement.

Table 7				
Multiple mediation of cognitive variables in science exam achievement				
	Bios model		Conv. model	
Variables	B	95% CI	B	95% CI
Reading	.26	[.057, .45]	.071	[-.17, .34]
Writing	.035	[-.13, .17]	.08	[-.27, .13]
Literacy	-.075	[-.38, .22]	.27	[-.15, .66]
Numeracy	.14	[.005, .27]	.16	[.001, .32]
R^2	.81		.68	
F	300***		132***	
Note: *N* (Bios) = 72, *N* (Conv.) = 64, CI = confidence interval.				
*p < .05, **p < .01, ***p < .001				

Table 7 presents the standardised mediated effect that cognitive variables had upon SC science exam achievement[21]. Both models indicate the numeracy skills made similar contributions to student achievement, again indicating that it is a skill unaffected by either type of L&T practice. In the Bios model, reading was the sole cognitive variable by which the prior learning of the trial science exam was carried forward to achievement in the SC science exam, i.e., its confidence interval did not include zero, .26 [.057, .45]. This effect also had (an unstandardised) positive contrast against the writing effect, .13 [.02, .23], suggesting that reading and writing skills co-exist and that Bios L&T practices favour reading skills over writing skills. Together, this suggests that Bios L&T practices had an effect that was more global in its influence upon classroom learning; one that went beyond the immediate and

[21] The multiple mediation models for growth in cognitive variables did not identify any significant indirect effects.

logical effect of reading as a contributor to exam achievement. Alternatively, all other coefficients of the Conv. G2 model included zero in their confidence interval, indicating their lack of involvement in transferring prior learning to new situations. Thus, the cognitive processes associated reading appears to represent the causal pathway by which Bios L&T practices had their effect upon the learning of students, an effect for which no counterpart exists for students who received Conv. L&T practices.

Both mediation models possessed statistical significance. The Bios total effects model had $F(1, 70) = 300$ at $p < .001$ and accounted for 81% of variance (R^2). The change in paths was from $c = .52$ [.46, .57] at $p < .001$ to $c' = .31$ [.22, .4] at $p < .001$. For the Conv. G2 total effects model, $F(1, 62) = 132$ at $p < .001$ and accounted for 68% of variance (R^2). The change in paths was from $c = .42$ [.34, .49] at $p < .001$ to $c' = .21$ [.08, .33] at $p < .01$. As the c' path was not reduced to zero in both models, mediation is only partial. Both models had power $\geq .8$.

The κ^2 effect size of reading only mediation for Bios and Conv. G2 was .44 [.31, .56] vs. .32 [.13, .4] respectively. As the Conv. G2 multiple mediation model did not identify any cognitive variables as exerting an indirect effect, the origin of this effect is attributable to a variable(s) outside the scope of those examined. In contrast, the Bios effect can be attributable to reading skills as precipitated by Bios L&T practices. As above, both mediation models possessed statistical significance. The Bios total effects model had $F(1, 71) = 302$ at $p < .001$ and accounted for 81% of variance (R^2). The change in paths was from $c = .35$ [.28, .43] to $c' = .17$ [.11, .24]. For the Conv. G2 total effects model had $F(1, 64) = 161$ at $p < .001$ and accounted for 72% of variance (R^2). The change in paths was from $c = .29$ [.18, .4] to $c' = .15$ [.06, .25]. As the c' path was not reduced to zero in both models, mediation is partial.

The general effect of Conventional L&T practices upon student learning.

Table 8

Predictors of SC exam achievement by teacher

	Teacher α		Teacher β		Teacher χ		Teacher δ		Teacher ε		Teacher ϕ	
Variable	B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Constant	55.1***	[49.5, 60.9]	50.6***	[41.9, 6.7]	55.1***	[27, 58.3]	53.8***	[43.4,60]	49.3***	[44.8, 54.8]	49.8***	[28.6, 56]
Trial	.45***	[.37, .52]	.48***	[.38, .57]	.35***	[.15, .44]	.41**	[.24, .54]	.5***	[.42, .57]	.49***	[.31, .58]
Read	-.016	[-.07, .034]	.038	[-.006, .11]	-.038	[-.098, .006]	.059	[-.028, .14]	-.002	[-.069, .071]	-.089	[-.089, .096]
Writing	.001	[-.041, .036]	.012	[-.025, .033]	-.014	[-.049, .013]	.047	[-.033, .13]	-.012	[-.063, .047]	.03	[-.034, .11]
Literacy	.017	[-.089, .13]	-.19	[-.058, .027]	.081	[-.013, .23]	-.12	[-.29, .69]	.002	[-.12, .11]	-.015	[-.18, .13]
Numeracy	-.002	[-.014, .25]	-.029	[-.052, -.011]	-.02	[-.064, .052]	.021	[-.027, .084]	.012	[-.021, .035]	-.007	[-.068, .075]
R^2(adj)	.72		.81		.68		.73		.8		.6	
F	27.9		32.3		17		16.5		33		12.8	
N	54		38		39		30		42		40	

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 8 (cont'd)

<u>Growth in predictors of SC exam achievement by teacher</u>

	Teacher α		Teacher β		Teacher χ		Teacher δ		Teacher ε		Teacher ϕ	
Variable	B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Constant	56.1***	[50.5, 62]	52.4**	[43 62.3]	57.3***	[51.5, 61.5]	47.9**	[19.1, 96.1]	49.1***	[45.6, 52.9]	52.7***	[46.2, 57.1]
Trial	.42***	[.32, .52]	.42**	[.23, .74]	.36***	[.26, .49]	.52*	[.34, .74]	.5***	[.41, .57]	.46***	[.37, .58]
Read G.	.009	[-.028, .49]	-.017	[-.29, .24]	-.041	[-.1, .017]	.037	[-.072, .13]	.032	[-.054, .098]	-.033	[-.11, .033]
Writing G.	-.018	[-.058, .038]	-.04	[-.097, .06]	-.011	[-.048, .03]	.08	[-.088, .13]	-.007	[-.069, .049]	.041	[-.038, .13]
Literacy G.	.003	[-.089, .074]	.14	[-.13, .24]	.097	[-.014, .2]	-.095	[-.33, .52]	-.022	[-.17, .15]	.009	[-.15, .18]
Numeracy G.	.009	[-.038, .056]	.004	[-.079, .056]	-.01	[-.048, .075]	.12	[-.2, .26]	.013	[-.036, .059]	.004	[-.062, .064]
R^2(adj)	.79		.78		.67		.66		.81		.67	
F	23.2***		14.9***		16.4***		7.3***		36.4***		16.7***	
N	31		21		39		17		42		40	

*$p < .05$, **$p < .01$, *** =$p < .001$

Table 9				
Regression and multiple mediation models of whole school science exam achievement				
	Regression model		Mediation Conv. model	
Variables	B	95% CI	B	95% CI
Constant	51.7***			
Trial	.46***	[.42, .5]		
Reading	.002	[-.024, .018]	.014	[-.16, .09]
Writing	-.005	[-.015, .026]	-.027	[-.11, .11]
Literacy	.006	[-.026, .031]	.033	[-.15, .25]
Numeracy	-.001	[-.008, .008]	-.01	[-.05, .039]
R^2	.72		.72	
F	125***		617***	
Note: *N* (Regression) =243, *N* (Mediation) = 243, CI = confidence interval.				
**p* < .05, ***p* < .01, ****p* < .001				

Tables 8 and presents the contribution of the cognitive variables and their growth scores to SC Science exam achievement in response to the L&T practices of individual teachers, whilst Table 9 condenses all that into one regression and one mediation model. First, as Table 8 indicates that the 95% CI of all cognitive predictors or growth in these predictors includes zero, it appears that Conv. L&T practices of individual teachers generally do not develop these cognitive skills nor co-opt their potential for growth in prior learning to any significant degree during classroom learning. The only predictor that possesses a 95% CI that did not include zero was the Trial science exam. Table 9 indicates the general effect of Conv. L&T practices on student learning and that these are not associated with indirect effects through which cognitive factors may contribute to prior learning. This pattern of student achievement relative to individual teachers is consistent with the pattern of matched students, with the exception being that numeracy did not show a positive contribution. In general, there seems to be a lack of effect of Conv. L&T practices upon cognitive variables.

These two models both possessed statistical significance, with the regression model having $F(5, 237) = 125$ at $p < .001$ and accounting for 73% of variance (R^2) and the mediation total effects model having $F(1, 241) = 617$ at $p < .001$ and accounting for 72% of variance (R^2). The change in paths was from $c = .47$ [.43, .51] at $p < .001$ to $c' = .46$ [.42, .5] at $p < .001$, indicating partial mediation[22]. All models had power $\geq .8$.

On the whole, this suggests that Conv. L&T practices: Are uniformly enacted by science teachers in the school; Do not impact cognitive skills; That student learning is independent of the individual teacher; That the propositions underpinning Conv. L&T practices are accurate depictions of the classroom learning environment; And finally, that all students have the capacity to more fully develop their learning potential.

[22] Field (2013) recommends that the whole model effect equation (c) be presented alongside the mediated model equation (c') to illustrate the magnitude of mediation upon the model.

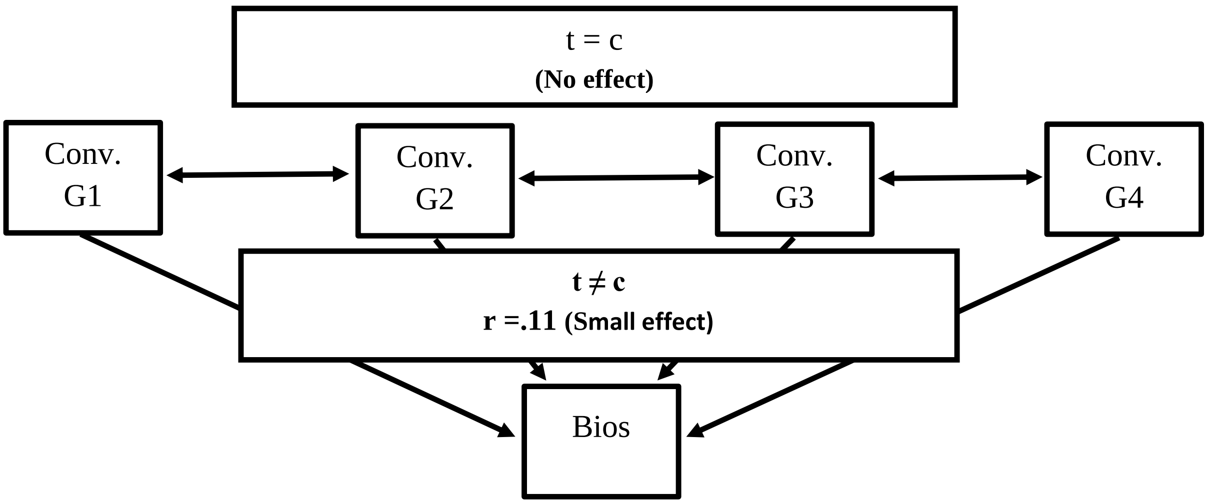
Adjusted effect sizes of Bios L&T practices.

All things being equal, the accumulation of results indicate that t ≠ c. No causal effect is associated with Conv. L&T practices whilst a specific causal effect is associated with Bios L&T practices. Figure 15 below summarises the adjusted Bios effect sizes, defined as t – c. The effects detected correspond to all statistical criteria needed to lend inferential credence to the hypothesis that Bios L&T practices had a distinct effect upon the classroom learning of science.

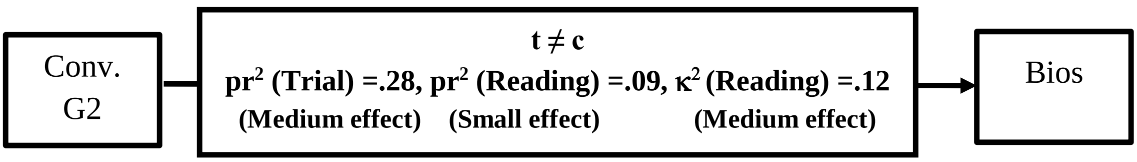
Figure 15

Corrected Bios effect sizes

Bivariate regressions



Multivariate and multiple mediation regressions



Classroom observations and reflections of the Bios teacher.

The following informal observations, whilst not a formal component of the quantitative data analysis, is generally relevant to the data as it provides a contextual perspective on the dynamics of student(s) and teacher interactions in response to Bios L&T practices.

As the Bios intervention teacher, I found that the change in classroom dynamics in response to my implementation of Bios L&T practices was most notable in the realm of attention. That is, as the Conv. G3 teacher, attention from students was something I expected and something I had to constantly cajole from my student. For example, if students got off-track with the lesson, i.e. were talkative, misbehaving, not focused, argumentative, defiant etc., typical corrective strategies included re-seating the student elsewhere in the classroom, preventing the student from participating in hands-on experiments, sending the student out of the classroom for a cool-off period (followed by a possible 'dressing down'), the threat of lunchtime detention to pick up litter, a formal 'room 1' lunchtime detention and finally, a letter home informing parents of their students' bad behaviour. In all of these cases, a unilateral exchange between myself (the teacher) and the student(s) occurred in which I informed the student what constituted acceptable classroom behaviour. This pattern of student teacher interaction continues to dominate Conv. L&T practices to-date.

Alternatively, in the Bios classroom, attention was something that was mostly given by students and for which I did not have to fight. Perhaps because students were given greater control of classroom dialogue, they were more willing to 'slip-into' acceptable classroom behaviour. On occasions when dialogue got too off-track, it was a simple matter of encouraging the class to get back on-track. Coercive techniques, such as those noted above, simply did not need to be applied and teaching became much easier and more engaging, for the class and teacher alike.

Additionally, the implementation of the Bios pedagogy coincided with a conscious change in character as a teacher. As one inculcated into Conv. L&T practices via a university qualification in secondary science teaching, my teacher character manifested itself from the role of teacher as one whose task it is to put students on the right path to adopting scientific truth. It was a dogmatic approach to science education in which my aim was to overwrite subjective knowledge with objective knowledge. However, intense apathy with the job after four years of the laissez-faire school management of student learning led to a year hiatus as a science education lecturer. In this academic environment, a ‘stepping back’ of character into my former research scientist occurred. In this mode of relating to science, it was the shared discovery of scientific ideas that occurs in research laboratories which manifested itself as my teacher character. Upon taking up teaching again one year later, every lesson became a science laboratory in which my ideas and student ideas (not necessarily of a scientific nature) were shared and let lose to reach a scientifically logical and defensible conclusion.

In making these observations, I must emphasise strongly that they are subjective; there may be a strong unconscious ‘wishful thinking’ bias favouring my perception of student behaviour in classroom as different from before. Indeed, it may simply be that I perceive a normally behaving class of students differently because I interpret their normal behaviour through my new Bios perspective. However, on the whole, the statistical analyses strongly indicate that something external to my unconscious bias did occur in response to my Bios perspective. Additionally, the simple fact that I did not have to fight for student attention and teaching became more enjoyable with less need to discipline students was tangible to my mental state and level of job satisfaction.

Summary.

Bios and Conv. L&T practices resulted in both groups of students arriving at similar levels of achievement in the SC science exam (as expected because of the Md matching strategy) but by statistically different pathways. This difference has substantial implications for future learning and teaching endeavours. Most noteworthy of the Conv. L&T practices is the lack of involvement of cognitive skills in the learning process, especially regarding literacy because it is to this skill that Conv. L&T practices were aimed. Additionally, this lack of effect seems to result in the prior learning of the Trial science exam contributing less than it potentially could relative to Bios L&T practices. This pattern of student response to Conv. L&T practices was conserved across the period of the study, irrespective of the L&T practices of individual teachers. In total, this is a future concern for both student learning and teacher practice. On the other hand, Bios L&T practices appear to exert a distinct influence upon student learning in the classroom. This effect is composed of a medium effect in prior learning of (pr^2 =.28) and a small effect in reading (pr^2 =.09), associated with which was a medium mediated effect (κ^2 =.11). Regarding classroom behaviour, less time was spent on managing student behaviour in response to Bios L&T practices compared to Conv. L&T practices and students were generally more accepting of one another, open to discussing ideas and more willing to ask questions.

CHAPTER 6: Discussion.

“Not full reductions, but better explanations” (Baars, 2012, p.40)

Preamble.

The origin of the Bios effects is attributed to the richness of the interpersonal dialogue that occurred between the teacher and students; the expected outcome of L&T practices that reflect the cognitive architecture of the mind[23]. From the teacher’s ‘whole class perspective’ (Loughran, 2006), this probably resulted in students being more engaged in the classroom because the teacher was a participant in (not manager of) classroom events. This then may have predisposed students to voluntarily reorientate their attention to classroom events and participate more favourably in what was being taught; which may have possibly promoted memory of classroom learning that is more personally rich and relevant to each student’s ZPD. On the whole, the interaction of these effects probably resulted in the development of the student ZPD on one’s own linguistic terms and under favourable affective conditions. Thus, cognitive skills that built upon language were brought to the forefront of classroom learning (i.e. reading) in response to Bios L&T practices. On the whole, it appears that simply letting students exert more control over the nature of classroom dialogue results in their being socially engaged with the classroom, which in turn leads to statistically significant direct and indirect effects and the generation of an overall positive classroom affect; results that are reminiscent of the Dubinsky et al. (2013) ‘Brain U’ results.

It is acknowledged that though Bios L&T practices were conceived of via a working memory framework to focus on the role of dialogue, no actual testing of working memory was employed

[23] To what extent Bios L&T practices reflect the cognitive architecture of the mind is arguable yet ultimately relative to one’s preferred conception of the human mind. At the least, I believe that the statistics of this work illustrate that some scientific conception of the mind is better for student learning than no conception at all.

in the work. Nor were any measures of episodic future thinking or autobiographical memory acquired. Hence, it is possible that the explanation for the Bios L&T effects resides elsewhere in the nebulous field of educational research.

For example, attachment theory as it relates to school achievement seems relevant (Bergen & Bergen, 2009). Attachment theory identifies four basic types of teacher-student relationships; secure, insecure/avoidant, insecure/resistant and insecure/disorganised-disoriented. Depending upon which type a student experiences, educational outcomes may vary, with the secure relationship being the most conducive to school achievement. Two assumptions underpin this assertion; that feelings of security encourage students to freely explore their world and that attachment is the basis of socialising students. Simply, feeling secure at school results in a positive affect toward learning and less risk of untoward events.

Nonetheless, Bergin and Bergin (2009) note that secondary schooling is associated with increasing levels of negativity. They identify two phenomena of teacher practices to account for this negativity. First, secondary teachers are more concerned with maintaining control of the classroom at the expense of student choice and self-management at a time when students are seeking more autonomy in their life. Consequently, teachers spend less time teaching. Second, this leads to teacher-student relationships that are less personal and less positive. Consequently, teachers see students as less trustworthy while students see teachers as less friendly. It is this state of affairs that typifies the Conv. L&T practices documented in this work and which stimulated my counterfactual thinking.

To overcome this state of affairs, Bergin and Bergin (2009) make six recommendations that teachers can apply to foster secure school attachments. These include cultivating warm and sensitive relationships with students; being well-prepared for class and holding high expectations for student achievement; providing choice whenever possible; avoiding coercive disciplinary measures; helping students be helpful, kind and accepting of one another and finally, implementing specific strategies for difficult relationships. Again, these are things that teachers do anyway (in my school at least) and so really do not provide any greater insight into professional practice. Ultimately, these recommendations reflect the social constructivist ideology: That is, attachment theory assumes that positive relationships will automatically result in improved student learning, independent of how the teacher teaches. But as Hardiman (2012) observes, teaching does not necessarily result in learning. How it is done and what is done makes a difference to student learning. Attachment theory does not, by my professional judgement, stimulate the mind to seek out other variables that may influence classroom learning or how these may be manipulated to promote classroom learning and cognitive development (especially regarding the centrality of language in learning).

The heuristic framework.

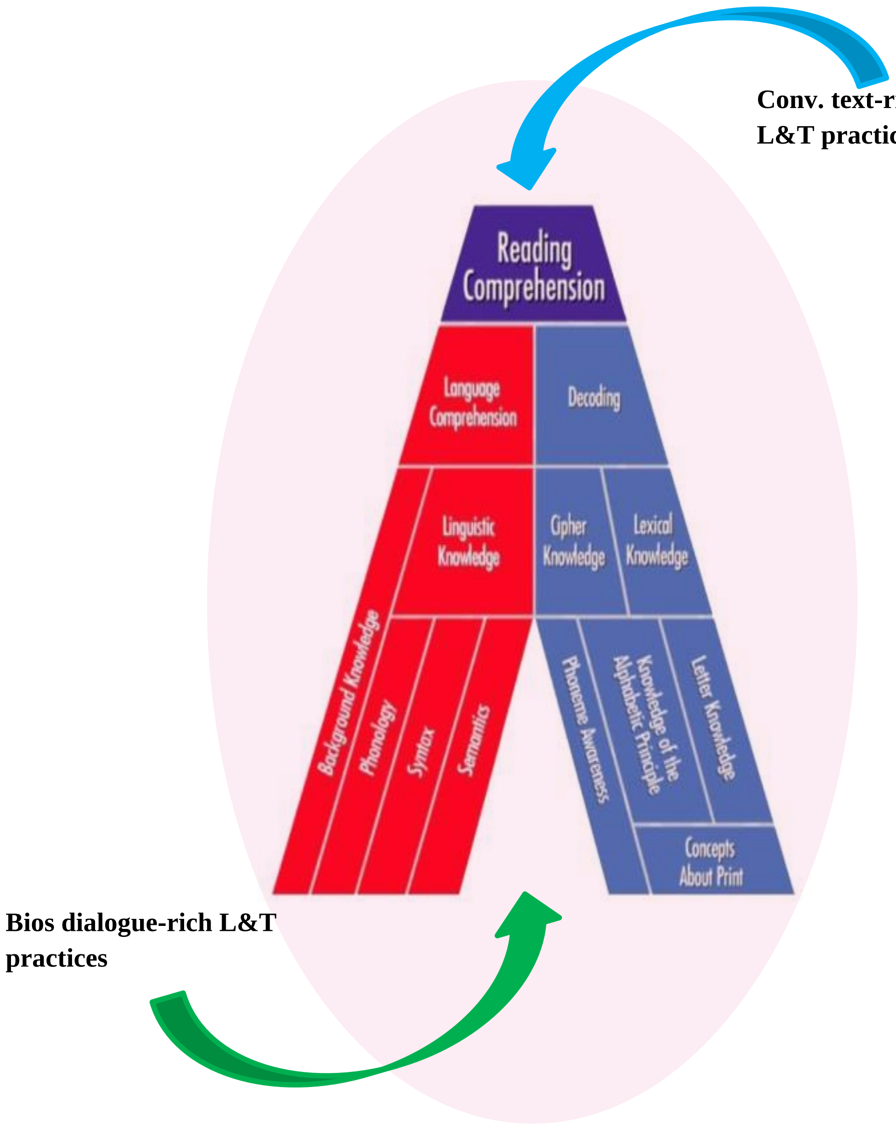
As the point of unique difference between student learning outcomes in response to the different L&T propositions is reading, use is made of Blair's (1999) 'Cognitive Foundations of Learning to Read Framework', as adapted by Wren (2000), as a heuristic device to guide the explanation of the data[24]. This is used in parallel with the multicomponent model of working memory and together, they are used to generate the most likely causal pathway of student learning in response to Conv. and Bios L&T practices.

Figure 16 below, the A-frame heuristic, indicates that numerous processes are associated with reading comprehension, that ability to understand text and generate cogent thoughts. These can be separated in to two streams: 1) Decoding, being the ability to convert words into speech sounds and; 2) language comprehension, being the ability to understand spoken language. As a heuristic device, the A-frame is viewed as a series of interconnected cognitive processes

[24] In my opinion, this device is consistent with Dehaene's (2009) 'Reading in the brain: The new science of how we read".

through which the teachers' word sounds pass on their way to being comprehended. The further up the frame sound progresses, the more subject it is to predictive, higher order cognitive processing. This processing is performed by working memory, as it is modulated by autobiographical memory processes. Thus, a strange word and/or context can confound the mind's predictive meaning-making efforts, leading to less stable and less accurate cognitive scaffolds through/on which subsequent learning occurs. In this framework, Conv. L&T practices are positioned as having a text-dominated top-down fit approach to student reading comprehension while Bios L&T practices have a bottom-up, dialogue-dominated approach to reading comprehension.

Figure 16
The A-frame heuristic



From *Cognitive Foundations of Learning to Read: A Framework* (p. 13), by S. Wren, 2000, Austin, TX: Southwest Educational Development Laboratory (SEDL). Copyright ©2000 by SEDL. Reprinted with permission of SEDL.

Learning in the counterfactual classroom.

Regarding the absence of statistically significant cognitive data that coincides with the pedagogical focus on literacy in Conv. L&T practices, it is proposed that the reliance on text (via summarising notes in text books, completing work sheets and copying teacher notes from the white board) as the primary learning mechanism draws too heavily upon the higher order cognitive skill of reading comprehension. Hence, the lack of pedagogical consideration given to the underpinning lower order processes in Conv. L&T practices results in new learning material lacking cognitive traction in the streams of decoding and language comprehension as the text feeds into the higher order cognitive skill of reading comprehension. This reduces the effectiveness of the brain's imperative toward self-directed meaning-making and dampens the ideational anchorage of new learning material onto pre-existing cognitive scaffolds. This is compounded by the coincident demand for behavioural compliance during student engagement with text and more broadly within the classroom. This places high demands upon central executive functions, depriving the student mind of resources that may be better utilised when directed to the cognitive processes underpinning reading comprehension instead of the monitoring of one's behaviour to ensure harmony with the teacher's behavioural expectations.

Under these conditions, the singularity of the student attention, socialness and dialogue relationship is fragmented, leading to a lack of synchrony within student mind receiving Conv. L&T practices. *Ipso facto*, paying attention requires more cognitive effort than can *naturally* be mustered, thus causing the redirection of cognitive processes away from reading comprehension on to those cognitive processes concomitant with behavioural compliance. Thus, students direct sustained attention to the inhibition of teenage socialness and dialogue at the expense of the cognitive processes underpinning reading comprehension. This forces students to fall back too heavily upon their prior knowledge as the epistemic (meaning-making) device with which to assimilate their new learning from the text into their current cognitive scaffolds. Meanwhile, the central executive is dealing with attentional matters, like inhibiting responses to external distractors, suppressing prepotent responses and assigning resources to the reading task at hand. As the social background of students is unlikely to possess adequate scientific prior knowledge to allow reading comprehension of scientific text, the teaching of science according to Conv. L&T practices is akin to Social Darwinism: Those students who can, do, while those students who cannot, learn as best they can on their own terms and independent of engagement with the teacher's expertise. Thus, the pr^2 of prior learning from the Trial Science exam was reduced by 2.5 times its value relative to Bios L&T practices. The cognitive processes of literacy, reading, writing and numeracy remained statistically insignificant contributors to SC Science exam achievement. In the case of these processes, their lack of significance is attributable to trial and error problem solving because Conv. L&T practices do not synchronise with the cognitive architecture of the mind.

It is to this dynamic of variables, the focus on text as the primary learning resources with the collateral separation of attention, socialness and dialogue via Conv. L&T practices that the uniformity of student learning across three temporally distinct data sets (Conv. G1/G2 and G3 G3) is attributed.

How reliance on text stifles classroom learning.

Credence for this interpretive perspective on the consequence of relying upon text as the primary learning resource is offered by several research findings. Cain and Oakhill (2009) note that many of the skills required of reading comprehension are common to listening comprehension. Additionally, Compton et al. (2009) note that deficits in lower order word recognition skills (those at the bottom of the A-frame in Figure 16) up to deficits in higher order advanced language skills and metacognitive skills (those at the top of the A-frame in Figure 16) have been detected as significant contributors to reading comprehension failure. Additionally, Perfetti (1985) observed that as reading is a dynamic process happening in real time, reading difficulties restrict text comprehension because cognitive resources are more focused on decoding text than comprehending the text. And as the meaning of text constructed at that point in time influences the meaning ascribed to subsequent words and sentences (Cain & Oakhill, 2009), reading comprehension failure is a highly likely outcome for every single student at some stage in the school year as they engage with text after text after text; all of which, in the case of science, address different topics with their own particular set of words/meanings. As Compton et al. (2009) indicate, having struggling readers read more text in the hope that they will build up adequate declarative (semantic and episodic memory) knowledge is not sufficient to overcome reading difficulties.

In reviewing the well documented interrelationship of vocabulary knowledge and declarative knowledge with reading comprehension, Beck, McKeown and Kucan (2002) note that text lacks many of the characteristics that oral language uses to support the learning of new words and contexts. For example, text does not communicate body language, intonation and pronunciation that automatically accompanies the spoken word. That is, it is the entirety of the context associated with spoken words that facilitates the inferring of meaning in dialogical exchanges. Nagy, Anderson and Herman (1987) estimated that from primary school to high school, children learn 10 to 15 new words per day. But because dialogue is much less rich in rare words compared to text (Hayes and Ahrens, 1998) i.e. science specific words, students have much less opportunity to broaden their vocabulary knowledge via dialogue and consequently, acquire less declarative knowledge. The significance of declarative knowledge for reading comprehension is that the more one has of the former, the better at reading comprehension one will be (Langer & Nicolich, 1981). Hence, it is logical that teachers rely heavily upon text in their attempts to develop declarative (science content) knowledge but it is illogical in light of the estimate that of every 100 rare words encountered in text, only 5 to 15 will enter vocabulary (i.e. lexical) knowledge (Nagy et al., 1987 and Swanborn & de Glopper, 1999). More broadly, rare words in text will not likely contribute to any substantive degree towards the interdependency of lexical, semantic, cipher and background knowledge because of their lack of personal context should such words be spoken. Consequently, text would contribute even less to the upstream, more fluid higher order aspects of reading comprehension where such rare words encompass more abstract concepts that could stimulate broader and deeper thinking.

Cain and Oakhill (2009) observed that it is rare for authors to make every detail in their text explicit to the reader. That is, the reader must fill in some assumed knowledge gaps that the author has omitted for whatever reason. Consequently, students must apply metacognitive skills ('language skills other than word recognition') and make predictions to 'fill the gaps' of what the author has omitted before a comprehension of the read text can be gained. Kitsch (1998) states that successful comprehension (reading and listening) results in a representation of the material that is integrated and coherent. Cain and Oakhill (2009) identified three metacognitive skills that facilitate the generation of coherent and integrated meaning from text, being inference and integration, comprehension monitoring and knowledge and use of narrative structure. By using these skills, readers and listeners are able to gauge when comprehension is adequate, being that state in which links between sentences or to other parts of the text are made to establish coherent and integrated meaning from the whole text, indicating that gap-filling has been effective.

Regarding inference and integration, it has been observed that inference making relies heavily upon general knowledge and that it improves in time (Bowyer-Crane & Snowling, 2005 and Barnes, Dennis & Haefete-Kalvaitis, 1996). They note that differences in the accuracy of inferring occur between the ages of 6 to 15 and teenage to adult years. In examining the role of memory in integration and inference in the earlier years, it was noted that good memory recall for explicit detail in text in poor comprehenders did not align with the difficulty experienced in text integration and inference-making. Finally, even when matched for age, word reading ability and sight word vocabulary, poor comprehenders exhibit difficulty in detecting the presence of false sentences spoken shortly after the original sentences. Accompanying poor integration and inference-making skills is poor comprehension monitoring. Generally, this describes the ability to detect text that does not integrate with the so-far generated meaning of the text or that is incongruent with general experience. To correct poor monitoring skills, students need to constantly to evaluate their own understanding of the text as they are reading it (Cain & Oakhill, 2009) via inference making and thereby remediate the so-far generated meaning. In class, this is a lot of work for students to do, especially considering that the class will probably move onto the next learning item before adequate time has been had to fully remediate one's errant meaning of the text.

On the inferential richness of oral language and reading comprehension, Eason and Cutting (2009) note that listening comprehension and word recognition account for 62% to 80% of variance in reading comprehension. Further, that these have different weightings as children progress from 2nd grade to 4th grade to 8th grade (or early high school). Catts et al. (2003, as cited in Eason & Cutting, 2009) note that the contribution of word recognition to reading comprehension steadily decreases as student's progress to 8th grade while the contribution of listening comprehension to reading comprehension steadily increases as student's progress to the early years of high school. That is, as students get older and progress through their grades, additional language skills supplant word recognition as a decoding skill in successful reading comprehension. In exploring the word recognition to listening comprehension transition, Eason and Cutting (2009) speculate on the nature of reading material as it spans primary to early high school. They observe that in the early years, reading is focused on phonics (the sound of words) and narrative texts whereas in later years, there is a greater emphasis on expository texts that have higher frequencies of rare words that are encountered in a silent reading situation. Hence, reading comprehension of expository science text in science classrooms subsequently requires a greater set of cognitive skills, being those associated with the inferential richness of talk, working memory and processing speed. On working memory and its contribution to reading difficulties, a metareview by Caretti, Borella, Cornoldi and De Beni (2009) identified verbal short term memory, verbal working memory (in children and young adults) and the central executive function of updating as possessing effect sizes ($d > .7$), twice those of the other components of working memory, thereby illustrating the central role that oral language plays in reading skills.

Despite the good will with which teachers employ the potential for text to enhance the semantic network in which rare words are embedded and increase declarative knowledge of science content, text is less than talk for inferring the meaning of new words (Jenkins, Matlock & Slocum, 1989). The lack of rich dialogical engagement by the teacher with classroom students, *en masse*, thus diminishes the opportunities students have of developing the metacognitive skills of integration and inference-making. This diminution of metacognitive opportunity is more so compounded because it is occurring at a time in which listening comprehension is in the ascension as a student learning resource for reading comprehension of text, be it summarising notes in text books, completing work sheets or copying teacher notes from the white board.

The work of Carreker et al. (2007) is thus significant because it reported that a Matthew effect was detectable in primary school children who experienced teachers employing ‘linguistically rich content knowledge.’ The Matthew effect (Stanovich, 1986) describes an effect in which reading competency builds upon itself to promote greater reading competency whilst those with less reading competency fall behind in their growth of reading competency. In this study, students who had been taught by primary teachers who had undergone language enrichment training in the sub-skills underpinning reading (*viz*, the heuristic A-frame) were found to have been significantly advantaged in their growth in reading comprehension two years later (from 3rd grade to 5th grade). Those students who did not receive pedagogical practices that were linguistically rich in content knowledge were found to not have achieved as much growth in their reading comprehension. This report demonstrated that different pedagogical practices precede different types of student learning outcomes in response to different types of dialogical inputs. That is, rich dialogue that encompasses the diversity of cognitive processes associated with reading results in better reading outcomes. The report also lends credence to the distinction of L&T practices on the basis of their dialogical versus text orientations. In the current context, it is logical that a teachers' over-reliance on text as a learning resource (at the expense of teacher-rich dialogue with students) serves more to bore and disconnect students from classroom learning than it does in engaging the student with classroom learning.

The comparative absence of educationally desirable student learning outcomes in response to the Conv. L&T practices is thus due in part to its inability to conceive of student dialogue as a keystone variable in the repertoire of pedagogical tools for use during classroom practices. Instead, the propensity for teenage students to engage in talk as the mechanism of social interaction is viewed as a keystone distractor of student learning that can only be overcome by soliciting attention via behavioural rewards and punishments. Hence, the focus on text as being the primary epistemic tool and the assumption that repeatedly engaging with text will result in reading comprehension by the passive uptake of its embedded cognitive structures is misplaced: Student attention is not voluntarily drawn into the text to engage with its embedded cognitive structures because the text cannot immediately answer questions that may spontaneously arise during such engagement. This lack of context knowledge subsequently serves to confound comprehension by inference making from the text. Thus, text is a one-way engagement with a learning resources that cannot provide knowledge when it is needed and thus ensure its comprehension. Consequently, the cognitive measurements of literacy, reading and writing were detected as insignificant contributors to SC science exam scores because Conv. L&T practices do not align with the biological origin of and interdependency of dialogue, socialness and attention in the teenage mind. It is to this lack of alignment between L&T practices and learning in the student mind that typically results in Conv. L&T practices developing only prior learning to a nominal level; the lack of synchrony between the cognitive process of literacy and the formation of prior learning knowledge. It is the rich, two-way dialogical exchanges with the teacher (not the one-way, passive uptake of text under teacher direction) that enables students to develop the skills essential to reading comprehension and thus allow reading to become a student-controlled learning device instead of a teacher-controlled learning resource.

More broadly, the lack of influence of Conv. L&T practices upon cognitive processes reflects one of the seven properties that Strauss and Ziv's (2013) identify as making teaching a unique human activity; that teaching occurs without teachers being aware of its underlying logic. Strauss and Shilony (1994) note that professional teachers could explain that they broke down complex learning material into smaller chunks to make it easier for students to learn but they could not adequately explain what benefit that action had for the cognitive processes underpinning the learning of that material or how it was connected to other actions, like the pacing of the lesson or covering too much material too quickly. That is, Conv. L&T practices are locked exclusively into the social view of education which 'sees' only those variables evident to the everyday practice of teaching and that appeal to 'common sense.' A manifestation of this is in feedback given to students about assessment tasks (at the primary, secondary and university level in the Author's experience): it frequently focuses on asking students to reword that section or explain their ideas in that paragraph a bit more clearly without providing any perspective on why the sentence is unclear or ideas are confusing. That is, all care is given but no responsibility taken for the quality of work submitted by the student because there is a lack of content mastery on the part of the teacher/lecturer providing the feedback.

The work of Kirschner et al. (2006) suggests that the inability of professional teachers to provide a cognitive justification for their practices stems from the disconnection of constructivist philosophy from the cognitive processes that underpin learning. This disconnect manifests as L&T practices in which students are immersed in an 'information-rich environment' (of better books, videos, animations, smart boards, the internet, software programs etc.) in order to discover by themselves or by social interaction the solution to the problem the teacher has placed in front of the students. With respect to the cognitive process of working memory, Kirschner et al. (2006) note that the novelty associated with the information-rich environment risks exceeding the biological limitations of working memory capacity, hence more effort is directed to processing the novelty of the environment at the expense of learning about the material. Subsequently, long term memory storage and retrieval of learning derived from the information-rich environment may not be effectively established. Indeed, Kirschner et al. (2006, p.77) state, "Any instructional recommendation that does not or cannot specify what has been changed in long term memory … is likely to be ineffective." Thus, Conv. L&T practices, as influenced by the hegemony of constructivism in education faculties in Australian universities, results in teachers and subsequent school leaders not possessing an adequate understanding of the biology of learning to permit critical self-reflection to evaluate and justify their instructional recommendations and practices. Without being aware of this, teaching practices and school leadership practices cannot evolve and the cognitive processes of literacy and prior knowledge formation fail to complement each other to any statistically significant degree.

Learning in the Bios classroom.

Withear (2009) cites the *Adult Literacy and Life Skills* Survey conducted by the Australian Bureau of Statistics (ABS, 2006) to state that literacy levels (the ability to read and write) in Australia tend to gradually decrease with age. However, the 15-19 years age group bucks this trend by having a lower level of literacy than the 20-24 years age group. Most pertinent is Withear's (2009) observation that texts aimed at high school students are written with the assumption that all users of the text are proficient readers. Further, that as reading at high school has evolved to become a mechanism for learning (Cahall, 1983 and Robb, 2002) instead of a skill to learn at primary school, the development of reading skills in the high school classroom needs to keep pace with the level of comprehension required by the text if students are to acquire a level of literacy that is useful to their education. Withear (2009, p.33) thus makes the recommendation that teachers need to "model the internal questioning (*inferencing*[25]*)* that occurs in the minds of proficient readers *to make them* visible to poor readers" in order to prevent these same students from experiencing reading difficulties in their adulthood years.

Withear (2009) terms this phenomenon of students with reading difficulties passing unaided through school classes as *slipping through the cracks*. Underpinning this event is the tolerance of reading difficulty in otherwise 'normal classrooms' as the result of developmental lag theory. She identifies this as a pervasive assumption amongst teachers who take a 'wait and see' approach that students with reading difficulties simply need time to 'bloom and catch-up' in their reading skills, presumably by spending more time practising their reading skills. However, she notes the dilemma with this assumption is that poor readers usually exhibit a reading difficulty of a phonological origin, which if not attended to, means that any time spent on practising reading is not time spent on correcting the underlying cause of the reading difficulty. For this reason, Withear (2009) indicates that safety nets to detect and correct reading difficulties are especially important in the high school years where the failure to do so may result in the entrenchment of lifelong reading difficulty.

Stanovich (1986) coined this entrenchment of reading difficulty as the Matthew effect. As the development of reading skills occurs along a continuum of increasingly complex processes, beginning in early childhood and continuing into adulthood, students with reading difficulties become less and less inclined to read, causing them to fall linguistically further and further behind their peers as time goes on. In high school adolescents, the Matthew effect is

[25] My italics.

compounded by motivation, school engagement and self-efficacy, i.e. they start to develop attitudinal resistance to being singled out (stigmatised) as a poor reader and attempt to rely on other cues to compensate for their reading difficulty and thus remain under the radar of teacher attention. Of these Matthew effect students, some have poor text decoding skills, making it hard for them to convert printed words in to sound words, while others have comprehension difficulties, making it hard for them to put meaning to the words of the text that has been decoded. Poor comprehension in adolescents can manifest itself from a range of other difficulties, including a restricted vocabulary, a lack of background knowledge, language fluency and rapid-naming deficits (Biancarosa & Snow, 2006).

Working memory and reading.

Swanson, Zheng and Jerman (2009) take a finer grain view of the Matthew effect. They conducted a metareview to investigate the contribution of short term memory and working memory to reading difficulties in children with and without reading difficulties. The meta-analysis examined 88 peer reviewed publications and had an age range of 5 to 18 years (which includes the same age group as students in this study, approximately 15 years of age). After controlling for the influence of IQ, age and reading level, it was determined that reading difficulties associated with short term and working memory exist independent of these factors but nonetheless persist across age. Further, they note the perplexing observation that “children with reading disabilities have normal intelligence” (Swanson et al. 2009, p.278). As these measures of student potential (IQ, age and reading ability) contribute to the professional judgement about the learning needs of individual students, and thus what constitutes appropriate L&T practices for those students, the student potential for learning is not adequately nurtured because the foundation of such judgement bears little relevance to the cognitive processes associated with learning. Further, as these reading difficulties are carried from class to class, and can exist in students with otherwise normal IQ, it is highly unlikely that a single class in any subject, English, mathematics, history, geography, physical education, art, wood and metal technology, information and food technology, is composed of entirely proficient readers. It is these students who Denti (2004) has described as the '*elephant in the living room'*, simply treading water in their formative educational years.

To explain the unrelatedness of reading difficulties to IQ, age and reading ability, Swanson et al. (2009) proposed a model of reading difficulties in which the inability to adequately draw upon phonological and central executive resources results in reading difficulties. The specific deficits in phonological requirements reflected storage limits of word sounds in short-term memory, i.e. words drop out of memory because they are displaced by a distractor, while in the phonological loop it was access to speech codes. That is, the inability of the phonological loop to accurately retrieve and store the sound structure of language from long-term memory for manipulation in working memory was the major contributor to reading deficiency. In the central executive, it was the requirement for concurrent monitoring of processing and storage demands that was the prime deficit. That is, when reading requires the parallel processing of several stream of information in the phonological loop, the central executive retrieves resources from long-term memory to support such processing but at the expense of its own efficiency. Hence, the central executive with its dual role of allocating and monitoring attentional processes of the phonological loop and retrieving long-term information to supplement the workings of the phonological loop, is easily over-taxed, leading to reading difficulties. Nonetheless, Swanson et al. (2009) speculate that children with reading difficulties can do well in some academic domains because they experience low demands on working memory operations and they make up for their memory limitations by increasing domain specific knowledge and/or relying more heavily on environmental cues. That is, students employ many cognitive resources in the learning process.

Working memory and writing.

Though writing was not detected as an individual significant contributor in either L&T model, its positive contrast with reading via the Bios partial mediation effect suggests that a linkage exists. Further, that because the primary reading response is consistent with the working memory literature, the secondary writing response is likewise possibly associated with working memory. Vanderberg and Swanson (2007) describe writing as a complex task, one that required numerous cognitive processes to be simultaneously active whilst writing. In reviewing the literature exploring the association of working memory and writing, they note it is characterised by a lack of consistency in the strength of the correlations reported to exist between writing and working memory, ranging from weak to moderate to strong. Nonetheless, the pattern of positive correlations existing between working memory and the writing process was noted. To clarify this relationship, Vandenberg and Swanson (2007) sought to map the Hayes and Flower (1981) model of writing onto the Baddeley (2002) multicomponent model of working memory and thus identify which components are significantly involved in the writing process.

The Hayes and Flower (1981) model of writing identifies three key processes. The first, planning, involves establishing the general ideas, structure, and organisation of the written task. Second, there is translating, in which planning ideas are put down on paper and which may undergo restructuring during translating. Finally, there is revision in which what has been written undergoes reviewing, editing and/or rewriting. When Vandenberg and Swanson (2007) mapped these factors from an analytical writing task (‘Write an essay about …) and a creative writing task (write a story about this image) onto measures of the components of working memory, it was found that only the central executive was significantly associated with achievement in these two different types of writing. The phonological loop and the visuospatial sketchpad did not account for any significant variance in these two types of writing tasks. Though the contribution of the central executive to writing is small, averaging 7.3% for the creative task and 6.3% for the analytical task, its pivotal role in significantly contributing to the microstructure of written text, i.e. high-order writing skills, punctuation and vocabulary, also accounted for an average 6.3% of variance.

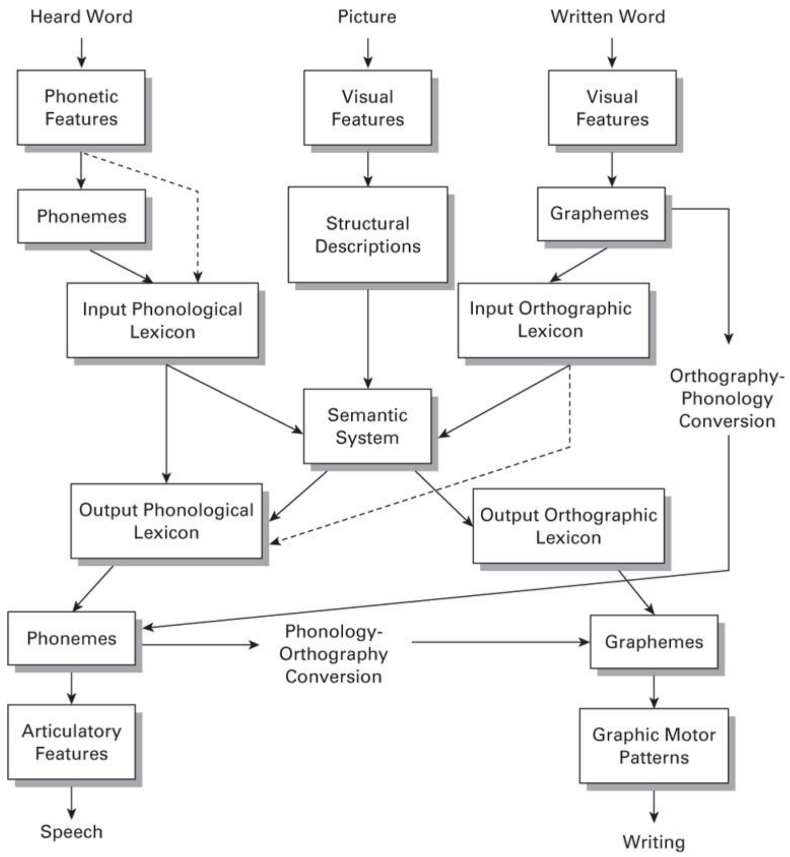
Vandenberg and Swanson (2007) offer an explanation for the lack of influence of the phonological loop and the visuospatial sketchpad on writing. In the process of writing, the central executive retrieves information from long term memory, manages the different cognitive skills (microstructure, planning, translating and revising) of the writing process and switches attention amongst the variety of thoughts associated with writing. Simply, the process of writing over-taxes the central executive, thus causing it to withdraw its contribution from the slave systems of the phonological loop and visuospatial sketchpad. Hence, the positive contrast of writing with reading in the partial mediation effect of Bios L&T practices.

Phonological processes and reading.

The linkage of dialogue to reading skills and then to writing skills in Bios L&T suggests that dialogue synchronised the cognitive processes students rely upon when learning. As its simplest level, classroom dialogue is the teacher's issuance of noise patterns representative of a coherent cognitive structure to which the students then respond. As this noise structure begins to make more sense, by students directly questioning the teacher and/or by listening to such exchanges, students begin to formulate increasingly coherent representations of topic knowledge. A prerequisite of making sense of classroom noise patterns is phonological processing. Anthony and Francis (2005) describe three phonological events that contribute to efficient phonological processing. The first two, phonological memory (in which the sound structure is temporarily stored) and phonological access to lexical storage (in which sound structures are retrieved from long term memory to facilitate meaning-making of the temporarily stored sound structure) are prominent in the early years of life as children become accustomed to the sound and meaning of words in their environment. Subsequently, phonological awareness, the skill with which a person recognises, discriminates and manipulates language sounds, develops. In the development of phonological awareness, Anthony and Francis (2005) note that as children mature two phonological processes overlap each other. First, there is an increased sensitivity to sound differences within words and second, there is increased detectability of similar and dissimilar sounding words before sounds within words can be manipulated. Subsequently, these phonological awareness skills are refined as children learn new phonological skills. Regarding phonological awareness and writing, Anthony and Francis (2005) state that once children learn to start writing, phonological awareness is dramatically influenced. This is possibly so because when writing words, there is a finer grain of attention required in converting sound to its visually equivalent word form, which itself is made up of a string of individual sounds.

Martin and Wu (2004) depict the role of phonological processes associated with meaning-making of a single word and how it may facilitate reading skills and writing skills (Figure 17 below). It indicates that three sensory inputs (the heard word, the written word and the picture) converge upon semantic long term memory systems and then feed out into speech and/or writing events. Additionally, the heard word and written word streams intersect with each other phonology-orthography conversions. Nonetheless, the heard word and the written word 'cross streams' in the semantic system, indicating that they both draw upon a common store of long term memory to construct and/or reconstruct the meaning of these inputs and also construct/reconstruct a speech or written response to inputs.

Figure 17
Models of single word processing



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On the identification of reading as the hallmark student response in Bios L&T practices, it is a logical assertion that the emphasis upon dialogue forged connections in the semantic system (and quite possibly across the broader long term memory structures, including working memory) which augmented speech output processes. Further, that the phonology-orthography conversion process was that much more practised in Bios students than in Conv. G3 students. Though the model illustrates the interdependent nature of the heard word and the written word processing, written word processing seems to be more dependent upon heard word processing, i.e. the more foundational the information is, the more widely networked in to the brain's processes it is. As Perfetti (2011, p.157) states, phonological processes are critical to reading because it is the "level of language that provides the surface interface to written words." That is, the heard word provides the platform upon which comprehension and response to the written word is built. Thus, dialogue created a feedback loop into the written word input processing system such that it forged connections in the semantic system but was not adequately forceful enough to forge orthography-phonology conversion. This forged cross-over of heard word input and into written word input and subsequently into written word output was thus detected as the significant response of reading to Bios L&T practices and subsequently, its significant combining with writing. Alternatively, the reliance on text in Conv. L&T practices did not adequately foster such semantic connections or orthography-phonology conversion to significantly contribute to written word processing and/or enhanced writing output.

Sequestering LTM into working memory.

Was and Woltz (2007), after investigating the contribution of available long term memory to working memory and listening comprehension, formulated a pathway model in which available long term memory had a unique contribution to working memory and listening comprehension. In their work, different types of verbal cues were used to activate long term memory to investigate how its availability impacted upon working memory. The model, weighted attention-driven WM to the listening comprehension pathway at .23 while the available LTM to listening comprehension pathway was more heavily weighted at .31. Prior content knowledge was also found to have a unique contribution to listening comprehension (weighted at .43) as well as contributing to available LTM and attention-drive working memory (weighted at .33 and .56 respectively). On the whole, they proposed that the ability of working memory to predict language comprehension tasks is due in part to the increased availability of long term memory for attention-driven process that occur in working memory.

In explaining the contribution of LTM within this triumvirate of cognitive events, Was and Woltz (2007) drew heavily upon Kintsch's theory of long term working memory (Kintsch, Patel and Ericcson, 1999). Briefly, this model posits that working memory draws more heavily upon long term memory for is operations (more so than does the model of working memory serving as the platform distinguishing L&T practices examined in this work). It suggests that the differences in individual comprehension skills result from the natural variability that individuals possess in their encoding of memory. Additionally, that the interpretation of discourse (dialogue and/or text) is somewhat determined by the quality of the encoded memory, i.e. as Was and Woltz (2007) speculate, listening comprehension is to some extent or other dependent upon the quality of verbal knowledge structures already in long term memory. They also note the two means by which Kintsch suggests that long term memory may be made available to working memory to aid discourse comprehension. First, the automatic associative route in which long term memory structures are automatically drawn in to working memory due to attention being focused on them and second, when an effortful and cognitively intense search for these structures must be performed before their retrieval in to working memory. Individual differences are also thought to exist in the ability to capture procedural and declarative (episodic and semantic) long term memory structures specific to discourse comprehension. The contribution that these cognitive structures make to the interpretation of discourse is also dependent upon background knowledge. That is, the presence of background knowledge facilitates the integration of incoming information with prior knowledge and thereby circumvents superficial engagement and processing of the new information. Finally, this background knowledge can influence the context in which discourse is interpreted and thus the constructive process of comprehension.

As memory retrieval is the flipside of memory encoding, Was and Woltz (2007) also indicate that better retrieval of long term memory may result from such memories being accessed more frequently, i.e. the verbal knowledge structures of some individuals is more easily retrievable because of prior experience doing so. From this dual encoding and retrieval perspective, Was and Woltz propose that the effect of semantic memory activation for increased availability in working memory was more likely due to persistent procedural memory, i.e. repeated cycles of the experimental task led to the operations of how to perform the feeding in to working memory, not the temporarily activated memory itself. Unfortunately, this study did not account for the possible contribution of episodic memory to long term memory formation, i.e. that type of long term memory enabling a person to re-experience past events in long term memory. It is feasible that the test conditions facilitated favourable episodic aspects of the required tasks which also manifested itself as enhanced availability of long term memory to working memory. In short, the specific identification of which long term memory structures interact and contribute their information to working memory is a still a vague area of knowledge.

Despite the doubt about the type of long term memory that interfaces the working memory and listening comprehension relationship, a hierarchy of effectiveness with which long term memory can be made available to attention-driven working memory seems to exist. In descending order of weightings, semantic activation is more effective than attribute activation which is more effective than category activation. This hierarchy does not seem to exist in the contribution of verbal (alphabetic and ABCD) factors activated in attention-driven working memory, which are both comparable.[26]

This hierarchy would appear to represent an effect manifested by the types of questions asked to stimulate priming. That is, in descending order, 'Were there more ***attributes*** of …', 'Were there more ***examples*** of …', and 'Were there more words ***meaning*** …'. As a teacher, it is the latter question, which is associated with the most effective cueing of long term memory, that requires broader, more comparative thinking in order to generate a response, i.e. the student mind is distanced from the information and required to make a comparative judgement about

[26] Though the contribution of the numeral activation for attention in WM is more significant than those of verbal factors, numeracy was not detected as a difference in L&T practices. This suggests that numeracy is a factor that both L&T practices could improve upon to enhance student learning potential.

how to answer the question. This offers more opportunity for sustained dialogue with students and thus ongoing dialogical negotiation on how to formulate an acceptable answer. Thus, open-ended questions lead to more open-ended questions and thus the availability of more long term for use in working memory. Alternatively, the remaining two types of questions descend in their comparative requirements, requiring less comparative thinking and lending themselves to the student mind generating a simple reflex response that terminates ongoing dialogue in negotiating acceptable answers. Therefore, closed questions do not provide much run-on questioning opportunity and do not prime long term memory as extensively. All this logically implies that general, open-ended dialogue with students is more effective at making long term memory available for learning purposes.

On the whole, the cognitive model of Was and Woltz (2007) suggests that the use of teacher dialogue as the primary learning resources to promote student learning most likely resulted in LTM being more effectively sequestered into working memory. Hence, the flow of this additional information through the long term memory, working memory and knowledge triumvirate subsequently favoured the more substantial available LTM pathway to listening comprehension. Thus, the heard word pathway of Martin and Wu (2004) was possibly driven that fraction more energetically by the dialogically rich Bios L&T practices, causing LTM to be frequently cycled through sequential encoding and retrieval processes. It is the frequency of these encoding and retrieval cycles that forged more efficient LTM cognitive structures that manifested themselves as the observed literacy effect in Bios L&T practices.

Episodic memory, the attention and LTM.

If the common science program is cast as that external body of semantic knowledge that students must commit to memory during their learning, then L&T practices can be cast as episodic knowledge, that particular memory that students employ to give contextual meaning to semantic memory as it is constructed and reconstructed into individualised cognitive structures.

From this perspective, L&T practices can viewed as a series of episodic classroom encounters with semantic knowledge that aim to sustain a classroom environment in which the student mind is made receptive to learning. In many ways, Conv. L&T practices aim to ‘calm the ripples of the student mind’ by placing a strict, work focused expectation upon student attention. The consequence of attention as work is to quell the internal dialogue with which the mind is spontaneously engaged and over time, condition the behaviour of students such that it reflects the teacher’s conception of what a class looks like and sounds like when it is paying attention to its learning. Thus, it is assumed by the teacher that an outwardly well-behaved student equates with an internal affective state of mind that is attentionally engaged with the learning resource at hand. Consequently, student attention in such behaviourally controlled conditions ought to result in clearer perceptions of the text in the student mind, leading to less distorted LTM memory encoding, more accurate construction/reconstruction of learned material, more effective retrieval of LTM and thus literacy of the knowledge.

Though this objective is common to Bios L&T practices, these aim to ‘sustain the ripples in the student mind’ to ensure that it is maximally receptive to its learning. The assumption here is that as the mind’s default state is to be constantly engaged with socialness and dialogue, allowing it to remain in that state whilst engaging in classroom learning (and teacher dialogue) would facilitate the student mind in making clearer its own perceptions of the learning material at hand. This would conceivably lead to less distorted memory encoding, more accurate construction/reconstruction of learned material and concomitantly, more effective retrieval of LTM and thus, improved reading skills associated with the newly formed knowledge. In the case of Bios L&T practices, the expectation of attention is that it is shared: The teacher accepts that one’s attention to the job of teaching will be distracted as student attention is sequestered from students by dialogue with the teacher. Consequently, students sustain their desired default mode state of mind whilst their focus of attention is on dialogue with the teacher; hence there is minimal need to call on students to stop being distracted and focus on the task at hand. In this way, attention is more teacher interactive and so more play-like yet still focused on the underlying learning work to be done in the classroom.

Coincident with this view of shared classroom attention in the Bios classroom is the axiom that the teacher is unable to exert any quality control whatsoever over the student brains' use of semantic knowledge once it has left the teacher and is subjected to constructive and reconstructive process. That is, the teacher cannot control the other factors occurring in the world of the student that may influence the nature of the cognitive scaffold. Neither can the student exert sufficient control over those influences to ensure that one has a state of mind uniformly receptive to classroom learning day-in and day-out. In view of this, it is the encoding and re-encoding of classroom information on a day-in and day-out basis over which L&T practices exert their greatest influence upon learning. Further, it is the attentional environment under which the encoding and re-encoding is enacted that determines the utility of classroom learning serving as a prior learning experience and its broader connectivity to cognitive skills of reading and writing.

Thus, working memory is not likely the sole origin of the difference detected in the Bios regressions. Nonetheless, working memory must have a role in generating the differences. A significant role for procedural memory (though not a component of the multicomponent model of working memory) is difficult to examine: In one case, it can be discounted because of the need for all teachers to move through the programme at a constant pace. That is, if any teacher spent more time on one topic to establish automatic responses to any one topic, they would not have kept pace with their colleagues and those students would not have covered enough of the science program. On the other hand, procedural memory may have evolved out of episodic engagement (as it is imbued with science) over the 30 weeks of classroom L&T experiences. That is, as a scientist (not a teacher), the teaching of cause and effect relationships was paramount to the manner in which the common science program was delivered, hence this may have established procedural memory regarding the process to work through when engaged in problem solving of Science questions. However, given the highly interactive nature of all the memory systems, some causal role for procedural memory must be attributed to the regression differences. On the whole, it is most likely the interaction that working memory has with episodic memory as cognitive work is being performed on the semantic knowledge being learned to which the difference in the regression data can be attributed. Further, that this interaction is mediated via voluntary attention, the single greatest affective difference observed between the different L&T practices.

Regarding the multicomponent model of working memory, its structure thus forms a fair reflection of classroom L&T practices. It is able to account for the presence of the reading effect in response to dialogue. However, from the Bios perspective of the classroom, it is the role of episodic memory in working memory that is more central to classroom learning than is the role of executive function. That is, in the classroom world of the student, the lower order role of episodic memory usurps the hierarchical position of executive function such that executive function and attention seem to evolve out of episodic engagement. It is arguable that this state naturally evolves from the practical necessity to maintain good relations between students and teacher, even if it is for the most mundane reason of avoiding conflict to maintain a decent working environment. However, if this state can be actively cultivated, i.e. good relations, then a reciprocated state of attention between student and teacher may also evolve. From a reciprocated state of attention/engagement between the teacher and students (viz. Dewey’s play as work), voluntary reorientation of attention becomes the norm of classroom on-goings. For the student, this facilitates more effective meshing of executive functions with the personal context of the semantic knowledge of the common science program, thus establishing more effective prior learning and concomitantly, reading skills associated with that learning. For the teacher, voluntary attention means less effort is placed on controlling student behaviour, freeing up working memory to tap more deeply into episodic memory to create engaging and individualised dialogue that is tethered to the semantic knowledge at-hand. In this manner, the working-self and self-defining memories may come into play during working memory activity to facilitate each individuals' knowledge construction process of classroom learning material.

That is, Vygotsky's 'Zone of Proximal Development' resides within autobiographical memory processes, as these are nested within working memory processes. The failure to adequately engage episodic memory of each and every student results in the failure to adequately deliver learning material to autobiographical memory processes (or the ZPD) and consequently, inadequate meshing of cognitive processes associated with memory formation and application unique in every single student. Thus, the delivery of learning material (via episodic memory) to autobiographical memory processes may free up central executive resources from addressing teacher behavioural expectations to focus on supplementing memory formation with cognitive processes, like reading, contributing to its greater prior learning status in response to Bios L&T practices.

On the unreciprocated nature of attention in Conv. L&T practices, episodic engagement (or the lack thereof) is highly predictable to the student because of the expectation of behavioural compliance even before the class begins. That is, as executive function of the student mind is attentionally focused on quelling its natural dialogical state to ensure compliance with behaviour that the teacher wants (or the getting away with unwanted behaviour by the student), cognitive resources are elsewhere deployed and not in the mind of the student with the learning at hand. Thus, this imposition of attentional focus and redirection of executive function diminishes the latitude that the student has in formulating their own episodic engagement with the learning at hand. Consequently, the extent to which the external semantic knowledge of the common science program, the cognitive processes occurring in working memory and the individualised episodic context mesh together to establish individualised LTM structures is diminished. From the teacher perspective, too much behavioural monitoring is required of working memory that it does not have the resources to draw upon itself to generate individualised episodic dialogue that would facilitate student contextual engagement with text. Hence, the teacher is displaced to be the secondary epistemic tool of student learning in favour of text from which students must draw their episodic engagement. As students simply may not possess adequate cognitive and/or social capital to successfully draw upon the text and establish stable LTM structures, Conv. L&T practices generate a lesser weighting of prior learning with the concomitant statistical diminution of cognitive skills.

On the interrelatedness of episodic and semantic memory, a causal pathway to LTM formation that reconciles Bios L&T with Conv. L&T practices can be derived from multiple trace theory (MTT) as presented by Ryan, Hoscheidt and Nadel (2008). MTT simply suggests that incoming sensory information attached with the science being learned is contextually stamped and stored as a trace within a group of cells located in the hippocampus. It is the contextual stamping of this trace with time, place and other detailed information that permits its recall as a unique personal experience for storage, retrieval and consequently, learning (Dickersen & Eichenbaum, 2010). This trace thus acts as a pointer to the location in the brain where different contextual aspects of incoming information are stored. This trace remains active over time with subsequent reactivations increasing the chance that the whole contextual experience will be able to be recalled from only a fragment of the initial experience. Thus, "The fundamental conclusion deriving from MTT is that every act of encoding engages a process akin to retrieval, and every act of retrieval engages processes akin to encoding. At the level of behaviour, therefore, encoding and retrieval are virtually indistinguishable from one another." (Ryan et al., 2008, p.13). So, well behaved students may look like they're encoding and retrieving their learning with maximum efficiency. In this manner, it is the attentional context of different L&T practices with which students are engaged in the simultaneous encoding and retrieval of classroom learning that is stamped into the cognitive structure that represent the LTM of semantic knowledge contained in the common science program.

The hippocampus thus serves as the brain's filter to 'find and bind' information pertinent to the individual. The criterion the hippocampus employs to fulfil this role relates to the requirements of the task at hand and the novelty associated with the task. On the task at hand, MTT proposes that the hippocampus uses context with the aim of predicting what is required to complete the task at hand and thereby retrieves any related memory traces to facilitate task completion. In retrieving related memory, it is from the entirety of an individual's memory from which memory traces are drawn, foremost from what is consciously occupying the mind at the moment but not exclusive of similar prior events, related semantic knowledge and whatever else may be associated with the retrieved knowledge structure(s). On novelty, the hippocampus compares current input with previous memory traces and encodes the input relative to the extent to which these two events coincide. A high degree of mismatch between the current and previous events indicates novelty, thus switching the hippocampus to emphasise encoding functions to bind the novelty of the current event with the context and/or related memory. A low degree of mismatch thus switches the hippocampus to retrieve congruent past events. This serves to identify semantic memory that can be used to predict the information needed to fill in the information gaps that caused the low degree of mismatch.

In the Conventional classroom, work is oriented around text and students expect this to be so. The result is a seamless transition of attentional environments from classroom to classroom so that students move in lock-step with the different inflections that each teacher has upon what behaviour corresponds to cognitive engagement as they encounter their text for the lesson. In the Bios classroom, novelty is an expected experience of every lesson. Foremost, students enter the class expecting that there will not be any textbook work, a major change from their last lesson and their next lesson. Further, students know that they will have a major role in shaping the course of the lesson because of the free flowing nature of dialogue, on and off task. Additionally, calls for more experiments or something different are met as frequently as possible, though they may not be directly relevant to the topic under study. It is from this expected novelty that the voluntary reorientation of attention derives. That is, the class knows that something different might be just around the corner and an attentional environment ensues in which students are open to engagement with what is just around the corner.

"Everybody knows what attention is."

To paraphrase William James (1890) in the classroom context, attention is that state of mind in which one consciously decides to withdraw from engaging with several simultaneous events to concentrate only on the task at hand and not be distracted by those other events. James also notes what everybody doesn't know about attention: That when subjective interest lays its 'weighty finger on particular items of experience', which may have little association with the task at hand, it has more influence to shape thought than those items relevant to the task at hand. It is not an illogical inference that autobiographical memory construction processes are in some way, greater than lesser, related to one's subjective interest in a topic. Hence, "The interest itself… makes experience more than it is made by *the experience itself*." That is, one is more interested in constructing knowledge that is coherent with one's self defining memories and the working self. In terms of L&T practices, James' observations delineate the nature of the different types of attention operational in Conv. and Bios classrooms. Conv. L&T practices focus on preventing distraction to sustain attention on the task at hand in order to learn what the teacher wants the class to learn from the text; it is Dewey's attention as work. Bios L&T

practices encourage the weighty finger of subjective interest to roam its experience and use that to motivate learning as reciprocated by episodic engagement with teacher dialogue; it is Dewey's attention as play. It is within this sphere of subjective interest and autobiographical knowledge construction that the origin of the Bios reading mediation effect resides.

On the voluntary reorientation of attention as an emergent characteristic in response to sustained socialness and dialogue and its role in forming LTM in the Bios classroom, the minds default mode (DM) is probably the seminal factor from which the Bios effect emanates The DM represents a resting state of brain activity that switches on when sustained attention to the task at hand is no longer propitious (Immordino-Yang al., 2012). The DM has thus been described as that mode of human thought implicated in social cognition, that mode of thinking which allows individuals to understand and delineate themselves from others via the application of metacognitive skills (Schilbach et al. 2008). On this understanding, they note that the self is relative to a given context and further, that the notion of self and other is bound by and developed within the particular context via reciprocal exchange. It is self-evident that humans have a preference to attend to social cues (like opportunities to talk about and to other students as opposed to cues for the learning of science and mathematics) and thus interpret social cues according to their overall social relevance.

The role that the DM plays in mental life appears to support internal mentation. Giugni et al. (2010) suggest that the spontaneous, stimulus-independent thought that occurs in the DM when people are left to think for themselves allows the brain to reiterate knowledge construction processes to form more useful forward-looking memory structures. That is, the incorporation of other bits and pieces of knowledge into the knowledge currently under construction in the classroom enriches cognitive structures such that it serves purposes beyond the context of the originally encoded information. This thus allows expectations to be formed about future events which are then reconciled with their outcome, which lead to subsequent rounds of prediction and reconciliation and so on and so forth. Bar (2009) suggests that the utility of context-specific events is that they reduce the attentional resources needed to monitor the context thus allowing the reallocation of attentional resources to find novelty in one's environment (that facilitates learning about the environment) as well as learning about potential surprises that should be avoided.

Consequently, students construct their classroom learning as a function of what they know is expected of their attention in the context of the classroom; behavioural compliance and engagement with text or the weighty finger of teacher dialogue. Hence, the DM has been linked to autobiographical memory processing (Qin and Northoff, 2011) whilst specific brain lesions in the DM have been associated with deficits of episodic and semantic aspects of autobiographical memory (Philippi, Tranel, Duff and Rudrauf, 2015). Further, Konishi, McLaren, Engen, and Smallwood (2015) reported that the DM facilitates the guiding of thought with information that is not immediately relevant to the task at hand. They proposed that higher forms of thought (like imagining of the future and the taking of another's perspective) require more introspective modes of thought which themselves depend upon the ability to be shaped by mental representations beyond the immediate external environment.

In their review of the DM and its psychosocial functioning, Immordino-Yang et al. (2012) coin the phrase constructive internal reflection. This phrase describes that internal mental state associated more with the processing of abstract psychological, affective and subjective knowledge about self and others and less with the processing of factual knowledge. In the latter case, attentional resources are consciously focused on the external task at hand whilst in the former they are inwardly focused on spontaneously roaming the knowledge structures of the mind to make deep connections between the internal world and the external world, be whatever they may. On the educational significance of this inward focus of attention, Immordino-Yang et al. (2012) speculate that it is the toggling between these two states of attention that would prove optimal for the educational achievement of students. Further, that it is the role of the teacher to specifically craft opportunities in L&T practices for the lapse of outward attentional focus so that the two attentional states are toggled between each other by the students. Thus, by allowing students the opportunity to engage with the inward attentional state whilst in the context of the classroom, self-relevant processing of their learning will result in their binding of affect, abstract concepts and cognitive processes to the semantic particulars of the topic at hand. As this self-relevant processing in the DM can be detected by the teacher as undesirable student behaviours of talking, socialising or daydreaming, i.e. wakeful but non-attentive mental states (Smallwood, Obonsawin & Heim, 2003), it is these behaviours that draw Conventional teacher attention and prompt the teacher to issue behavioural cues (rewards or punishments) to refocus attention back to the task at hand. Unfortunately, it is these very states of behaviour Immordino-Yang et al. (2012) suggest may be most helpful to students owning and developing their learning skills.

To substantiate this claim, the group documents a wide range of findings in which the relationship of the DM to socioemotional and cognitive functioning is correlated (duplicated from earlier). Themes of their review that are most relevant to the classroom include the following:

1. Attention is an emergent property and that internal mental processes are vulnerable to distraction by calls for outward focus attention.
2. Inward attention and outward attention co-regulate each other and predict the functioning of the other.
3. The quality of DM activity is related to the quality of neural and behavioural responses to environmental events.

4. The fluctuations between inward and outward attention is important for perception, attention and cognition associated with specific objectives.
5. Training inward attention can alter DM activity and promote sustained attention to the task at hand.
6. The efficiency with which toggling between inward and outward states occurs is associated with social and emotional health.
7. Reading, memory and attention demanding cognitive processes are associated with rest in the brain's DM.
8. Engaging the DM may promote cross-talk in the brain that results in more efficient networking of disparate pieces of knowledge and thus the construction of more personally meaningful knowledge structures.
9. The hub of the DM network is related to characteristics of self-awareness, episodic memory retrieval, day dreaming, moral judgement and empathy.
10. The DM activation represents half of the brain's mental functioning, being the processing of abstract ideas relative to the psychological, affective and subjective realms of oneself and of others.

In view of the functions of the brain's DM, it is proposed that Conv. L&T practices do not permit efficient toggling between the inward and outward states of attention. Specifically, that it is the sustaining of outward attentional focus on the task at hand, being the engagement with secondary learning resources and the monitoring of one's behaviour to ensure compliance to teacher expectations, comes at the expense of episodic, bottom-up dialogical engagement between the student and the teacher. This deprives the student and the teacher alike of a shared 'weighty finger of interest' and the minimisation of inward attentional processes contribute to establishment of positive affect with and abstract processing of learning. Thus, Conv. L&T practices do not generate a context in which the semantic knowledge of the common science program is personalised, resulting in LTM knowledge structures being less meshed with the cognitive architecture of the learning mind as they all converge for processing in working memory. Thus, the observed absence of a distinct pattern in the statistical analysis of Conventional data consistent with L&T practices that employ literacy is the primary learning resource instead of the teacher.

Alternatively, the weighty finger of shared interest is cultivated with dialogue in Bios L&T practices. It is the nexus of teenage socialness, dialogue and attention as an integral part of classroom on-goings by which inward attentional DM processes contribute to LTM knowledge structures that are well meshed with reading and writing processes as they all converge in working memory. Thus, dialogue that is tethered (however loosely and seemingly unrelated on the part of student interest) to the semantic knowledge of the common science program is affectively and abstractly cogitated upon by each student mind to generate the unique patterns detected in the statistical analyses of Bios data due to the teacher being the primary learning resource of L&T practices.

The pedagogical model.

Based upon the differences measured in the ability of comparable classes of students to convert their Trial Science exam scores into SC Science exam scores, an alternative model of classroom practices is proposed. The Bios model is based upon the importance of autobiographical knowledge construction purposes and student learning in the classroom. This is diametrical to the Conv. L&T practices. Bios L&T practices improve upon student learning with the corrected effects of pr^2 (trial exam) =.28, pr^2 (reading) =.09 and κ^2 (reading) =.12.

These small to moderate effects are significant for three principle reasons. First, there is no reason to suspect that students in the matched (counterfactual) groups could not have attained the same learning outcomes. Second, the theoretical concerns associated with L&T practices not grounded in the cognitive architecture of how the brain learns have been borne out in the natural classroom setting; an observation substantiated by the lack of contribution of any cognitive skill to student learning in response to Conv. L&T practices. Third, as achievement at Year 10 is the largest single contributor to HSC (university admission) achievement, accounting for 50% of HSC variance, Bios L&T practices increase the role of the single largest contributor to HSC achievement. Fourth, the effect cognitively manifests itself via reading skills that are associated with the cognitive structure of prior learning. As reading provides cognitive capital for the use of reading as both a learning tool and a thinking tool, students developed a skill that is transportable and not restricted to the learning of Science. Finally, Bios L&T practices made the work of teaching and the work of student learning more enjoyable and play-like.

The corrected effect sizes of Bios L&T practices is attributed to the role of episodic memory in the encoding of semantic knowledge embedded in the common science program and its interaction with the cognitive processes associated with reading, as all of these events are converged in working memory to be bound by dialogue. It is the voluntary re-orientation of attention by students that facilitates the binding of all these factors in working memory that allows students to give individual (autobiographical) context to the learning of science. The attentional environment itself is intimately dependent upon teenage socialness and dialogue and managed such that the weighty finger of interest promotes student-teacher dialogical engagement over student-student dialogue. This establishes a positive feedback loop in both student and teacher affect, hence learning and teaching becomes a dynamic, interactive, evolving process that is relative to the needs of the student at that moment. It is thus the nature of the episodic engagement between the teacher and student that is the primary determinant of the students' classroom engagement with learning processes.

This implies that the focus on literacy and behavioural compliance as the marker of attention in Conventional practices does not sustain cognitive engagement nor facilitate voluntary attention. This is possibly because literacy, as a high order cognitive skill, is beyond the general cognitive maturity of the average student at this age/stage of education. That is, literacy, as a higher order cognitive skill dependent upon reading skill, which is itself dependent upon efficient lower order decoding and language comprehension processes, may not be developed enough in all students to permit it to respond effectively to Conv. L&T practices that rely upon literacy as the cornerstone of student learning. Thus, L&T practices that target literacy do not adequately embrace the breadth of lower order reading skills that exists in the classroom in order for content specific knowledge contained in texts to be effectively (and rewardingly) extracted. This results in the minds of many students remaining unsynchronised with classroom learning opportunities (teacher and/or student initiated) and who are consequently dragged along to do their learning by osmosis.

This is not the case with Bios practices. Here, a greater proportion of the student mind is capable of participating in classroom on-goings because the common currency is dialogue about what one does not know and what interests one, not what one is able to extract from written text because of more refined lower order reading skills.

In terms of teacher classroom practices, the model advocates for greater interpersonal engagement via talk with students about student interests to nurture and encourage the development of their own learning instinct. Thus, teacher discourse is placed as the primary informational media upon which students cogitate as they consolidate their new learning into new cognitive structures. Thus, as the discourse takes place on students' terms, the construction of knowledge, also takes place on student terms. Hence, an idiosyncratic cognitive structure is generated which results in students more fluidly binding their classroom learning experiences, their prior learning of the Trial Science exam as well as cognitive processes associated with reading. It is this free flowing and wide ranging 'episodic dialogue' which is contextualised with the to-be-learned semantic knowledge that sustains voluntary attention and cognitive engagement. Consequently, the mind is primed to be receptive to engaging with and favourably processing new learning.

Ipso facto, the use of text as the primary informational media under guidance of the teacher is minimised because it encourages the importation and transposition of pre-formed knowledge onto the student's developing cognitive structures. As this itself is dependent upon a pre-requisite level of reading skills to extract meaning from the text, skills intimately bound to the social background of students, student knowledge (and thus literacy of the knowledge) is not constructed upon student terms but on the terms of the texts' dialogue. Hence, a hybridised cognitive structure is built upon unfamiliar and affectively decontextualized text that results in less efficient binding of classroom and prior learning experiences to solve new problems.

The core of the effect is most likely due to greater confidence of Bios students in verbally communicating their learning and/or broader curiosity amongst their classroom peers because they possessed the words needed to express their nascent thoughts. They were also possibly more likely to give their thoughts more attention and stick with their thought until it had formed into words for written communication. This most likely leads to greater social confidence, a sense of content mastery and thus more effective binding of experiences, of school classroom and broader life origin, for use in later situations. Consequently, students taught themselves to become scientifically literate. That is, students were more engaged with self-defining memories and the working self in autobiographical knowledge constructions processes, as solicited by teacher dialogue.

On the whole, the model suggests that students would benefit to some degree or other in their learning by the teacher being the primary learning resource of student learning instead of the manager of secondary learning resources. In short, talk with the teacher is the *driver* that negotiates the interaction and reconfiguration of the neural structures that store cognitive scaffolds.

In short, talk **with** students. Interested brains will let the mind do best what it does naturally, constructing its autobiographical self.

Limitations and future direction of the research.

The primary limitation of this research resides in the number of teachers who enacted the Bios pedagogy, being only myself. Having other teachers enact the Bios pedagogy and analysing student learning would provide a more accurate platform with which to gauge the learning response of students. This in itself has its own limitation, as implementing the Bios pedagogy into classroom lessons requires background content knowledge of cognitive neuroscience, as well as substantial content knowledge of the subject in order to sustain dialogue about the science being learned. Such sustained dialogue can be very draining and more personally demanding than teaching according to Conv. L&T practices. Another limitation is the qualitative observations of voluntary attention. Perhaps I, the Bios teacher, am biased in my observations of the state of classroom attention. Having other teachers observe the Bios teacher would help clarify such qualitative observations.

More broadly, the limitations of ex post facto research must be acknowledged. Cohen et al. (2007) document the disadvantages of ex post facto research as including:

1. Lack of control over the manipulation of the independent variable and randomisation of subjects.
2. Cannot know for certain whether causal factor has been included or identified.
3. No single factor may be the cause of the results.
4. A particular result may result from different causes on different occasions.

5. It is difficult to determine the direction of causality.
6. The statistical relationship of two factors does not establish a cause and effect relationship.
7. Classifying into dichotomous groups can be problematic.
8. Can be difficult to interpret and prone to post-hoc assumptions.
9. Findings often based upon too small a sample size.
10. May fail to single out really significant factor(s) and recognise that events have multiple causes.
11. Regarded by some as too flexible a method.
12. Lacks nullifiability and confirmation.

Simply, the seemingly numerous disadvantages of ex post facto research are due to its inability to precisely manipulate the independent variable under experimentally controlled conditions. Consequently, this reduces the scientific veracity of proposed cause and effect relationships. However, in the natural setting of the school classroom, the manipulation of these variables may pose ethical and/or organisational issues that make their strict control untenable. For instance, it could prove unethical to randomly assign students to teachers with different L&T practices and have one group fall behind in their learning as a result of the experiment. Likewise, it may not prove organisationally feasible to compile classes of students that are comparable (due to timetable constraints and the different elective choices of different students) and then to measure the effect of different pedagogical practices upon these comparable groups. In either case, it would prove awkward for administrators to have the foundations of their judgements about the characteristics of teachers undermined should their expectations not cohere to the data acquired from the strict scientific manipulation of the independent variable(s).

Finally, a major limitation yet opportunity for future research is the conceptual foundation of the research. Though Bios L&T practices were premised on working memory, no measurement of working memory was taken during the course of the study. This could mean that all of this work is more 'coherent' with some other conceptual understanding of human learning but for which there is inadequate 'ecologically valid' literature relating to its role in classroom learning, like the mentioned attachment theory (Bergen & Bergen, 2009). As this strongly emphasises the quality of human relationships for healthily developing children (an observation I concur with as experienced via my Bios L&T practices) in which the origin and evolution of executive function is rooted (Carlson, 2009), an avenue of future research would be to examine executive function of students receiving Bios and Conv. L&T practices. So, it could be that Bios L&T practices exerted their effect in the social origins of executive function, viz. my communication with Prof. Alan Baddeley. Consequently, the environment in the Bios classroom may have improved the effectiveness of executive function was amplified. This may have cascaded down into working memory processes where it was detected as differences in memory and reading. Indeed, Raver and Clancy (2014) suggest that such 'environmental repair' (as may have occurred in the Bios classroom) may have significant benefits for the neurocognitive and emotional development of children, helping children be more engaged at school to achieve more at school. Thus, the next step for this research would be to use the Behavior Rating Inventory of Executive Function (BRIEF) questionnaire (Gioia, Isquith, Guy and Kenworthy, 2000) with students who received Bios and Conv. L&T practices and integrate that data with NAPLAN data and other measures of student achievement. On the basis of the current research, it is hypothesised that executive function would be more active in response to Bios L&T practices than Conv. L&T practices.

CHAPTER 7: Exegesis.

The significance of the Bios pedagogical model stems from its use of science to provide a pedagogical framework that informs improved teacher and student outcomes. Such an informing role for science has generally been overlooked in the school in which this research was conducted. Goswami (2004) indicates that the different views of learning possessed by neuroscientists and teachers may be a major contributor to this situation. The former group (and myself) view learning as a series of cellular processes that span from the individual cell to the alteration of tissue structure via plasticity in response to learning. Diametrically opposed to this biological view is the educators' view that learning is the result of the interaction of social factors like curriculum, classroom and family environment. To bridge these views, Dommett, Devonshire, Plateau, Westwell and Greenfield (2011) formulated a collaborative exchange between educators and neuroscientists to promote the scientific literacy of educators and thus the utility of neuroscience in informing classroom L&T practices. Care was also taken on the part of the scientists to not be prescriptive about the use of the science and who also conducted the sessions in an unstructured 'inquiry-like' manner. Dommett et al. (2011, p.386) reported that educators, *en masse,* felt that the scientific material about learning was relevant to their teaching. In particular, it was reported that "*the majority of teachers felt that their decision making and interactions in the classroom were altered*" as well as their awareness of student learning and behaviour. Thus, as Ansari and Coch (2006) note, though medical practitioners are trained in molecular biology, such knowledge is only partially and unpredictably transferred to their practice, without any substantial changes to the latter. Rather it is in the thinking of how they perform the work of their practice. Likewise teachers and educational neuroscience: No major changes would be needed in specific content knowledge. Rather, the way in which teachers think about how they deliver the content knowledge would change, with any such change not being detected until some much later date. Dommett et al.

(2011) do indicate that a program to promote scientific literacy amongst teachers would not be useful at the undergraduate level of teacher education because of the requirement to reflect critically upon how such knowledge could be used to inform one's L&T practices. That is, new teachers do not possess enough experience to critically and holistically reflect upon their work. Instead they recommend a series of professional development sessions for teachers who have practical experience against which the new learning may find ideational anchorage.

Hille (2011) provides a comparable perspective upon the difficulty of translating neuroscience into classroom practice. She notes that the word neuroscience, when used in the educational setting, generates strong emotions that range from hostility to 'submissive awe' to unrealistic expectations about what it can achieve for students. Hille (2011, p.63), citing the *US Department of Education Strategic Plan for 2002-2007* (2001), notes that "the field of education operates largely on the basis of ideology and professional consensus … that is incapable of the cumulative progress that follows from the application of the scientific method." On the role of data informing educational practices, Hattie's (2009) expressed surprise about the paucity of data use/analysis in the education of new teachers, suggesting that at university is where future teachers learn to ignore evidence. The downside of this is that in becoming a teacher, the work is portrayed as a craft and that one seeks favourable anecdotal evidence that one is somehow making a difference to the education of students. Snyder and Lit (2010, as cited in Hille, 2011, p.63) note that in the USA, "little of the knowledge of how children and adolescents grow and learn has made its way into schools or educator preparation programs". These observations resonate with my own 13 years of teaching experience in New South Wales, Australia; so it appears that the situation in Australia differs little to that described in the USA.

On the education of future teachers, it is my view that student teachers and qualified teachers require exposure to neuroscience language as it pertains to classroom L&T practices. From this, they would acquire a complementary set of lexical structures with which to view anew everyday classroom observations. Consequently, teachers could construct/reconstruct new meaning for everyday classroom observations about the how and why of student learning and share that with their peers. And given the multifaceted nature of student learning, every little bit of knowledge will have its place at some point in the career of a teacher. More importantly for the professional practice of teaching, knowledge of educational neuroscience would provide that bridge to translate theory into classroom practices to accumulate the incremental advances in teacher professionalism and student learning. Thus, the more comfortable one is personally with the specialist language of educational neuroscience and with scientific thinking processes, the more intellectual mastery one has over that body of knowledge, making it easier to manipulate that body of knowledge in a wide range of circumstances for the greater common good of all students. As described by Hille (2011, p.69), student teachers do not "get a glimpse at what happens *between* 'in' and 'out' and why a certain input may lead to a distinct output" (with that *between* being how the brain processes information to construct knowledge). In the absence of high quality lexical structures to aid the understanding of how knowledge is constructed by the brain, professional conversations about the role of science and data in informing educational practices cannot keep pace with and realise the potential that students have for learning. And, professional conversations devolve into statements of opinion and the ignoring of data in favour of intuition.

Pragmatic information and knowledge.

In the professional workplace of teaching, effective teaching requires teachers to use whatever trick of the trade is at their disposal, despite whatever potential there is for irrelevant theoretical contradictions. "As experienced teachers know, no method (*or theory)* will work for everyone in a given class, and nothing works for anyone all the time" (Hruby & Goswami, 2011, p. 268). So, what else is it that teachers should learn about (at university as information and in the workplace as knowledge) if their nascent L&T practice is to serve as a high quality, flexible and evolving framework capable of addressing the learning of the student mind? Yet, one that is also able to mutate knowledge to make it useful in its current environment? To achieve this, the following actions are recommended to improve student and practising teacher achievement outcomes:

1. That they learn about the how and why of student learning.
2. That they learn how to analyse and interpret numerical data.
3. That they learn about the role of language as a means of generating high quality lexical structures.
4. That they learn about the structure and roles of different types of memory and how these relate to classroom L&T practices.
5. That they learn about the brain's default mode of brain function and how to control the attentional state of a class to toggle automatically between outward and inward attentional states.
6. They develop intellectual skills to confidently mutate knowledge to serve the needs of the local environment.

The lexical quality hypothesis and working memory.

It is projected that an appropriate starting point to achieve the six listed actions would be to make use of Perfetti's (2007) lexical quality hypothesis and Baddeley's (2007) multicomponent model of working memory. By understanding these two ideas, the former of which can really only be appreciated by teachers exchanging dialogue with each other, thereby ensuring cognitive engagement with the professional development, teachers would be able to monitor their classroom dialogue in real time to adapt that to ensure it is as working memory 'friendly' as possible.

Perfetti's (2007) lexical quality hypothesis suggests that reading comprehension arises from the retrieval of word identities; word meanings that possess a contextual association. High quality word identities describes that state of words in which their spelling (orthography), pronunciation (phonology) and meaning (semantics) have been 'bound' together with another constituent. It is proposed that this other constituent is episodic engagement via the teacher applying the weighty finger of interest. With this episodic binding, the individual features of word identities cohere to form precise and flexible mental representations (i.e. cognitive structures) of that word. The state of precision describes that state in which the spelling and pronunciation of a word allows its distinction from similar words (e.g. slight and sight, either and neither) whilst flexibility describes the meaning of a word as well as its general use such that it can be pronounced and/or read in a given context (e.g. the word *record* has two different pronunciations depending on its context, 'Do not *record* the performance' and 'Keep a *record* of your donations for tax purposes.')

In the process of reading, high quality lexical structures allow word identities to be retrieved and integrated with other word meanings within and between sentences to facilitate comprehension of the read text. Logically, low quality word identities thus impede reading comprehension by not retrieving written or spoken associations of that word when encountered in the text, by uncoordinated activation and retrieval of word identities that results in partial and/or wrong comprehension of that word when encountered in the text and finally, reducing overall comprehension of the read text because of these blank spaces in the cognitive structures of the word identities.

On the nature of constituent binding and its role in cohering the spelling, pronunciation and meaning of words, Perfetti (2007) highlights a possible role for episodic memory as being that entity associated with the new word that lends it stability (making it a high quality cognitive structure). In comparing the learning of new words by skilled readers and less skilled readers, a major difference in nerve activity associated with episodic memory was detected in skilled readers but not in less skilled readers. Specifically, that the amplitude of nerve activity in less skilled readers at a time point after stimulation was significantly reduced in comparison to skilled readers. On the whole, the sum of these comparative differences led Perfetti (2007, p.368) to conclude that "all learners respond to the distinctive letter pattern of a recently trained word, but they differ in recognising the word episode – for example, this is the word *gloaming* that I just experienced a few minutes ago."

Perfetti (2007) notes that though the lexical quality hypothesis was derived from an orthographical (spelling) perspective, it can be equally applied to spoken language, i.e. the sound structure of words are interchangeable with their written structure (Perfetti and Sandak, 2000). In the spoken language case, the focus is on phonological representations of words and their meanings which undergo episodic binding to form precise and flexible cognitive structures. As Perfetti (2011) observes, reading is built upon the sound of words and word sounds come from language.

On the matter of binding and working memory, Baddeley, Hitch and Allen (2009) investigated whether or not the central executive and attentional focus was required for the chunking of verbal material (in individual sentences) in short term memory. Chunking refers to the recoding of simple verbal material into higher order cognitive structures according to one's prior knowledge (Miller, 1956). Of prime interest to Baddeley et al. (2009) was whether or not these higher order chunks required the participation of the higher order cognitive processes associated with the central executive. In short, Baddeley et al. (2009) determined that the binding of verbal material into higher order chunks in short term memory was automatic and that a limited amount of these chunks enter into the episodic buffer for subsequent use in working memory processes. Interestingly, the binding and entrance of these chunks into the episodic buffer was not under attentional control of working memory. Those chunks that then entered the episodic buffer could then become the focus of attention for subsequent working memory processes. These findings by Baddeley et al. (2009) suggest that substantial memory construction and reconstruction processes associated with verbal information occur as soon as new material enters the mind.

On encouraging the mutation of academic information into effective professional practice, the dominance of constructivism as a pedagogical approach needs to be more broadly challenged. If I may speculate, perhaps teacher education programmes could include greater coverage of the cognitive neuroscience of learning in their curriculum. This would focus broadly on the sociocultural model of autobiographical memory, more specifically on episodic future thinking and in great detail on the role of language in memory formation and cognitive development. Assessment tasks would develop the skill of counterfactual reasoning and the interpretation of statistical data, as well as *viva voce* exams, as it is this type of exam that is most reminiscent of what teachers encounter in the classroom.

Closing.

Everyone has an opinion about how teachers (I) should do my job. Ironically, the loudest of those voices belong to those not doing the job of teaching: The academics who study students and teachers to make real-world recommendations but with little real-world experience, the politicians who spruik change to look busy, the scientists who generate copious amounts of information but don’t know how to use it in the classroom, the bureaucrats who enforce professional standards formulated by academics, politicians and scientists and finally, school administrators who want data to drive pedagogical practices but who have little expertise in its collection, analysis and conversion to classroom practices. The upshot of all this is that the self of the teacher is subjugated to special interest groups, with no need on the part of the teacher to engage academically in developing their knowledge about teaching. ‘Teaching is work so forget about play and pay attention to your work!

But it is the voice of the parents that is most forgotten in the cacophony of chatter vocalised by these groups, a voice that just wants their teacher to the best job they can to keep their child interested in and happy at school. Of these voices, I have found that it is the parents' voice that is most easy to take on board and use to improve teaching practice. I think that they too realise just how hard it is to get young adults to engage with something and stay with that engagement for a sustained period of time in order to develop a deeper understanding of that something because it just may be good for their future. Just like when I met Ben, a former student, at a pub who told me that the only useful thing he remembered from school science was about series and parallel circuits. Ben was hard work but when he told me he was working as a bomb diffuser in Afghanistan, well it was all good. For keeping kids interested in school, parents are grateful for being a positive influence in their child's learning. No amount of theorising, politicking, bureaucratising, administrating, standardising, curriculum rewrites or anything else will guarantee that a teacher is a good influence. One just has to try and be so for the good of the kids.

Feedback from academics that I did take on board include the following. At the time, I used SPSS (Version 17) to perform the statistical analysis. The way I initially did this was admittedly laborious: I viewed the data as a three dimensional body and performed copious amounts of split, forward and backward regressions to identify data patterns that were common to and different from the control and treatment groups. When I updated to SPSS (Version 22), I was able to apply bootstrapping to the data to identify direct and indirect effects. On the direct effects, the same data patterns were generated but the 95% confidence intervals greatly simplified the analysis and meaning-making of the data patterns. The indirect (mediated effect) analysis also identified an effect. On the whole, the data upon which this thesis is built did not change and so I have not modified my discussion. It is in that section that my thought processes, as driven by my self-concept, working-self and self-defining memories, are most transparently presented.

Most damaging of the academic and scientific feedback was the willingness with which anonymous commentary was personally targeted and the willingness of the UNE to accept such commentary as being impartial. As noted already, the Ombudsman described the words of the adjudicator as outrageous. The impact of this was to significantly undermine my sense of self and the confidence I had in myself as a teacher; it's rather hard to keep one's self esteem and enthusiasm propped up against the weight of anonymous institutional character assassinations. (Is that the intended function of critical feedback, is that the role of a university in developing knowledge for society?). You thus may perceive that I have an exuberant scepticism for academic and scientific opinion when it comes to the work I do as a teacher, viz. the quotes of Dewey. So, if I use a secondary quote, it is because the secondary source provides greater contextual meaning than what I could extract from the original article; it is to those 'contextual' authors that I offer acknowledgement because they facilitated my thinking and understanding. If you think that some of my work is more assertion than research fact, I believe I am allowed to make assertions in my professional practice. I believe that much future thinking in science is itself little more than personal assertion awaiting the test of time. If you prefer the soft style of academic writing versus my more 'definitive' style, well "Who I am in how I teach is the message" (Keltchermans, 2009). It is also how I was taught to write when I wrote my Ph.D. in biochemistry/cell biology. It is also how I teach science: Getting students to accept that science is something factual and concrete; which can be built upon if one wants to; that the world can be better built if we just think; no matter how ridiculous or boring the science may seem. Finally, when I speak with parents, they also want the learning of their child spoken about definitively; one comes across professionally lame if all one can say is, "Oh yes, little Johnny could do a bit more of this and a bit more of that and maybe that would help his learning."

In the time between initially submitting my thesis and re-enrolling, several publications came out that bolstered the work I present in my thesis. I have already made reference to the work of Gott and Lah (2014), Ulm (2013), Kent (2013) and Dubinsky et al. (2013) and a few papers relating to counterfactual thinking and episodic memory. However, these publications presented a quandary: Should I go back and reframe my work so that it aligns seamlessly with ideas currently developing in cognitive neuroscience or should I sustain the integrity of my ideas and address these developing ideas a bit later. Pragmatically, I chose a bit of both but focused on the latter in order to defend the independence of my ideas, *ipso facto* the creative, *a priori* nature of my work.

First, there were two ‘scientific’ publications. The Barbey, Colom, Paul and Grafman (2014) publication used brain lesion studies to explore the overlap of working memory and fluid intelligence. Most notably and unsurprisingly, they reported that verbal (and numeric) skills in working memory were the single largest contributor to the ability to manipulate information in working memory. Numeric skills were identified in this work as contributing to learning in response to both Conv. and Bios L&T practices; yet it was only in response to Bios L&T practices that verbal (i.e. reading) skills were identified as contributing to learning. As a teacher, this is hardly surprising: Teacher’s use language to give context and meaning to dialogical exchanges with students every moment of every lesson. In so doing, one simply makes the almost *passe* observation that the sharing of language allows students and teachers alike to manipulate ideas to generate creative insights and personally meaningful responses to all manner of stimuli.

The second scientific paper, by Gruber, Gelman and Ranganath (2014), reported that curiosity had a favourable effect upon memory formation of target material as well as incidental material. Thus, if one is curious about something, the presentation of incidental learning material along with the curiosity material results in both sets of material being committed to memory. They proposed that it was the predictive[27] activity of the brain that mediated this effect via the hippocampus, that brain structure that stamps incoming memory episodes with emotional salience as a function of the curious state of mind. This curiosity effect on memory was speculated to involve a linkage between extrinsic reward motivation (engagement with the teacher and the classroom) and intrinsic curiosity specific of the individual (what the teacher says and does to promote curiosity coming to the forefront of the student mind relative to the topic being addressed by the teacher). In terms of professional practice, get the student interested and the student will do the learning, if only by accident as a function of their curious mind; namely James' observation that the memory of an event may have a greater influence upon the shaping of that memory than the actual event itself! Thus, the personal communication with Lah (2014) can begin to be reworded; "*it is **becoming clearer** that an increase in recall of episodic details of learning also enhances students learning capacity (i.e., underlying cognitive skills) and has a positive effect on behavior.*"

Next come publications that dealt with language in the classroom. Topping and Trickey (2014) reported that teacher modelling of exploratory talk to primary school students resulted in more teacher-student dialogue and less teacher-whole class dialogue. Accompanying this were more open-ended questions, greater student participation in discussions and improved reasoning skills. The gains in cognitive abilities in response to dialogue were carried through to secondary school, without any follow-up. Changes in teacher behaviour and student behaviour (affect toward learning) were also reported. Topping and Trickey (2014) also observed that changing teacher and student verbal behaviour is not easy. To wit, Oyoo (2012) reported that high school physics teachers (and as I argue, teachers in general) lack understanding of the difficulty that

[27] The publication uses the word anticipation. Personal communication with Matthais Gruber (26th November, 2015) indicated that the word prediction may be substituted for anticipation without any semantic issues arising with the intent of their work.

students face in comprehending instructional dialogue that is loaded with technical content even though such words may be encountered in everyday language.

Brevik, Fosse and Rødnes (2014) examined how the use of specialised language affects reasoning and learning amongst upper high school students, university student-teachers and teachers at high school. Specialised language is described as the use of words and the concepts they refer to in subject matter, e.g. inertia in physics. Most pertinent was their finding that the use of specialised words during learning interactions allowed for the development of more abstract understandings of learning material, i.e. the sharing of specialised language itself became the tool by which students and teacher alike developed their knowledge and communication ability. The caveat to this finding was that it is the teacher oneself who must introduce the specialised language into the learning context if it is to prove a useful resource for student learning. Brevik et al. (2014) also note that the teacher simply providing students with a list of specialised words to learn is not the same as providing firsthand experience with the use of those words at the same time that the subject matter is being taught. Hence the recommendation that teachers and student teachers need to raise their own awareness of the power that specialised language can exert upon the learning process; a task the authors identify as having its roots in teacher education programmes, ipso facto, education academics need to raise their own awareness of the specialised words of cognitive neuroscience.

Piertarinen, Soini and Pyhältö (2014) examined junior high school students' emotional and cognitive engagement as a function of the well-being they felt at school. They reported that student-teacher relations were a major contributor to student perceived well-being and that this subsequently was a major contributor (accounting for 70% of variance) to cognitive engagement. Additionally, the student-teacher relation also manifested as a mediated (indirect) effect on perceived cognitive engagement (a result reported in my thesis). Simply, emotional (indeed, episodic) engagement with the teacher leads to cognitive engagement. Additionally, the description that Piertarinen et al. (2014) give of pedagogical practices according to Vygotsky is consistent with the description of Conv. L&T practices presented in this work, i.e. it seems that teaching practices are to some extent conserved within the broader teaching profession.

Very interestingly, two publications dealt with auditory plasticity. Chandrasekaran, Skoe and Kraus (2014) formulated the integrative model of auditory plasticity. This suggests that incoming auditory information (the soundscape) may be differentially encoded for memory on a predictive basis, i.e. the encoding of memory itself may be plastic, depending upon present context and predictions made from experience. This encoding occurs in real time and is updated instantaneously with respect to current predictions; if predictions change, then encoding changes. Hence encoding is plastic. The current context acts as a bottom-up processing of sound and is primarily involved in establishing developmental memories of the soundscape. This functions to enhance the representation of novel sounds in memory. For example, the behavioural expectations that teachers place upon students in the soundscape of the classroom may modify incoming aspects of the soundscape (relative to the teacher's expectations) which are subsequently stored in memory. Or if in the presence of a repetitive soundscape, sound may be attenuated and 'dropped from memory'. Once these developmental representations are established, they then act as the basis for feedback with subsequent top-down processing. In this case, predictions are made about what is most likely to be important in the soundscape and thus what is most desirable for storage in memory. This functions to enhance behaviourally relevant and/or ego-centric signals in the soundscape or generally enhance audition in noisy (cocktail party) conditions. The feedback loops associated with predictive processing also assist in establishing selective attention to aspects of the soundscape by enhancing global sound processing and inhibiting sound processing detrimental to the attentional focus.

A complementary publication proposed that auditory plasticity results from the interaction of layers of auditory experience (Skoe & Chandrasekaran, in press 2014). As the auditory system is permanently on (running 24 hours a day) during one's lifespan, each individual accumulates an auditory fingerprint that is stored in memory. This neural fingerprint is composed of numerous layers, from events in the present to events in the long past, that may interact in a multimodal manner (with other senses or motor events) to constrain subsequent auditory prediction and thus the formation of new auditory layers. That is, the soundscape of one's past may influence one's future. Skoe and Chandrasekaran (2014) thus observe that the environmental impoverishment associated with low-SES status may establish a layer of plasticity, which via bottom-up and top-down feedback predictive loops, imposes limits on future auditory plasticity. In this way, the Matthew effect is accounted for (Stanovich, 1986). As Dewey (1938, p.140) observed, "…every experience lives in a future experience."

Gamlem and Munthe (2014) published work in which they examined the characteristics of high quality oral feedback on lower high school student learning. This was premised on the rationale that teachers who acted as the scaffold to support student learning by investigating their experiences, understanding and thinking would facilitate the development of their understanding and engagement with classroom learning. (A rationale that is eerily reminiscent of the work I present in this thesis because of its focus on teacher language, the teacher being the focal point of classroom attention and the most important learning resource because of one's ability to answer questions in a way that no other classroom learning resource can.) The work was done via examining feedback loops (dialogue exchanges) between students and teacher as they occurred in the class and later reviewed on video. The authors note two different types of scaffolding use by teachers; Scaffolding task, which focuses on giving hints on what is right and wrong and what deficiencies exist in the work done so far (i.e. as occurs in in Conv. L&T practices) and scaffolding process, which focuses on giving hints to students to facilitate thought processes coming to completion about how to solve the task-at-hand (as occurs in Bios L&T practices). It was the latter, scaffolding process, which showed the highest correlation to metacognition, the self-monitoring of the learning process. It is metacognition that is associated with self-regulation and the ability of students to transfer their learning to new contexts without the need for direct instruction on how to do so (Askew & Lodge, 2000; and Black & William, 2009).

Gamlem and Munthe (2014) also note the importance of a positive classroom environment to the quality of teacher-student interactions. However, the quality of feedback that students received was not so strongly related to the positive environment, indicating that a positive environment does not automatically translate into quality feedback, i.e. scaffolding process that promotes metacognition. The authors suggest that this is because teachers are better skilled at fostering supportive social and emotional environments than in providing high quality teaching environments. Interestingly, in negative classroom environments, metacognition (and learning targets) did not possess a statistically significant negative correlation; suggesting that metacognition is a mental process that proceeds independent of the classroom environment but which can be significantly co-opted into the learning process by appropriate language use by the teacher, i.e. scaffolding process.

A final scan of the literature before re-submission turned up three publications associated with Martin A. Conway. First, Morrison and Conway (2010) proposed the irretrievability hypothesis to help explain the role of language in forming long-term memory, one valid for infants to adults. Simply, several months pass from when a word is acquired to when it is encoded in long term memory. They suggests that in this period, episodic memories are verbally labelled to permit the isolation and identification of detailed information associated with these episodes. In this process, verbally labelled memories activate other long-term memories (cognitive structures), thereafter a summation of these memories becomes associated with that verbally labelled memory to generate a new concept. This new concept itself is verbally labelled and under the influence the social environment (viz. as described by Nelson and Fivush's 2004 model of autobiographical memory) may be abstracted to generate new cognitive structures that permit access to other unyet associated long-term memories. The authors also note that it was the lexical features of words (its familiarity and ease of mental representation as used in everyday language) that was more associated with accessing memories than was the vividness and personal importance of the memory itself. Finally, Martin and Conway (2010) suggest that episodic memory is an essential precursor of acquired knowledge, i.e. knowledge of something does not immediately graft onto prior knowledge in the formation of long-term memory, it must first pass through personal construction processes. From this cyclical process, vocabulary and language may come to develop.

Conway, Gardiner, Perfect, Anderson and Cohen (1997) earlier characterised this episodic to conceptual long-term memory as the remember-to-know (R-to-K) shift. These authors explored this shift in undergraduate psychology students in two types of learning environments, the lecture theatre and laboratory practicals. In response to the former, they found that remembering was the principal means by which answers to multiple choice tests were derived, i.e. they remembered the learning episode associated with question. In contrast, it was knowing that was the means by which students gave answers to laboratory practical tests. The reason offered for this switch from remembering to knowing is attributed to learning environment; the latter was more interactive and this facilitated the extraction of episodic detail for the formation of known conceptual knowledge.

Dewhurst, Conway and Brandt (2009) later performed similar experiments but under experimentally controlled laboratory conditions. A similar result was found, indicating that the R-to-K shift was not attributable to uncontrolled covariates (like additional homework, prior knowledge and other learning materials). Together, Conway et al. (2010), Conway et al. (1997)

and Dewhurst et al. (2009) indicate that it is the nature of the episodic engagement in the learning environment that facilitates the R-to-K shift and that this is driven by language.

Would knowing about Conway's work in this educational context have provided any short cuts to improve my professional practice and my own cognitive structures? Do I feel a bit dopey in not having found this work of Conway's? Maybe and maybe. First, it would have propelled me to the intellectual position I presently occupy. But that ironically may have made my thoughts more rigid and less patient in my attempts to change my own understanding of the biological magnitude of the task that one is up against as one tries to change the way students learn. The greatest obstacle to tapping into the plasticity of student thought is the lack of plasticity in teacher thought. Second, one just has to keep searching for scientific (correspondence) truth. And it is this I believe that the university education of future teachers is most at fault: Mathematics and cognitive neuroscience is not a part of any teacher education programme in New South Wales. So how can teachers and students improve if the predominant criteria in the profession is coherence to whatever educational initiative is the flavour of the moment and not the testing of that flavour for its practical value? Plato's cave comes to mind…

Finally, the OECD's *Students, Computers and Learning* (2015) investigation into the effect of ICT upon student learning. Reading, writing and numeracy scores have been decling for over a decade, an observation that corresponds with the rising use of ICT in the classroom. This OECD report notes that the greater penetration of ICT into the classroom, the greater the negative outcome on student reading, writing and numeracy. The report offers two explanations for this; that teachers just don't have the skills or out-of-the-box software applications to adequately exploit the pedagogical opportunities that ICT may offer and/or that developing deep learning and higher order thinking skills in students requires intensive teacher-student interaction. In other words, deep learning and higher order thinking skills evolve by teacher' actively engaging, *via personal dialogue*, with their students and thus serve as a template upon which students may fine tune their own unique way of thinking about the world and communicating about the world. The work presented in this thesis is in step with the OECD report.

In total, these post-submission publications (and Conway's above listed work) lend credence (correspondence and coherence) to the thesis: That by the teacher using dialogue to be the focal point of classroom on-goings, teenage socialness and attention can be brought together to foster engagement with classroom learning, resulting in improved memory and language (reading) skills. This is not an unexpected event as much theoretical literature and a little naturalistic literature exists suggesting that dialogue is an (if not the) essential learning tool and that the teacher standing in front of the class is a major influence on student learning outcomes. I don't believe that it is contentious to argue that this effect probably has its origin in the depths of autobiographical memory where self-defining memories, self-concept and the working-self are forming the character of students as they interact with teacher dialogue and each other. The focus on personalised talk with each student probably trickles through to working memory where sound is manipulated to form cognitive structures, against which new learning is cross referenced, resulting in the data patterns detected in response to Bios L&T practices. Yes, they are small to medium effects and isolated to my professional practice. But, there is no reason whatsoever (given that these effects are based upon talk, something every single teacher and human being does) to suspect that they would not amplify if other teachers were more cognisant about the importance of themselves as the linguistic scaffold upon which student learning is built.

From this whole experience, the words of Galileo Galilei, for me a giant in the land of counterfactual thinking, ring truer than ever in the endeavour of teaching:

"You cannot teach a man anything, you can only help him find it within himself."[28]

[28] Thanks Maria for sharing with me this little gem of a quote!

A request of the Examiners.

My experience with UNE Education academia has, I believe, given me just cause to be sceptical about the integrity of its administrative practices. If it acknowledges that it does not have appropriately qualified supervisors and does not believe anyone else is suitably qualified to examine my thesis, then how is it possible for it to fairly interpret the examiner reports let alone make a fair judgement on whether or not my work meets Doctoral criteria? In examining this thesis, I would greatly appreciate simultaneous consideration being given to the aims of the Ed.D. and the Ph.D.; I believe this work overlaps both sets of aims.

Ed.D. aims.[29]

1. To improve the professional practice through the applied nature of the course work and dissertation.
2. To cater to the educational practitioners' advanced research training needs.
3. To apply the research skills of practitioners to the professional workplace.

Ph.D. aims.

"To uncover new knowledge either by the discovery of new facts, the formulation of theories, the development of new interpretive arguments/frameworks, innovative critical analysis, and/or the innovative re-interpretation of known data and established ideas." (UNE, 2007, p. 59).

No criteria for assessment of the Ed.D. are evident. I was personally advised by Dr. Terry Hays of the UNE (prior to my initial submission) that the Ed.D. assessment criteria was basically, "How well you have engaged with the literature." However, the following criteria for assessment of the Ph.D. are noted (UNE, 2007, p. 59-60).

[29] These aims were taken from the UNE website sometime after September, 2013. They are no longer present on the website.

(i) Does the candidate show sufficient familiarity with, and understanding of, the relevant literature?

(ii) Does the thesis provide a sufficiently comprehensive investigation of the topic?

(iii) Are the methods and techniques adopted appropriate to the subject matter and are they applied suitably?

(iv) Are the results set out clearly and logically and accompanied by adequate exposition and interpretation?

(v) Are conclusions and implication developed appropriately and linked clearly to the nature and content of the research framework and findings?

(vi) Is the literary quality and general presentation of the thesis of a suitably high standard?

(vii) Does the thesis as a whole constitute a substantive original contribution to knowledge in the subject area with which it deals?

In this thesis, I claim:

1. That the work is an innovative re-interpretation of conventional pedagogical practices.
2. That this a priori framework was arrived at via a critical analysis of established pedagogical practices.
3. That this generated new facts at the 95% confidence interval.
4. That new knowledge has been uncovered by testing the new interpretive framework of professional practice.
5. That my professional practice as a teacher has improved through the applied nature of the course work and dissertation
6. That this has been applied successfully to the professional workplace.

Simply, the theoretical concerns associated with social constructivist teaching practices have credence in the practical setting of the classroom. Consequently, the desired outcomes of student learning (cognitive development and memory formation) are not likely to eventuate because Conv. L&T practices do not mesh with the cognitive architecture of the student mind.

In making your recommendation of pass, pass with corrections or fail to the UNE, it would be greatly appreciated that criticisms of my Ph.D./Ed.D. claims be supported by references to the literature and not simply represent opinion. In short, a mini counter-thesis is sought. Doing so would clarify whether or not the nature of criticism were matters of correspondence (science) or coherence (ideology). This would aid institutional transparency and should I be required to make corrections, I would thus be able to do so with greater critical understanding of what is being requested.

Conclusion.

It is concluded that the application of cognitive neuroscience to classroom L&T practices has practical value in student learning.

Appendix 1.

Table 10				
NAPLAN (2009-2010) predictors of SC exam achievement				
	Bios model		Conv. G2 model	
Variables	B	95% CI	B	95% CI
Constant	15.55	[-1.69, 34.23]	30.66**	[11.21, 51.91]
Trial exam	.22**	[.098, .35]	.18**	[.067, .3]
Reading	.062*	[.016, .012]	.011	[-.032, .05]
Writing	.028	[-.012, .078]	-.017	[-.056, .012]
Literacy	-.022	[-.11, .056]	.059	[-.01, .13]
Numeracy	.014	[-.02 .044]	.01	[-.014, .047]
R^2	.86		.81	
F	43.12		24.91	
Note: *N* (Bios) = 39, *N* (Conv.) = 35, CI = 95% confidence interval (bias correction and accelerated, 2000 bootstraps)				
* *p* < .05, ** *p* < .01				

These regression models are in effect a split regression that aims to validate the overall integrity of the NAPLAN and NAPLAN-moderated data; comparable results indicating equivalence of the two data sets and thus the validity of associated findings (Snee, 1977). Table 10 indicates that the Bios model is distinguished from the Conv. G2 model by the presence of two variables (the Trial science exam and reading) not incorporating zero in their 95% CIs. Alternatively, the Conv. model has only one variable not incorporating zero in its 95% CI (the Trial exam). The bios model accounted for 86% of variance with F(5, 34) =43, p <.001 and the Conv. G2 model accounted for 81% of variance with F(5, 30) =25, p < .001, with power > .8 for both models.

As the data derived from the NAPLAN-only multivariate Bios and Conv. models is identical to those discussed in the thesis, the inclusion of the 2008 NAPLAN-moderated data did not distort the data pattern that forms the foundation of the thesis.

Ethics approval.

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HUMAN RESEARCH ETHICS COMMITTEE

MEMORANDUM TO: Prof J Geake, Dr P Fletcher & Dr S Tynan
School of Education

This is to advise you that the Human Research Ethics Committee has approved the following:

PROJECT TITLE: The effect of the BIOS pedagogy on student achievement in NSW School Certificate (Year 10) science exams.

APPROVAL No.: HE09/170

COMMENCEMENT DATE: 01/02/2010

APPROVAL VALID TO: 01/02/2011

COMMENTS: Nil. Conditions met in full.

The Human Research Ethics Committee may grant approval for up to a maximum of three years.
For approval periods greater than 12 months, researchers are required to submit an application for renewal at each twelve-month period. All researchers are required to submit a Final Report at the completion of their project. The Progress/Final Report Form is available at the following web address: http://www.une.edu.au/research-services/researchdevelopmentintegrity/ethics/human-ethics/hrecforms.php

The *NHMRC National Statement on Ethical Conduct in Research Involving Humans* requires that researchers must report immediately to the Human Research Ethics Committee anything that might affect ethical acceptance of the protocol. This includes adverse reactions of participants, proposed changes in the protocol, and any other unforeseen events that might affect the continued ethical acceptability of the project.

In issuing this approval number, it is required that all data and consent forms are stored in a secure location for a minimum period of five years. These documents may be required for compliance audit processes during that time. If the location at which data and documentation are retained is changed within that five year period, the Research Ethics Officer should be advised of the new location.

[redacted]

Jo-Ann Sozou
Secretary

09/11/2009

REFERENCES.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2012). *Reliability and validity of NAPLAN*. Retrieved from http://www.acara.edu.au/verve/_resources/Reliability_and_validity_of_NAPLAN.pdf

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2014). *Guide to understanding 2013 Index of Community Socio-educational Advantage (ICSEA) values Retrieved from http://www.acara.edu.au/verve/_resources/Guide_to_understanding_2013_ICSEA_values.pdf*

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2015). *What does the ICSEA value mean? Retrieved from http://www.acara.edu.au/verve/_resources/About_icsea_2014.pdf*

Adank, P., Hagoort, P., & Bekkering, H. (2010). Imitation improves language comprehension. *Psychological Science*, *21* (12), 1903-1909.

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning and the psychological processes that mediate their relationship. *Journal of Educational Psychology*, *93*(4), 545-561.

Al-Ahmadi, F., & Oraif, F. (2009). Working memory capacity, confidence and scientific thinking. *Research in Science & Technological Education*, *27*(2), 225-243.

Alexander, P.A., Schallert, D.L., & Hare, V.C. (1991). Coming to terms: How researchers in learning and literacy talk about knowledge. *Review of Educational Research, 61(3),* 315-343.

Allal, L. (2013). Teachers' professional judgement in assessment: a cognitive act and a socially situated practice. *Assessment in education: Principles, policy and practice, 20*(1), 20-34.

Alloway, T.P., Gathercole, S.E., Kirkwood, H., & Elliott, J. (2009). The cognitive characteristics of children with low working memory. *Child Development, 80*(2), 606-621.

Alloway, T.P., & Alloway, R.G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*, 20-29.

Anderson, R. (2004). *Towards dialogic teaching*. Cambridge, England: Dialogos.

Ansari, D., & Coch, D. (2006). Bridges over troubled water: Education and cognitive neuroscience. *Trends in Cognitive Science, 10*, 146-151.

Anthony, J.K., & Francis, D.J. (2005). Development of phonological awareness. *Current Directions in Psychological Science, 14*(5), 255-259.

Arnett, J.J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist, 55,* 469–480.

Aristotle. (1961). *The Politics of Aristotle*. E. Barker (Ed. and translated). Oxford; Clarendon Press.

Askew, S., & Lodge, C. (2000). Gifts, ping pong and loops: Linking feedback and learning. In: S. Askew (Ed.), *Feedback for learning,* (pp. 1–17). London: Routledge.

Atkinson, R.C., & Shiffrin, R.M. (1968). Human memory: A proposed system and its control processes. In K.W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory (Vol. 2).* New York: Academic Press.

Ausubel, D.P. (1963). Cognitive structures and the facilitation of meaningful verbal learning. *Journal of Teacher Education, XIV* (1), 219-222.

Ausubel, D.P. (2000). *The acquisition and retention of knowledge: A cognitive view*. Dordrecht, Holland: Springer Science+Business Media.

Baars, B. (1997). *In the theatre of consciousness, the workshop of the mind*. New York, USA: Oxford University Press.

Baars, B.J. (2012). Not full reductions, but better explanations. Comment on "Neuroontology, neurobiological naturalism and consciousness: A challenge to scientific reduction and a solution" by Todd E. Feinberg. *Physics of Life Reviews 9*, 40-42.

Baddeley, A. (2000). The episodic buffer: a new component of working memory. *Trends in Cognitive Sciences*, *4*(11), 417-423.

Baddeley, A.D. (2007). *Working memory, thought, and action.* Oxford, United Kingdom: Oxford University Press.

Baddeley, A.D., Hitch, G.J., & Allen, R.J. (2009). Working memory and binding in sentence recall. *Journal of Memory and Language, 61*, 438-456.

Baddeley, A.D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, 63, 1-29.

Bar, M. (2007). The proactive brain: using analogies and associations to generate predictions. *Trends in Cognitive Science*, *11*, 280-289.

Bar, M. (2009). The proactive brain: Memory for prediction. *Philosophical Transactions of the Royal Society B*, *364*, 1235-1243.

Barbey, A.K., & Barsalou, L.W. (2009). Reasoning and problem solving: Models. In L.R. Squire (Ed.), *Encyclopedia of Neuroscience* (Vol. 8, pp 35-43). doi:10.1016/B978-008045046-9.00435-6

Barbey, A.K., Colom, R., Paul, E.J., & Grafman, J. (2014). Architecture of fluid intelligence and working memory revealed by lesion mapping. *Brain Structure and Function, 219*, 485-494.

Barbey, A.K., & Patterson, R. (2011). Architecture of explanatory inference in the human prefrontal cortex. *Frontiers in Psychology, 2*, 1-9.

Barnes, M.A., Dennis, M., & Haefete-Kalvaitis, J. (1996). The effects of knowledge accessibility on coherence and elaborative inferencing in children six to fifteen years of age. *Journal of Experimental Child Psychology, 61*(3), 216-241.

Barsalou, L.W., Breazeal, C. & Smith, L.B. (2007). Cognition as coordinated non-cognition. *Cognitive Processing, 8*, 79-91.

Battro, A.M., Calero, C.I., Goldin, A.P., Holper, L., Pezzatti, L., Shal´om, D.E., & Sigman, M. (2013). The Cognitive Neuroscience of the Teacher–Student Interaction. *Mind, Brain and Education, 7*(3), 177-181.

Beck, I.L., McKeown, M.G., & Kucan, L. (2002). *Bringing words to life: Robust vocabulary instruction.* New York, USA: Guilford Press.

Bergin, C., & Bergin, D. (2009). Attachment in the classroom. *Educational Psychology Review, 21*, 141-170.

Berninger, V.W., Abbott, R.D., Thomson, J., Wagner, R., Swanson, H.L. Wijsman, E.M., & Raskind, W. (2006). Modelling phonological core deficits within a working memory architecture in children and adults with developmental dyslexia. *Scientific studies of reading, 10*(2), 165–198.

Biancarosa, C., & Snow, C.E. (2006). Reading next: A vision for action and research in middle and high school literacy. A report to the Carnegie Corporation of New York. 2nd Edition, Washington, D.C.: Alliance for Excellent Education.

Black, P., & William, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*, 5-31.

Blair, L. (1999). Ensuring early literacy through coherent instruction. *SEDL Letter, 12* (1), 3-6. Retrieved from http://www.sedl.org/pubs/sedletter/v11n01/3.html on the SEDL website.

Board of Studies Teaching and Educational Standards NSW, (2014). *Literacy learning in the early years.* Sydney, Australia: Author.

Bowyer-Crane, C., & Snowling, M. (2005). Assessing children's inference generation: What do tests of reading comprehension measure? *British Journal of Educational Psychology, 75*(2), 189-201.

Brevik, L.M., Fosse, B.O., & Rødnes, K.A. (2014). Language, learning, and teacher professionalism: An investigation of specialised language use among pupils, teachers, and student teachers. *International Journal of Educational Research 68*, 45-56.

Bromme, R., & Tillema, H. (1995). Fusing experience and theory. *Learning and Instruction, 5*, 261-267.

Brooks, D.W., & Shell, F.S. (2006). Working memory, motivation and teacher-initiated learning. *Journal of Science Education and Technology, 15*(1), 17-30.

Bunge, M. (1967). *Scientific Research II.: The Search for Truth.* Berlin, Germany: Springer-Verlag.

Bunge, M. (2012). The correspondence theory of truth. *Semiotica: Journal of the International Association for Semiotic Studies, 188 (Feb),* p65-75.

Cacioppo. J.T., Lorig, T.S., Berntson, G.G., Norris, C.J., Rickett, E., & Nusbaum, H. (2003). Just because you're imaging the brain doesn't mean you can stop using your head: A primer and set of first principles. *Journal of Personality and Social Psychology*, *85*(4), 650–661.

Cain, K., & Oakhill, J. (2009). Reading comprehension development from 8 to 14 years: The contribution of component skills and processes. In R. Wagner, C. Schatschneider & C. Phythian-Sence (Eds.), *Beyond Decoding: The Behavioural and Biological Foundations of Reading Comprehension* (pp. 143-175). New York, USA: Guilford Press.

Cahall, J.S. (1983). *Stages of reading development.* New York, USA: McGraw-Hill.

Caretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences, 19*(246-251).

Carlson, S.M. (2009). Social origins of executive function development. In C. Lewis and J.I.M Carpendale (Eds.), Social interaction and the development of executive function. *New directions in child and adolescent development, 123 (Special Issue),* 87-97.

Carraway, K. (2014). *Transforming your teaching: Practical classroom strategies informed by cognitive neuroscience.* New York, USA: W. W. Norton & Company.

Carreker, S.H., Neuhaus, G.F., Swank, P.R., Johnson, P., Monfils, M.J., & Montemayor, M.L. (2007). Teachers with linguistically informed knowledge of reading subskills are associated with Matthew effect in reading comprehension for monolingual and bilingual students. *Reading Psychology, 28*(187-212).

Chandrasekaran, B., Skoe, E., & Kraus, N. (2014). An integrative model of subcortical auditory plasticity. *Brain Topography, 27* (539-552).

Cherry E.C. (1953). Some experiments on the recognition of speech, with one and two ears. *Journal of the Acoustical Society of America*, *25*, 975-979.

Chng, E., Yew, E.H.J., & Schmidt, H. (2011). Effects of tutor-related behaviour on the process of problem-based learning. *Advances in Health Science Education*, *20*(16), 491-503.

Chomsky, N. (2011). Language and other cognitive systems: *Language Learning and Development*, *7,* 263-278.

Choo, S.S.Y., Rotgans, J.I., Yew, W.H.J., & Schmidt, H.G. (2011). Effect of worksheet scaffolds on student learning in problem-based learning. *Advances in Health Science Education, 16,* 517-528.

Christensen, W.D., & Hooker, C.A. (2000). An interactivist-constructivist approach to intelligence: Self-directed anticipative learning. *Philosophical Psychology, 13* (1), 5-45.

Clark, A. (2008). *Supersizing the mind: Embodiment, action, and cognitive extension*. New York, USA: Oxford University Press.

Clayton, D.F. (2000). The genomic action potential. *Neurobiology of Learning and Memory, 74*: 185-206.

Clayton, D.F. (2013). The genomics of memory and learning in songbirds. *Annual review of Genomics and Human Genetics, 14*: 45-65.

Cogmed. (2013). *Claims and evidence: Cogmed working memory training, Pearson Clinical Assessment (Version 2)*. Retrieved from http://www2.cogmed.com/l/6032/2012-03-27/7st5w/6032/48666

Cohen, A.L., Sandborn, A.M., & Shiffrin, R.M. (2008) Model evaluation using grouped and individual data, *Psychonomic Bulletin and Review*, *15*(4) 692-712.

Cohen, G. (2008). Memory for knowledge: General knowledge and expert knowledge. In G. Cohen and M.A. Conway (Eds.), *Memory in the real world, 3rd Edition* (207-228). East Sussex, England: Psychology Press.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd Ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. Hoboken, USA: Routledge.

Coll, R.K., & Taylor, N. (2004). Probing scientists' beliefs: How open minded are modern scientists? *International Journal of Science Education, 26 (*6), 757-778.

Collins, K.M.T., Onwuegbuzie, A.J., & Jiao, Q.G. (2007). A mixed methods investigation of mixed methods sampling designs in social and health science research. *Journal of Mixed Methods Research, 1*; 267-294.

Compton, D.L., Elleman, A.M., Olinghouse, N.G., Lawrence, J., Bigelow, E., Gilbert, J.K., & Davis, G.N. (2009). The influence of in-text instruction on declarative knowledge and vocabulary learning in struggling readers: How IQ confounds the story. In R. Wagner, C. Schatschneider & C. Phythian-Sence (Eds.), *Beyond Decoding: The Behavioural and Biological Foundations of Reading Comprehension* (pp. 46-71). New York, USA: Guilford Press.

Conway, C.M., Pisoni, D.B., & Kronenberger, W.G. (2009). The importance of sound for cognitive sequencing abilities: The auditory scaffolding hypothesis. *Current direction in Psychological Science, 18* (5), 578-579.

Conway, M.A., Gardiner, J.M., Perfect, T.J., Anderson, S.J., & Cohen, G.M. (1997). Changes in memory awareness during learning: The acquisition of knowledge by psychology undergraduates. *Journal of Experimental Psychology: General*, *126*(4), 393-413.

Conway, M.A., & Pleydell-Pearce, C.W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107* (2), 261-288.

Conway, M.A. (2005). Memory and the self. *Journal of Memory and Language, 53*, 594-628.

Conway, M.A., & Williams, H.L. (2008). Autobiographical memory. In J.H. Bryan (Ed. in chief), *Learning and Memory: A comprehensive reference* (pp. 893-906). California, USA: Elsevier.

Corballis, M.C. (2009). Mental time travel and the shaping of language. *Experimental Brain Research 192*, 553-560.

Cowan, N., Elliott, E.M., Saults, J.S., Morey, C.C., Mattox, S., Hismjatullina, A., & Conway, A.R.A. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology, 51*, 42–100.

Cumming, G. (2011). ESCI Software for Windows: 4th July update [Computer software]. Retrieved from: http://www.latrobe.edu.au/psy/research/projects/esci. Melbourne, Australia.

Daniel, D.B., & Chew, S.L. (2013). The tribalism of teaching and learning. *Teaching of Psychology*, *44*(4), 363-367.

Daniels, H. (2001). *Vygotsky and pedagogy*. London: Routledge-Falmer.

D'Argembeau, A., & Demblon, J. (2012). On the representational systems underlying prospection: Evidence from the event-cuing paradigm. *Cognition 125*, 160–167.

De Brigard, F., Addis, D.R., Ford, J.H., Schacter, D.L., & Giovanello, K.S. (2013). Remembering what could have happened: Neural correlates of episodic counterfactual thinking. *Neuropsychologia 51*, 2401–2414.

De Brigard, F., Spreng, R.N., Mitchell, J.P., & Schacter, D.L. (2015). Neural activity associated with self, other, and object based counterfactual thinking. *NeuroImage*, *109*, 12-26.

DeCourcy, J.S. (2011). HSC and SC data analysis project: Report on HSC and SC 2010. Catholic Education Commission. Sydney, Australia.

Dehaene, S. (2009). *Reading in the brain. The new science of how we read.* New York: Penguin Group.

Delors, J. (1996). Learning: The treasure within. Chairman: J. Delors. *Report to UNESCO of the International Commission on Education for the Twenty first* Century. UNESCO Publishing.

Denti, L. (2004). Introduction: Pointing the way. Teaching reading to struggling readers at the secondary level. *Reading and Writing Quarterly, 20*(2), 109-112.

Department of Education, Science and Technology. (2005). *Teaching Reading: Report and Recommendations, National Inquiry into the Teaching of Literacy.* Canberra, Australia.

Desforges, C. (1995). How does experience affect theoretical knowledge for teaching? *Learning and Instruction 5* (4), 358-400.

Dewey, J. (1899). *Interest as related to will*. New York: Herbart Society

Dewey, J. (1913). *Interest and effort in education.* New York: Halton Mifflin.

Dewey, J. (1933). How we think: A restatement of the relation of reflective thinking to the educative process. Boston: D.C. Heath.

Dewey, J. (1938). *Education and experience*. Macmillan: New York.

Dewey, J. (1987). The challenge of democracy to education. In J. A. Boydston (Ed.), *The later works of John Dewey, 1925 – 1953: Volume 11, 1935-1937: Essays, reviews, Trotsky inquiry, miscellany and liberalism and social action*. Carbondale, USA: Board of Trustees, Southern Illinois University.

Dewhurst, S.A., Conway, M.A., & Brandt, K.R. (2009). Tracking the R-to-K shift: Changes in memory awareness across repeated tests. *Applied Cognitive Psychology, 23,* 849-858.

Dickersen, B.C., & Eichenbaum, H. (2010). The episodic memory system: Neurocircuitry and disorders. *Neuropsychopharmacology Reviews 35*, 86-104.

Dinham, S. (2014). 'Primary schooling in Australia: Pseudo-Science plus extras times growing inequality equals decline', keynote address, *Australian College of Educators National Conference,* Adelaide, 11th September.

Doidge, N. (2007). *The brain that changes itself: Stories of personal triumph from the frontiers of brain science.* London: Penguin Books.

Dommett, E.J., Devonshire, I.M., Plateau, C.R., Westwell, M.S., & Greenfield, S.A. (2011). From scientific theory to classroom practice. *The Neuroscientist, 17*(4), 382-388.

Dousa, T.M. (2009). Classical pragmatism and its varieties: On a pluriform metatheoretical perspective for knowledge organisation. *Proceedings from the North American Symposium on Knowledge Organisation, 2*, 1-9.

Dubinsky, J.M., Roehrig, G., & Varma, S. (2013). Infusing neuroscience into teacher professional development. *Educational Researcher, 42*(6), 317-329.

Dubuc, B. (2012). *The brain from top to bottom*. Retrieved from http://thebrain.mcgill.ca/avance.php

Dunlap, W.P., Cortina, J.M., Vaslow, J.B., & Burke, M.J. (1996). Meta-analysis of experiments with matched groups or repeated measures designs. *Psychological Methods, 1*(2), 170-177.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14,* 4-58.

Eason, S.H., & Cutting, L.E. (2009). Examining sources of poor comprehension in older poor readers; Preliminary findings, issues and challenges. In R. Wagner, C. Schatschneider & C. Phythian-Sence (Eds.), *Beyond Decoding: The Behavioural and Biological Foundations of Reading Comprehension* (pp. 46-71). New York, USA: Guilford Press.

Efron, B., & Tibshirani, R. (1993*). An introduction to the bootstrap*. New York: Chapman & Hall.

Eichenbaum, H., & Fortin, N.J. (2009). The neurobiology of memory based predictions. *Philosophical Transactions of the Royal Society B, 364,* 1183-1191.

Elkjaer, B. (2009). Pragmatism: A learning theory for the future. In K. Illeris (Ed.), *Contemporary theories of learning: Learning theorists… in their own words* (pp. 74-89). Abingdon, England: Routledge.

Epstude, K., & Roese, N.J. (2008). The functional theory of counterfactual thinking. *Personality and Social Psychology Review, 12*(2), 168-192.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behaviour Research Methods, 41*, 1149-1160.

Ferguson, C. J. (2009). An effect size primer: a guide for clinicians and researchers. *Professional Psychology: Research and Practice*, *40*, 532-538.

Ferrari, J. (2015, Jan. 5). Teacher training fails at literacy; 'Too much theory at uni.' The Australian, p1.

Field, A. (2013). Discovering Statistics using IBM SPSS Statistics. SAGE Publications Ltd. Kindle Edition.

Fivush, R., Habermas, T., Waters, T.E.A., & Zaman, W. (2011). The making of autobiographical memory: Intersections of culture, narratives and identity. *International Journal of Psychology, 46* (5), 321-345.

Funderburk, B. W., Eyberg, S. M., Rich, B. A., & Behar, L. (2003). Further psychometric evaluation of the Eyberg and Behar rating scales for parents and teachers of pre-schoolers. *Early Education and Development*, *14*, 67–81.

G*Power (Version 3.1.3) [Computer software]. Dusseldorf, Germany. Retrieved from: http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/download-and-register.

Galinsky, A. D., & Kray, L. J. (2004). From thinking about what might have been to sharing what we know: The effects of counterfactual mind-sets on information sharing in groups. *Journal of Experimental Social Psychology, 40*, 606-618.

Gamlem, S.M., & Munthe, E. (2014). Mapping the quality of feedback to support students' learning in lower secondary classrooms. *Cambridge Journal of Education, 44*(1), 75-92.

Gathercole, S.E., Lamont, E., & Alloway, T.L. (2006). Working memory in the classroom. In S.J. Pickering (Ed.) *Working memory and education* (pp. 219-240). Oxford, U.K.: Elsevier.

Gathercole, S.E., & Alloway, T.P. (2007). *Understanding working memory: A classroom guide*. Harcourt Assessment: London, UK. Downloaded from http://psychology.dur.ac.uk/research/wm/index.htm

Gathercole, S.E., Alloway, T.P., Kirkwood, H.J., Elliott, J.G., Holmes, H., & Hilton, K.A. (2008). Attentional and executive function behaviours in children with poor working memory. *Learning and Individual Differences*, *18*, 214-223.

Gathercole, S.E. (2008). Working memory in the classroom. *The Psychologist, 21*(5), 382-385.

Gauffroy, C., & Barrouillet, P. (2009) Heuristic and analytic processes in mental models for conditionals: An integrative developmental theory. *Developmental Review 29*, 249–282.

Gee, J.P. (2004). *Situated Language and Learning: A critique of traditional schooling*. London: Routledge.

Gelman, A., & Hill, J. (2006). *Data analysis using regression and multilevel/hierarchical models*. Cambridge, United Kingdom: Oxford University Press.

Georgescu, J. (2013). Quantum entanglement; now you see it. *Nature Physics, 9*, 394.

Gentner, D., & Christie, S. (2010). Mutual bootstrapping between language and analogical processing. *Language and Cognition, 2*(2), 261-283.

Gioia, G.A., Isquith, P.K., Guy S.C., & Kenworthy, L. (2000). *Behaviour rating inventory of executive function: Professional Manual*. Lutz, FL: Psychological Assessment.

Giugni, E., Vadala, R., Vincentiis, C.De. Colica, C., & Bastianello, S. (2010). The brain's default mode network: A mind "sentinel" role? *Functional Neurology, 20*(4), 189-190.

Goswami, U. (2004). Neuroscience and Education. *British Journal of Educational Psychology, 74I, 1-14.*

Gott, C., & Lah, S. (2014). Episodic future thinking in children compared to adolescents. *Child Neuropsychology, 20 (5), 625-640.*

Graff, J., & Mansuy, I.M. (2008). Epigenetic codes in cognition and behaviour. *Behavioural Brain Research, 192*, 70-87.

Greicius, M.D., Krasnow, B., Reiss, A.L., & Menon, V. (2003). Functional connectivity in the resting brain: A network analysis of the default mode hypothesis. *Proceedings of the National Academy of Science of the United States of America, 100*(1), 253-253.

Gruber, M.J., Gelman, B.D., & Ranganath, C. (2014). States of curiosity modulate hippocampus-dependent learning by the dopaminergic system. *Neuron, 84*, 486-496.

Halford, G.S., Wilson, W.H., & Phillips, S. (2010). Relational knowledge: the foundation of higher cognition. *Trends in Cognitive Sciences, 14*(11), 497-505.

Hannover, B. (1998). The development of self-concept and interests. In L. Hoffmann, A. Krapp, K.A. Renninger, and J. Baumert (Eds.), *Interest in learning: Proceedings of the Seeon Conference on interest and gender* (pp. 105-125). Kiel, Germany: IPN.

Hardiman, M. (2012). *The brain-targeted teaching model for 21st century schools.* Thousand Oaks, California: Corwin.

Hattie, J.A.C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London, United Kingdom: Routledge.

Hayes, A.F., & Preacher, K.J. (2014). Statistical mediation analysis with multicategorical independent variables. *British Journal of Mathematical and Statistical Psychology, 67* (3), 451-470.

Hayes, J.R., & Flower, L. (1981). A cognitive process theory of writing. *College Composition and Communication, 32*(4), 365-387.

Hayes, D.P., & Ahrens, M. (1998). Vocabulary simplification for children: A special case of 'motherese"? *Journal of Child Language, 15*, 395-410.

Hebb, D.O. (1949). *The organisation of behaviour, a neuropsychological theory*. New York, USA: Wiley.

Hendrix, G. (1961). Learning by discovery. *Mathematics Teacher, 54*, 290-299.

Hendrix, G. (1947). A new clue to transfer of training. *Elementary School Journal, 48*, 197-208.

Herman, M.A. (2004). A definition of causal effect for epidemiological research. *Journal of Epidemiology and Community Health, 58*, 265-271.

Hill, A.B. (1965). The environment and disease: Association or causation? *Proceedings of the Royal Society of Medicine, 58*, 295-300.

Hille, K. (2011). Bringing research into educational practice: Lessons learned. *Mind, Brain, and Education, 5*(2), 63-70.

Höfler, M. (2005). Causal inference based on counterfactuals. *BMC Medical Research Methodology, 5*(28). doi:10.1186/1471-2288-5-28.

Hofstadter, D.R. (1985). *Metamagical themas: Questing for the essence of mind and pattern*. New York: Basic Books.

Holland, A.C., & Kensinger, E.A. (2010). Emotion and Autobiographical Memory. *Physics of Life Reviews*, *7*(1): 88–131.

Howe, C., & Abedin, M. 2013 Classroom dialogue: a systematic review across four decades of research. Cambridge Journal of Education, 43(3), 325-356.

Hruby, G.C., & Goswami, U. (2011). Neuroscience and reading: A review for reading education researchers. *Reading Research Quarterly*, *46*(2), 156-172.

Hubbard, A.E., Ahern, J., Fleischer, N.L., Van der Laan, M., Lippman, S.A., Jewell, N., Bruckner, T., & Satariano, W.A. (2010). To GEE or not to GEE: Comparing population average and mixed models for estimating the associations between neighbourhood risk factors and health. *Epidemiology 21*(4), 467-474.

Hussein, F., & Reid, N. (2009) Working memory and difficulties in school chemistry. *Research in Science & Technological Education, 27*(2), 161-185.

Illeris, K. (2009). A comprehensive understanding of human learning. In K. Illeris (Ed.), *Contemporary theories of learning: Learning theorists… in their own words* (pp. 7-20). Abingdon, England: Routledge.

Immordino-Yang, M.H., Christodoulou, J.A., & Singh, V. (2012). Rest is not idleness: Implications for the Brain's default mode for human development and education. *Perspective on Psychological Science*, *7*(4), 352-364.

Ingvar, D.H. (1979) Hyperfrontal distribution of the cerebral grey matter flow in resting wakefulness: on the functional anatomy of the conscious state. *Acta Neurologica Scandinavia 60*, 12–25.

Institute of Medicine (US) Forum on Neuroscience and Nervous System Disorders. (2008). *From Molecules to Minds: Challenges for the 21st Century: Workshop Summary*. Washington (DC): National Academies Press. Downloaded from: http://www.ncbi.nlm.nih.gov/books/NBK50995/

Jacob, E. (2000). The legacy of pragmatism: implications for knowledge organization in a pluralistic universe. In C. Beghtol, L.C. Howarth, and N.J. Williamson (Eds.), *Dynamism and stability in knowledge organization: proceedings of the Sixth International ISKO Conference,* 10-13 July 2000, Toronto, Canada (pp. 16-22). Würzburg, Germany: Ergon Verlag.

James, W. (1890). *The Principles of Psychology*. Retrieved from http://psychclassics.asu.edu/James/Principles/prin11.htm

Jenkins, J.R., Matlock, M., & Slocum, T.A. (1989). Two approaches to vocabulary meanings and practice in deriving word meanings from context. *Reading Research Quarterly, 24*, 216-235.

Karli, P. (2008). The human brain as a mediating, integrating and unifying central agency. *Society and Business Review, 3(2), 107-118.*

Keltchermans, G. (2009). Who I am in how I teach is the message: Self-understanding, vulnerability and reflection. *Teacher and Teaching: Theory and Practice 15*(2), 257-272.

Kent, A. (2013). Synchronization as a classroom dynamic: A practitioner's perspective. *Mind, Brain, and Education, 7*(1), 13-18.

Kintsch, W., Patel, V.L., & Ericcson, K.A. (1999). The role of long term memory on text comprehension. *Psychologia, 42,* 186-198.

Kirschner, P.A., Sweller, J., & Clark, R.E. (2006). Why minimal guidance does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75-86.

Kitsch, W. (1998). *Comprehension: A paradigm for cognition.* New York, USA: Cambridge University Press.

Konishi, M., McLaren D.G., Engen, H., & Smallwood, J. (2015) Shaped by the Past: The Default Mode Network Supports Cognition that Is Independent of Immediate Perceptual Input. *PLoS ONE 10*(6), e0132209.

Konkel, A., & Cohen, N.J. (2009). Relational memory and the hippocampus: Representations and methods. *Frontiers in Neuroscience, 3* (2), 166-174.

Kray, L.J., & Galinsky, A.D. (2003). The debiasing effect of counterfactual mind-sets: Increasing the search for disconfirmatory information in group decisions. *Organizational Behavior and Human Decision Processes, 91*, 69-81.

Lalonde, R.J. (1986). Evaluating the econometric evaluations of training programs with experimental data. *American Economic Review, 76*, 604-620.

Langer, J., & Nicolich, M. (1981). Prior knowledge and its relationship to comprehensions. *Journal of Reading Behaviour, 13*, 373-379.

Leinhardt, G., McCarthy Young, K., & Merriman, J. (1995). Integrating professional knowledge: The theory of practice and the practice of theory. *Learning and Instruction, 5,* 401-408.

Levinson, R., & Thomas, J. (2005). *Science today: Problem or crisis.* London: Routledge.

Long, J.F., & Hoy, A.W. (2006). Interested instructors: A composite portrait of individual differences and effectiveness. *Teaching and Teacher Education 22,* 303-314.

Loughran, J.J. (2006). *Developing a pedagogy of teacher education: Understanding teaching and learning about teaching*. London: Routledge.

McCallum, R.C., & Austin, J.T. (2000). Applications of structural equation modelling in psychological research. *Annual Review of Psychology, 51*, 201-226.

McDonald, R.P., & Ringo Ho, M.H. (2002). Principles and practice in reporting structural equation analyses. *Psychological Methods, 7*, 64-82.

Mackenzie, D. (2015). Sound advice. *New Scientist, 227* (3030), 36-38.

March, J. S., Parker, J. D. A., Sullivan, K., Stallings, P., & Conners, C. K. (1997). The Multidimensional Anxiety Scale for Children (MASC): Factor structure, reliability, and validity. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*, 554–565.

Markman, K.D., Lindberg, M.J., Kray, L.J., & Galinsky, A.D. (2007). Implications of counterfactual structure for creative generation and analytical problem solving. *Personality and Social Psychology 33*(3), 312-324.

Martin, R., & Wu, D. (2004). The cognitive neuropsychology of language. In K. Lamberts and R.L. Goldstone. (Eds.), *Handbook of Cognition* (pp. 383-405). Thousand Oaks, CA: Sage. doi**:** 10.4135/9781848608177

Matthews, M.R. (1992). Old wine in new bottles: A problem with constructivist epistemology. In H.A. Alexander (Ed.), *Philosophy of Education* (303-311). Urbana, Illinois: Philosophy of Education Society.

Matthews, M.R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education, 11*(2), 121-134.

Mayer, D. (1999) *Building teaching identities: implications for pre-service teacher education*. Paper presented to the Australian Association for Research in Education, Melbourne.

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 49*(2), 270-291.

Miller, G.A. (1950). Verbal context and the recall of meaningful material. *American Journal of Psychology, 63,* 176-185.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81-97.

Minter, R.L. (2011). The learning theory jungle. *Journal of College Teaching and Learning, 8* (6), 7-15.

Morrison, C.M., & Conway, M.A. (2010). First words and first memories. *Cognition, 111*, 12-32.

Moss, C.M., & Brookhart, S.M. 2009. *Advancing formative assessment in every classroom: A guide for instructional leaders*. ASCD: Alexandria, USA.

Nagy, W., Anderson, R., & Herman, P. (1987). Learning word meanings form context during normal reading. *American Educational Research Journal, 24,* 237-270.

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review, 111*, 486–511.

Nias, J. (1996). Thinking about feeling: the emotions in teaching. *Cambridge Journal of Education, 26*(3), 293–306.

Nickerson, R.S. (1977). Some comments on human memory as a very large database. In B.C. Housel and A.G. Mertel (Eds.), *Proceedings of the third international conference on very large data bases* (Vol. 3, pp. 159-168). VLDB Endowment: USA.

Oberauer, K. (2009). Design for a working memory. *Psychology of Learning and Motivation, 51*, 45-100.

Oberauer, K., & Klein, L. (2012). Attention to information in working memory. *Current Directions in Psychological Science, 21*(3), 164-169.

O'Connor, A.K., Moulin, C.J.A., & Cohen, G. (2008). Memory and consciousness. In G. Cohen and M.A. Conway (Eds.), *Memory in the real world, 3rd Edition* (249-268). East Sussex, England: Psychology Press.

OECD (2015). *Student, Computers and Learning: Making the Connection.* PISA, OECD Publishing.

Olson, R.K., Keenan, J.M., Byrne, B., and Samuelsson, S. (2014). Why do children differ in their development of reading and related skills? *Scientific Studies of Reading, 18*(1), 38-54.

Onyon, C. (2012). Problem-based learning: A review of the educational and psychological theory. *The Clinical Techer, 9*, 22-26.

Ost, J., & Costall, A. (2009). Misremembering Bartlett: A study in serial reproduction. *British Journal of Psychology, 93*(2), 243-255.

Oyoo, S.O. (2012). Language in science classrooms: An analysis of physics teachers' use of and beliefs about language. *Research in Science Education 42*, 849-873.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105-119.

Pehmer, A.-K, Gröschner, A., & Seidel, T. 2015. How teacher professional development regarding classroom dialogue affects students' higher-order learning. *Teaching and Techer Education, 47*, 108-119.

Perfetti, C. (1985). *Reading ability.* New York, USA: Oxford University Press.

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading, 11*(4), 357-383.

Perfetti, C. (2011). Phonology is critical in reading: But a phonological deficit is not the only source of low reading skill. In S.A. Brady, D. Braze & C.A. Fowler (Eds.), *Explaining individual differences in reading: Theory and evidence* (pp. 153-171). New York, New York: Psychology Press.

Perfetti, C., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. *Journal of Deaf Studies and Deaf Education, 5*(1), 32-50.

Perlovksy, L. (2009). Language and cognition. *Neural Networks, 22*, 247-257.

Phan, H.P. (2012). Trajectories of self-efficacy and achievement goals: A developmental approach. *Journal of Educational and Developmental Psychology, 2*(2), 126.

Phelps, E.A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. *Current opinion in neurobiology 14*, 198-202.

Phelps, E.A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Reviews in Psychology 57*, 27-53.

Philippi, C.L., Tranel, D., Duff, M., & Rudrauf, D. (2015). Damage to the default mode network disrupts autobiographical memory retrieval. *Social Cognitive and Affective Neuroscience, 10*(3).

Piertarinen, J., Soini, T., & Pyhältö, K. (2014). Students' emotional and cognitive engagement as the determinants of well-being and achievement in school. *International Journal of Educational Research 67*, 40-51.

Pinker S. (1995). *The language instinct. How the mind creates language.* Cambridge: The MIT Press.

Pinker, S. (2003) Language as an adaptation to the cognitive niche. In M.H. Christiansen and S. Kirby (Eds.), *Language Evolution: The States of the Art* (16-37), Oxford, UK: Oxford University Press.

Pinker, S. (2010). The cognitive niche: Coevolution of intelligence, sociality, and language. *Proceedings of the National Academy of Sciences of the United States of America, 107*(2), 8993-8999.

Preacher, K.J., & Kelly, K. (2011). Effect size measures for mediation models: Quantitative strategies for communicating indirect effects. *Psychological Methods 16*(2), 93-115.

Qin, P., & Northoff, G. (2011). How is our self-related to midline regions and the default-mode network? *NeuroImage 57*: 1221–1233.

R (Version 2.12.1) [Computer software]. R Foundation for Statistical Computing, Vienna, Austria.

Ramsden, S., Richardson, F.M., Josse, G., & Price, C.J. (2011). Verbal and nonverbal intelligence changes in the teenage brain. *Nature, 479*(7371), 113-116.

Raver, C.C., & Blair, C. (2014). At the crossroads of education and development neuroscience: Perspectives on executive function. *Perspectives on Language and Literacy, 40*(2), 27-30.

Renninger, K.A., & Wozniak, R.H. (1985). Effect of interest on attentional shift, recognition, and recall in young children. *Developmental Psychology, 21*, 624-632.

Renninger, K.A. (2000). Individual interest and its implications for understanding intrinsic motivation. In C. Sansone, & J.M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 373-404). San Diego, USA: Academic Press.

Richards, T.L., Aylward, E.H., Field, K.M., Grimme, A.C., … Berninger, V.W. (2006). Converging evidence for triple word form theory in children with dyslexia. *Developmental Neuropsychology, 30*(1), 547-589.

Rizzolatti, G., & Craighero, L. (2004). The mirror neuron system. *Annual Review of Neuroscience, 27,* 169-192.

Robb, L. (2002). The myth learn to read/read to learn. *Instructor, 11*(8), 23-25.

Rodriguez, V. (2013). The teaching brain and the end of the empty vessel. *Mind, Brain and Education, 6*(4), 177-185.

Roese, N.J. (1997). Counterfactual thinking. *Psychological Bulletin, 121*(1), 133-148.

Roese, N. J., & Olson, J. M. (1993). The structure of counterfactual thought. *Personality and Social Psychology Bulletin, 19*, 312-319.

Rosenbaum, P.R. (2005). Observational study. In B.S. Everett & D.C. Howell (Eds.), *Encyclopedia of statistics in behavioural science* (pp1451-1462). Chichester, UK: John Wiley & Sons.

Rowe, K. (2003). The importance of teacher quality as a key determinant of students' experiences and outcomes of schooling.

Retrieved from http://research.acer.edu.au/research_conference_2003/3

Rowe, K. (2006). Effective teaching practices for students with and without learning difficulties: Constructivism as a legitimate theory of learning AND of teaching? Retrieved from http://research.acer.edu.au/learning_processes/10

Rowe, K. (2007). The imperative of evidence-based practices for the teaching and assessment of numeracy. Invited submission to National Numeracy Review. Copy of submission provided by Dr Ken Rowe, Research Director, *Learning Processes* Research Program, Australian Council for Educational Research, Private Bag 55, Camberwell, VIC 3124.

Ryan, L., Hoscheidt, S., & Nadel, L. (2008). Perspectives on episodic and semantic memory retrieval. In E. Dere, L. Easton, L. Nadel and J.P. Houston (Eds.), *Handbook of Episodic Memory* (pp5-7). Oxford, UK: Elsevier.

Sasson, G.M. (2001). The retreat from inquiry and knowledge in special education. *Journal of Special Education, 34*(4), 178-193.

Schacter, D.L., & Addis, D.R. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Philosophical Transactions of the Royal Society B 36*, 773-786.

Schacter, D.L., Donna Rose Addis, D.R., Hassabis, D., Martin, V.C. Spreng, R.N., & Szpunar, K.K. (2012). The Future of Memory: Remembering, Imagining, and the Brain. *Neuron 76*, 677-694.

Schiefele, U. (1996). Topic interest, text representation, and quality of experience. *Educational Psychologist, 26*(3 & 4), 299-323.

Schiefele, U. (1998). Individual interest and learning what we know. In L. Hoffman, A. Krapp, K.A. Renninger, & J. Baumert (Eds), *Interest and learning: Proceedings of the Seon Conference on interest and gender*(pp.91-104). Kiel, Germany: IPN.

Schiefele, U., & Csikszentmihalyi, M. (1994). Interest and the quality of experience in classrooms. *European Journal of Psychology of Education, 9*(3), 251-270.

Schilbach, L., Eickhoff, S.B., Rotarska-Jagiela, A., Fink, G.R., & Vogeley, K. (2008). Minds at rest? Social cognition as the default mode of cognizing and its putative relationship to the "default system" of the brain. *Consciousness and Cognition, 17,* 457-467.

Schmidt, H.G., & Moust, H.C. (1995). What makes a tutor effective? A structural equations modelling approach to learning in problem-based curricula. *Academic Medicine*, *70*, 708-714.

Schön, D. (1983). *The reflective practitioner.* New York: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner.* San Francisco: Jossey-Bass.

Schön, D. (1992). The theory of inquiry: Dewey's legacy to education. *Curriculum Inquiry, 2*(2), 119-139.

Science Council. (2010). Defining science. Retrieved December, 19, 2014, from http://www.sciencecouncil.org/definition

Shell, D.F., Brooks, D.W., Trainin, G., Wilson, K.M., Kauffman, D.F., & Herr, L.M. (2010). *The unified learning model*. New York, USA: Springer.

Shing, Y.L., & Lindenberger, U. (2011). The development of episodic memory: Lifespan lessons. *Child Development Perspectives,* 5(2), 148-155.

Shirey, L., & Reynolds, R.E. (1988). Effect of interest on attention and learning. *Journal of Educational Psychology, 80*(2), 159-166.

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception, 28*(9), 1059-1074.

Sinclair, J.Mc.H., & Coulthard, M. 1975. *Towards an analysis of discourse: The English used by pupils and teachers.* Oxford: Oxford University Press.

Skinner B.F. (1938). The behaviour of organisms: An experimental analysis. New York, USA: Appleton-Century.

Skoe, E. & Chandrasekaran, B. (2014). The layering of auditory experiences in driving experience-dependent subcortical plasticity. *Hearing Research, 311*(36-48).

Slater, H., Davies, N.M., & Burgess, S. (2012). Do teachers matter? Measuring the variation in teacher effectiveness in England. *Oxford Bulletin of Economics and Statistics, 74* (5), 629-645.

Slavich, G.M., & Zimbardo, P.G. (2012). Transformational teaching: Theoretical underpinnings, basic principles and core methods. *Educational Psychology Review, 24,* 569-608.

Smallwood, J., Obonsawin, M., & Heim, D. (2003). Task unrelated thought: The role of distributed processing. *Consciousness and Cognition,* 12, 169-189.

Smithson, M. (2001). Correct confidence intervals for various regression effect sizes and parameters: The importance of non-central distributions in computing intervals. *Educational and Psychological Measurement, 61*(4), 605-632.

Snee, R.D. (1977). Validation of regression models: Methods and examples. *Technometrics 19*(4), 415-428.

Snow, R.E., Corno, L., & Jackson, D. (1996). Individual differences in affective and conative functions. In D. Berliner and R. Calfee (Eds.), *Handbook of Educational Psychology,* (pp. 243-310). New York, USA: Macmillan.

Sousa, D.A. (2006). How the brain learns. Heatherton, Australia: Hawker Brownlow Education.

SPSS (Version 22) [Computer software] St. Leonards, NSW: IBM Australia Ltd.

St. Clair-Thompson, H.L., & Gathercole, S.E. (2006). Executive functions and achievements in school: shifting updating inhibition and working memory. *The Quarterly Journal of Experimental Psychology, 59*(4), 745-759.

Stanovich, K.E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*, 360-406.

Staudenmaier, J. (1985). *Technology's storytellers: Reweaving the human fabric.* Cambridge MA and London: Society for the History of Technology and the MIT Press.

Stefanski, L.A. (2001). Measurement error models. In *Statistics in the 21st century.* Ed. Rafferty, A.E., Tanner, M.A., & Wells, M.T. London: Chapman and Hall.

Stern, R. (2004). Coherence as a test for truth. *Philosophy and Phenomenological Research,* LXIX (2), 296-326.

Strauss, S., & Shilony, T. (1994). Teachers' models and children's minds and learning. In L.A. Hirschfield & S.A. Gelman (Eds.), *Mapping the mind: Domain-specificity in cognition and culture*. Cambridge, U.K.: Cambridge University Press.

Strauss, S., & Ziv, M. (2013). Teaching is a natural cognitive ability for humans. *Mind, Brain and Education, 6*(4), 186-196.

Stuart, E.A., & Rubin, D.B. (2007). Best practice in quasi-experimental designs. In J. Osborne (Ed.), *Best practice in quantitative social science* (pp155-176). Thousand Oaks, CA: Sage Publications.

Suchting, W.A. (1992). Constructivism deconstructed. *Science and Education, 1*, 223-254.

Sutton, J. (2011). Influences on memory. *Memory Studies*, 4(4), 355-359.

Swanborn, M.S.L., and de Glopper, K. (1999). Incidental word learning while reading: A meta-analysis. *Review of Educational Research, 69*, 261-285.

Swanson, H.L., Zheng, X., & Jerman, O. (2009). Working memory, short-term memory and reading disabilities: A selective meta-analysis of the literature. *Journal of Learning Disabilities, 42*(3), 260-287.

Taylor, N., & Maxwell, T.M. (2004). Enhancing the relevance of a professional doctorate: The case of the Doctor of Education degree at the University of New England. *Asia-Pacific Journal of Cooperative Education, 5(1),* 60-69.

Thorsen, C.A., & DeVore, S. (2013). Analyzing reflection on/for action: A new approach. *Reflective Practice, 14*(1), 88-103.

Tillema, H. (1995). Changing the professional knowledge and beliefs of teachers: A training study. *Learning and Instruction, 5,* 291-318.

Topping, K.J., & Trickey, S. (2014). The role of dialog in philosophy for children. 2014. *International Journal of Educational Research 63*, 69-78.

Trickey, S., & Topping, K.J. (2004). Philosophy for children: A systematic review. *Research Papers in Education, 19*(3), 365-380.

Tulving, E. (2000). Memory: Introduction. In M.S. Gazzinga (Ed.), *The New Cognitive Neurosciences, 2nd Ed.* (pp.727-732). London, England: A Bradford Book.

Tulving, E. (2007). Are there 256 different kinds of memory? In James S. Nairn (Ed.), *The foundations in remembering: Essays in honor of Henry L, Roedeers, III.* New York, USA: Psychology Press.

Tytler, R. (2003). A window for a purpose: Developing a framework for describing effective science teaching and learning. *Research in Science Education, 33,* 273-298.

Ulm, M.S. (2013). Communicating brains from neuroscience to phenomenology. *Trends in Neuroscience and Education, 2*, 7-12.

University Admission Centre (UAC). (2015). *Educational Access Schemes; Disadvantage Code SO1E. Retrieved from http://www.uac.edu.au/documents/eas/S01E.pdf*

University of New England. (2007). *Quality in Research Higher Degrees: A handbook for higher degree research students and supervisors, (The Gold Book).* Armidale, Australia: University of New England.

Vanderberg, R., & Swanson, H.L. (2007). Which components of working memory are important in the writing process? *Reading and Writing, 20*, 721-752.

Van Hoeck, N., Ma, N., Ampe, L., Baetens, K., Vandekerckhove, M., & Van Overwalle, F. (2013). Counterfactual thinking: an fMRI study on changing the past for a better future. *SCAN 8*, 556-564.

van Merriënboer, J.J.G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology review, 17*(2), 147-177.

van Merriënboer, J.J.G., & Sweller, J. (2010). Cognitive load theory in health professional education: Design principles and strategies. *Medical Education, 44,* 85-93.

Verloop, N., Van Driel, J., & Meijer, P. (2001). Teacher knowledge and the knowledge base of teaching. *International Journal of Education Research, 35,* 441-461.

Vygotsky, L.S. (1986). *Thought and language*. Cambridge, MA: MIT Press.

Walkington, J. (2010). Becoming a teacher: Encouraging development of teacher identity through reflective practice. *Asia-Pacific Journal of Teacher Education, 33*(1), 53-64.

Wallis, S.E. (2010). Toward a science of metatheory. *Integral Reviews, 6 (3),* 73-120.

Wainer, H. (2011). Value-added models to evaluate teachers: A cry for help. *Chance 24*(1), 11-13.

Walker, S., Brownlee, J., Whiteford, C., Exely, B., & Woods, A. (2012). A longitudinal study of change in preservice teachers' personal epistemologies. *Australian Journal of Teacher Education, 37*(5), 24-35.

Was, C.A., & Woltz, D.J. (2007). Reexamining the relationship between working memory and comprehension: The role of available long term memory, *Journal of Memory and Language 56*, 86-102.

Watson, J. B. (1913). Psychology as the behaviorist views it. Psychological Review, *20*, 158-177.

Watts, D.M. (1994). Constructivism, re-constructivism and task-oriented problem solving. In P. Fensham, R. Gunstone, and R. White (Eds), *The content of science: A constructivist approach to its teaching and learning* (p.39-58). Falmer Press: London, U.K.

Webber, R., Mangus, J.M., & Huskey, R. (2015) Brain Imaging in Communication Research: A Practical Guide to Understanding and Evaluating fMRI Studies. *Communication Methods and Measures, 9*, 5-29.

Wergin, J.F. (2011). Rebooting the Ed.D. *Harvard Educational Review, 81* (1), 119-139.

Westwood, P. (1999). Constructivist approaches to mathematical learning: A note of caution. In D. Barwood, D. Greaves, & P. Jeffrey (Eds.), *Teaching numeracy and literacy: Interventions and strategies for 'at risk' students*. Coldstream, Victoria: Australian Resource Educators' Association.

Wheeler, M., & Clark, A. (2008). Culture, embodiment and genes: unravelling the triple helix. *Philosophical Transactions of the Royal Society B, Biological Sciences, 36*, 3563–3575.

Whelan, R., Conrod, P.J., Poline, J.-B., …the IMAGEN Consortium, (2012). Adolescent impulsivity phenotypes characterized by distinct brain networks. *Nature Neuroscience, 15* (6), 920-927.

Williams, H., Conway, M., & Cohen, G. (2008). Autobiographical Memory. In G. Cohen and M.A. Conway (Eds.). *Memory in the real world* (pp. 21-90). Sussex, England: Psychological Press.

Willis, J. (2014). Neuroscience reveals that boredom hurts. *Phi Delta Kappan, 95*(8), 28-32.

Winship, C., & Morgan, S.L. (1999). The estimation of causal effects from observational data. *Annual Reviews of Sociology, 25*, 659-707.

Withear, J.L. (2009). Slipping through the cracks: Why too many adolescents still struggle to read. *Literacy Learning: The Middle Years 17*(2), 30-45.

Wren, S. (2000). *Cognitive foundations of learning to read: A framework*. Austin, TX: Southwest Educational Development Laboratory (SEDL). Copyright ©2000 by SEDL. Retrieved from http://www.sedl.org/reading/framework on the SEDL website.

Yalaki, Y., & Çakmakcı, G. (2010). A conversation with Michael R. Matthews: The contribution of history and philosophy of science to science teaching and research. *Eurasia Journal of Mathematics, Science and Technology Education, 6*(4), 287-309.

Zaretskii, V.K. (2009). The zone of proximal development. *The Journal of Russian and East European Psychology, 47*(6), 70-93.

Zhou, J. (2012). The effects of reciprocal imitation on teacher-student relationships and student learning outcomes. *Mind, Brain, and Education, 6(2),* 66-73.