CONCEPTUAL MEDIATION:

A NEW THEORY AND A NEW METHOD

OF CONCEPTUAL CHANGE

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(1) Dole, S., Cooper, T.J. & Lyndon, H. (1997). Error patterns, conceptual change and accelerated forgetting: Another dimension to the jigsaw of effective conceptual mediation in mathematics

(2) Lyndon, H. (1989). I did it my way! An introduction to "Old Way/New Way" methodology

(3) Lyndon, H. (1995). Conceptual Mediation

(4) Baxter, P., Lyndon, H., Dole, S., Cooper, T., Battistutta, D. & Blakeley, J. (1997). Skill correction & accelerated learning in the workplace. An experimental field trial of the Conceptual Mediation Program and Old Way/New Way

(5) Dawson, C. & Lyndon, H. (1997). Conceptual mediation: A new perspective on conceptual exchange

(6) Rowell, J.A., Dawson, C.J. & Lyndon, E.H. (1990). Changing misconceptions: A challenge to science educators

(7) "Hot" and "Cold" Procedures used in Rowell, J.A., Dawson, C.J. & Lyndon, E.H. (1990)

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ABSTRACT

This thesis presents a new theory and a new method of cognitive change and reports on their practical application in the "mediation" between conflicting habits and/or skills and between conflicting concepts in science education. The term, mediation, is here used to mean that an individual consciously attempts to bring about a reconciliation between his or her conflicting habits, skills or concepts.

The theoretical perspective proposes that the well-documented learning difficulties experienced by science students and others arise as an outcome of the natural tendency of the mind to conserve prior learning in the face of conflicting new experience. It will be argued that this tendency is a universal attribute of human cognitive development, caused by the associated phenomena of both proactive inhibition and accelerated forgetting. In this dissertation, accelerated forgetting is contrasted with the normal rates of forgetting associated with the practice of concepts not in conflict with prior knowledge or experience. A new interpretation of a theory of learning and retention known as associative interference theory is presented. An attempt is then made to integrate the outcomes of various research programs within science education with the new theory.

Two studies providing significant support for the theory are described. The first study presents data confirming that the use of Old Way/New Way (a method for changing habits and skills) alters the rate of forgetting of new but conflicting skills from an accelerated to a normal rate of forgetting, and can subsequently facilitate skill mastery. The results of a second study, which involves the use of conceptual mediation with a whole class of students, shows that, for the majority of students, the accelerated forgetting of conflicting concepts is controlled, and that for these students conceptual change is achieved.

The development of a procedure for conceptual mediation is described both at a theoretical and a practical level. The results of an independent evaluation of its influence on the attitudes to the learning of mathematics and science amongst students at a public secondary school are also presented.

DECLARATION

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my dissertation, when deposited in the University Library, being available for loan and photocopying.

30/3/2000

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1 INTRODUCTION

Science educators have shown a great interest in the pre-scientific, everyday understanding of phenomena that students bring to science classrooms. Of particular concern has been the fact that such pre-scientific understandings are often difficult to replace with scientific views. While students often appear to have learned the scientific view, it is well documented that over time they frequently revert to their original explanations of phenomena. The identification of students' prior knowledge has been a major focus of research in science education, as has been the ongoing development of methods for better developing and understanding the scientific view. The extent of the literature in this area is considerable. Wandersee (1992) noted that there were more than 2,400 studies, many consistent with the view that:

> Children do have pre-scientific views–often at variance with those of today's scientists and they cling to such views quite tenaciously.
>
> (Wandersee, 1992, p. 427)

It has also been noted that apparently successful students of science, that is those who are able to pass examinations and write meaningful essays, and even university graduates conducting research, are nonetheless prone to particular and persistent misconceptions (Pines & West, 1986). Their apparent success in some aspects of their science understanding raises the question as to the nature of the transferability of particular scientific knowledge.

By 1994, Pfundt & Duit reported that 3448 studies had been completed with the data collected showing that:

> the main emphasis has been given to investigating student's conceptions and...the development and empirical evaluation of new teaching and learning approaches has been given substantial emphasis, however with a certain delay.
>
> (Pfundt & Duit, 1994, p. xxiv)

Nevertheless it is clear from Matthews (1995) that this research, with its predominantly constructivist epistemology, and despite its great quantity, has contributed "precious little learning theory". Also, as White (1994) has said, there has been just as little advice on how to teach the various topics researched under the alternative frameworks banner.

1.1 Continuity and Change: What is the Norm?

Conceptual change of both a normal and of a revolutionary kind (Kuhn, 1962) is inherent in the notion of progress in science and in the progression of individuals' scientific knowledge. It is then more than justified that we should interest ourselves in the associated phenomenon of conceptual continuity. It is clear that resistance to change does not occur within a conceptual vacuum. Some form of experience that creates dissatisfaction with the status quo and some feeling that signals the need for change are clearly necessary. It is widely believed that the readily observed resistance to change is simply problematic rather than being the norm.

Gunstone (1988) noted five consistent outcomes of research into what has been termed "children's science" (Gilbert & Osborne, 1980; Gilbert, Osborne & Fensham, 1982), findings that are still relevant today.

(i) Students come to the learning of science with their own way of understanding the world. This view of the world, derived predominantly from experience rather than from formal instruction, is thus perceptually driven rather than conceptually driven. Driver, Guesne & Tiberghien (1985), for example, use the term "conceptual spectacles" as a metaphor to describe this observation. Science is, however, in large part, a creative cognitive activity that deals with the construction of conceptual models to account for what we cannot directly perceive.

(ii) Not only do students hold personal views but it would also appear that there is a degree of commonality between students in these views. This observation has even led some to draw parallels between the history of the development of science as a cultural phenomenon and the difficulties experienced by students in their scientific development. Driver et al. (1985), however, warn against pursuing this intuitively powerful line of thought. There are, they state, in children's science "only a few features in common" with real science and a certain lack of "coherence" in children's naive views. This point, however, is not presented as an argument against the search for what Garcia (1987) refers to as an "invariant quantity", common to both the views of scientists and non-scientists:

> If it is true that we may appeal to psychology in order to understand the development of science itself, i.e., the development of the human cognitive system, it means–and this is the hypothesis–that there are common

> mechanisms underlying both individual development and the development of science. (Garcia, 1987, p. 128)

In accounts of the history and the sociology of science we find many cases of conceptual conflict which took significant periods of time and great intellectual effort to resolve. An interesting example is provided by Garcia (1987) on the discovery, by Clausius and Thomson, of the principle of conservation of energy, a finding that followed from the implications of an experiment conducted by Joule. Joule's relatively simple experiment of measuring the amount of heat produced by the mechanical agitation of water eventually led to major conceptual restructuring of the accepted theory of thermodynamics. At first Joule's experiment attracted little interest and was, Garcia tells us, given an unfavourable review by the Royal Society, probably by Faraday. It seems from Joule's own account of the incident that had it not been for the intervention of Thompson the new theory would have passed without much comment or interest. Thompson, however, was perplexed by the matter and found in Joule's work a major contradiction which troubled him "for the next couple of years". We may draw from this observation (and there are many more such examples in historical science literature) that the variable of intelligence does not account for the problems of conceptual change. The intelligence of scientists of the status of Joule and Thompson is not in question. The natural course of conceptual change is, as history shows, distinctly protracted.

The interesting question is: what psychological variable could be at work here? And if readily identified, could it be controlled in order to facilitate conceptual change, if not in scientists themselves, then perhaps in students of already established science?

(iii) Gunstone noted that there also appears to be a "remarkable" consistency within age groups and across nationalities with regards to children's science. As to the question raised earlier: "Continuity or change, what is the norm?" it appears that when it comes to science education, it is the norm for students to be primed for conceptual confusion and for the continuity of their prior beliefs.

(iv) Some individuals are observed to hold two or more conflicting views which they, often unconsciously, move between. The cueing effect of an anticipated and structured situation such as a test of scientific understanding may lead to the presentation of the accepted scientific view. The alternative personal and conflicting view however, Gunstone tells us, is "often retained to interpret the world".

A simple cue dependency or perceptual compartmentalization of knowledge may be viewed as a means of preventing inner confusion and its attempted resolution, and can as such, be viewed as evidence for a lack of genuine understanding. With many students of science, such confusion is readily apparent. It will be argued that a state of confusion is a necessary, though not sufficient, stage in the process of conceptual change. A fuller exploration of this proposition is presented in following chapters.

(v) For many students their personal views are not changed by conventional approaches to the teaching of science. It appears that students resolve the confusion caused by the teaching of new but conflicting scientific concepts by reverting to their prior beliefs. There exists a powerful belief or hope that improved teaching techniques will eventually lead to conceptual change. Consequently, a major direction in the research has been the analysis of teaching strategies with the

associated development of improved teaching methods. There has been a move from the naive conflict approach to conceptual change (Karmiloff-Smith & Inhelder, 1975) to the co-operative debate approach adopted by Rowell & Dawson (1985). We have also seen the rise of interest in metacognitive programs which seek to provide conceptual aids for students in taking responsibility for their own learning (Osborne & Wittrock, 1985; Baird, 1986, 1998; Baird & Mitchell, 1986; White & Gunstone, 1989).

A concern raised here however is that a plausible psychological theory of conceptual change has not been proposed by constructivists to support their curriculum developments. As White & Gunstone (1989, p. 578) point out:

> Leading theorists who have written about changes in knowledge include Ausubel (1968) and Piaget (1971)...Unfortunately, neither theorist provides clear procedures for promoting these changes.

The constructivist notion that the inter-relationship of teacher and student knowledge depends to a significant extent on the students' prior knowledge, cannot be proposed as a theory in itself. Presented on its own, this is only a statement of empirical fact. As such, it is not sufficient as a basis for proposed or implied changes to the way science education is or ought to be carried out. Any attempt at model or theory building within science education must of necessity take into account the psychological nature of conceptual change (Dawson & Lyndon, 1997). It is essential then that a comprehensive psychological theory of conceptual change be developed if science education is to remain progressive. Such a theory is developed and presented in this thesis.

The perspective offered by Luria (1979) in his attempt at unifying the neurological and psychological sciences is informative in this matter:

> When considering human conscious activity...the focus of attention is on preserving its coherence while screening out all the extraneous features. The single most important factor to this entire process is attempting to make the data presented and retrieved a "closed system" (i.e., closed to all extraneous and confounding influences except the actual material preserved and coded). Corollary to this objective is avoiding any possibility of converting it over to an "open system" that allows one's immediate impressions and/or associations to confound the preservation of coherence and coding of the material memorized.
>
> (Luria, 1979, p. 280)

It is clear from Luria that continuity, both perceptual and conceptual, is essential for the coherence of conscious human activity. It is a central factor in normal human development and functioning. In this context then, a psychological explanation of conceptual change will necessarily introduce new issues and perspectives.

When science educators consider the problems of conceptual change, they do so in the knowledge that a complete analysis involves addressing fundamental aspects of epistemology, history, pedagogy, psychology and sociology. The contributions of this thesis to the understanding of conceptual change are predominantly pedagogical and psychological. This thesis will describe the development and the evaluation of a new method for conceptual change, conceptual mediation, and will present a new psychological theory of the learning and the retention of scientific concepts.

Learning, as a psychological construct, is operationally defined as the measure of the change that occurs in an individual as a result of either experience or practice (Hilgard & Bower, 1966). It is clear that any model of science education must take into account the relevant empirical facts of learning. Such a fact is that new and conflicting knowledge quickly becomes unavailable to the learner (Ebbinghaus, 1913; Underwood, 1957).

The perspective to be developed in this dissertation is that the well-documented learning difficulties experienced by science students arise as a natural outcome of the tendency of the mind to conserve prior learning in the face of conflicting new experience. It will be argued that the rapid unavailability of conflicting new knowledge, despite its practice, is caused by the operation of an accelerated forgetting mechanism. The phenomenon of accelerated forgetting (Underwood, 1957), when understood from Luria's perspective, is both a necessary and adaptive aspect of human cognitive development. It is my proposal that the mechanism of accelerated forgetting can be controlled by the use of a conceptual mediation procedure. This specific cognitive strategy will be described and its role in changing habits, skills and concepts will be explained.

Accelerated forgetting will be proposed as both the rate of forgetting associated with learning from experience and the rate of forgetting initiated whenever there is a conflict between what is already known and what is being taught. This accelerated rate of forgetting is in contrast to what is referred to as the "normal" rate of forgetting, associated with learning through practice of new concepts or skills which are not in conflict with prior experience (Slamecka & McElree, 1983).

The issue of what is to be considered normal in science teaching, that is, what we should expect from our didactic interaction with others, is significant because it is evident that the so-called problems associated with the continuity of personal knowledge are associated not only with science teaching. Similar concerns are raised in the many subject areas within formal education (Ausubel, 1968; Ashlock, 1992; Lyndon, 1989; Yates & Chandler, 1991). The issue of normality is also raised in the belief that, once we have reconsidered our basic assumptions about learning, we may expect and achieve conceptual change as the norm. What then are the limitations of conceptual change and how may we improve our current educational practices to facilitate the learning of essential scientific and other concepts?

1.2 The Influence of Prior Knowledge on Learning

The fact that conceptual change is difficult to achieve and the fact that the continuity of original conceptions is so prevalent have given rise in the field of science education to a number of theories and models of conceptual change. One early, though influential, example of a psychological model is the Generative Learning Model (Osborne & Wittrock, 1983, 1985). These authors argue that:

> The fundamental premise of generative learning is that people tend to generate perceptions and meanings that are consistent with their prior learning.
>
> (Osborne & Wittrock, 1985, p. 64)

Another example is the epistemological theory of conceptual exchange initially proposed by Posner, Strike, Hewson & Gertzog (1982), and later extended by Hewson & Thorley (1989). This framework, which has been greatly utilized by constructivist science educators for conceptualizing learning, incorporates a proposal for the development of a method of conceptual exchange. Conceptual exchange is distinguished from the more specific notion of conceptual change essentially in terms of the breadth of the changes seen as necessary by the authors. Conceptual exchange involves a major "revolutionary" shift in conceptual framework, examples being the shift from an Aristotelian to a Newtonian and from the Newtonian to the Einsteinian perspective (Hewson 1980, 1981; Pines & West, 1986). More recently Hewson, Beeth & Thorley (1998) have revisited the model and its applicability to teaching for conceptual change:

> The central concepts of the model are status and conceptual ecology. The *status* that an idea has for a person holding it is an indication of the degree to which he or she knows and accepts it: status is determined by its intelligibility, plausibility, and fruitfulness to that person. The idea of a conceptual ecology deals with all the knowledge that a person holds, recognises that it consists of different kinds, focuses attention on the interactions within this knowledge base, and identifies the role that these interactions play in defining niches that support some ideas (raise their status) and discourage others (reduce their status). Learning something, then, means that the learner has raised its status within the context of his or her conceptual ecology.
>
> (Hewson, Beeth, & Thorley, 1998, p. 200)

Central to these models is the idea that we are dealing with a substantial and conservative influence of some prior knowledge on learning. It is worth noting that the substantial beneficial effects on learning of relevant prior knowledge are well known, and these will not be directly pursued. In psychology, the opposite phenomenon of the decrement in the learning and retention of conflicting new knowledge is descriptively referred to as proactive interference and from an explanatory perspective is also referred to as proactive inhibition. The distinction between the terms interference and inhibition are relevant to an understanding of conceptual change and will be developed in Chapter 5.

Ausubel was one of the first educational psychologists to express concern over the phenomenon of students rapidly forgetting scientific ideas and to emphasize the relevance of proactive inhibition in understanding this significant problem:

> Why do high-school and university students, for example, tend to forget so readily previous day-to-day learning's as they are exposed to new lessons? The traditional answer...of educational psychology...has been...retroactive inhibition. But would it not be more credible to postulate that...(*it is*) proactive inhibition.
>
> (Ausubel, 1963, p. 24)

The commonly observed phenomenon of the conservative effect of prior knowledge on learning is understandably not new to philosophy, psychology or education. William McDougal in his book *An Outline of Psychology*, first published in 1923, illustrates this fact well:

> As all the world knows, since Plato and Herbart, each subject perceives only what he is capable of perceiving, only what he is prepared by nature and by experience to perceive.
>
> (McDougal, 1949, p. 245)

From an educational perspective we can readily trace the issue of the significance of students' prior knowledge to the pioneering work of Herbart (Adams, 1898; Compayre, 1908; Stout, 1888; Ufer, 1894). One of the world's great educators, he was also the first to combine psychology and education (Flugel, 1959). Herbart's fundamental non-associationist concepts of apperception, interest and equilibrium provided the conceptual seeds for the future development of cognitive approaches to psychological theorising (Lange, 1899). For Herbart, apperception was a process that involved:

> the assimilation and identification of a new idea by the mass of ideas already in the mind...Progress in knowledge is a process of apperception, the nature of the perceptions being determined by those which have gone before.
>
> (Curtis & Boultwood, 1964, p. 358)

Today's science educators would readily recognize Herbart's main theoretical framework as being of a constructivist nature in the same manner that Piaget's theory of equilibration is distinguished from other theorists by the central importance Piaget placed on constructivism, this being the concept of the active construction of knowledge by the individual, involving the processes of assimilation, accommodation and the lesser recognized mechanism of elimination (Piaget, 1983). This last mechanism is central to an understanding of the continuity of assimilatory structures

and will be discussed in detail in Section 7.3 of this thesis. Of historical interest is Herbart's concept of equilibrium, an idea similar to that which was to form the central aspect of Piaget's influential genetic epistemology (Piaget, 1970).

The construct of equilibrium, or conceptual continuity, is also central to the theory of cognitive dissonance developed by Festinger (Festinger, 1957). It is no surprise then that Festinger's theory has been tentatively proposed by some science educators as a potentially valuable addition to their models of conceptual change or exchange (Pines & West, 1986). Cognitive dissonance can be defined as:

> a state of psychological discomfort or tension which motivates efforts to achieve consonance. *Dissonance* is the name for a disequilibrium and *consonance* the name for an equilibrium. Two *cognitive elements,* A and B, are dissonant if one *implies* the negation of the other; i.e., if A implies not-B.
>
> (Brown, 1967, p. 584)

Festinger defines the term "cognitive element" very broadly as "any knowledge, opinion, or belief about the environment, about oneself, or about one's behaviour" (Festinger, 1957, p. 3).

It is of interest to note however that a critical review of the attempts to develop systematic theories of attitude change, based on the principle of cognitive consistency, says of Festinger's work:

> We will call it a theory, the dissonance theory, even though the principles involved do not stand in the kind of deductive relation that the word theory implies. Dissonance theory is actually a collection of loosely related ideas.
>
> (Brown, 1967, p. 550)

Posner, Strike, Hewson & Gertzog (1982) also note that there is no novelty in the notion that learning is influenced by prior conceptions. They trace this concept back to the work of the Gestalt school of psychology. Pines & West (1986) on the other hand, like McDougal (1949), trace such notions to the works of the Greek philosophers, and especially to Plato. It is perhaps sufficient at this point to note that the ideas shaping current analysis in the field of science education have a significant philosophical and psychological heritage, and they have been variously explored by those involved in this field. This serves to highlight the complexities involved in any attempt at constructing a model or theory of conceptual change.

A new psychological theory of and method for conceptual change, which are the contributions of this thesis to pedagogy and in particular to science education, begin in Chapter 2 with an examination of the psychological foundations of Plato's epistemology as described in the *Meno*.

2 A NEW PERSPECTIVE ON THE SOCRATIC METHOD FOR CONCEPTUAL CHANGE

The direct relevance of Plato's epistemology to modern issues of science education has been recently raised by Nola (1997) in a comprehensive critique of the place of constructivism in science and science education. It is not the purpose here to discuss the complex epistemological issues that are raised by Nola's criticism of "radical constructivism" (von Glasersfeld, 1988) and his invitation to contrast this viewpoint with Plato's epistemology. The purpose here is to speak directly to the issues of pedagogy, and especially of learning and retention, that are raised in this connection. Nola himself both asks and answers a relevant question:

> What has the venerable philosophical debate between realists and anti-realists about scientific knowledge to do with the teaching and learning of science? There is no necessary connection.
>
> (Nola, 1997, p. 57)

At the same time there is considerable interest in Plato's *Meno* because of its powerful and evocative metaphors which appear directly relevant to facilitating an understanding of the place of conceptual mediation in science education and education generally. As such it will be of value to explore the *Meno* and see what it holds for us:

> Down the ages the works of Plato have been an important source for educationalists. The *Meno* not only provides us with the first attempt at a definition of knowledge as opposed to belief but also, in Socrates' encounter with the Slave Boy, a model for pedagogy which is non-didactic and thus important for both constructivists and non-constructivists alike.
>
> (Nola, 1997, p. 58)

In the *Meno*, Plato raises many issues fundamental to an understanding of how knowledge is acquired and also provides us with an intriguing description of the psychological attributes of beliefs, opinions and knowledge. Within it, we find a metaphorical description of Plato's epistemology as attributed to Socrates, an account of Socrates' ideal pedagogy and, of particular interest, a metaphorical model of the central attributes of human memory.

2.1 The *Elenchus*: The First Phase of the Socratic Method

The dialogue between Meno and Socrates is ostensibly about the meaning of "virtue" and how it may be acquired. Its true purpose is to provide Plato with an opportunity to draw the reader's attention to significant philosophical issues regarding the differing attributes of belief *(doxa)* and knowledge:

> In the Meno we have the first appearance of *doxa* as an intermediate stage between sheer ignorance and knowledge, a concept which acquires great importance later in the dialogue.
>
> (Guthrie, 1956, p. 112)

It is moreover an attempt to have his readers share in the experience of *elenchus*, the dialectical strategy used by Socrates to create in his opponents, or students, a mental state beyond that of mere confusion, a state of awareness of self-contradiction, that he calls perplexity. During the dialogue, Socrates sometimes indirectly, but at other times quite openly, leads the individual to become consciously aware of a crisis in understanding of the particular concept being discussed. The individual is made aware of the existence of major self-contradiction and the feelings that are aroused are of the most powerful kind, feelings that demand a resolution of the inner conflict. This state of perplexity comes about as a result of Socrates' skilful use of probing questions based on his personal understanding of an issue or, as he sometimes professes, as a result of his lack of understanding of an issue.

For Socrates, perplexity is a necessary condition if an individual is to commence the process of the change of belief or opinion, to that of knowledge. (The terms "belief" and "opinion" are used interchangeably by Plato.)

> The value of the Socratic elenchus (as this part of the process is called) is that it (a) clears away the conceit of false knowledge and (b) instills the desire to learn as a natural consequence of coming to realize one's ignorance.
>
> (Guthrie, 1956, p. 108)

The dialogue between Socrates and Meno and, later, that between Socrates and one of Meno's attendants, a slave boy, illustrate the Socratic method in detail. Meno has come to Socrates seeking to debate the meaning of virtue. Socrates however, by way of strategy, begins his contribution to the dialogue by claiming that he no longer knows what virtue is, because he has become confused on the matter:

> Meno. No. But is this true about yourself, Socrates, that you don't even know what virtue is? Is this the report that we are to take home about you?
>
> Socrates. Not only that; you may also say that, to the best of my belief, I have never yet met anyone who did know.
>
> Meno. What! Didn't you meet Gorgias when he was here?
>
> Socrates. Yes.
>
> (Guthrie, 1956, p. 116, 71-C, D)

Gorgias was one of the most famous of the Greek sophists, a title given to learned, though practical, men who taught "rhetoric" for a living, this being the art of political communication and persuasion commonly practised in that age. For Sophists, debate on impractical philosophical issues was avoided, as for them it represented a waste of effort. From within this profession many interesting "paradoxes" were created to test the thinking skills of its students. Perhaps the most famous one is the "learning paradox" which asks the question, "If we can only learn what we do not already know, then how is it that we can know what to seek to learn?"

> Meno. And you still didn't think he knew?
>
> Socrates. I'm a forgetful sort of person, and I can't say just now what I thought at the time. Probably he did know, and I expect you know what he used to say about it. So remind me what it was, or tell me yourself if you will. No doubt you agree with him.
>
> Meno. Yes I do.
>
> Socrates. Then let's leave him out of it, since after all he isn't here. What do you say virtue is? I do ask you in all earnestness not to refuse me, but to speak out.

> I shall be only too happy to be proved wrong if you and Gorgias turn out to know this, although I said I had never met anyone who did.
>
> (Guthrie, 1956, p. 116, 71-C, D)

Meno is led into further elicitation or recollection of his understanding of virtue by Socrates' entreaty. Meno informs us that he has spoken on this subject on many previous occasions. He confidently provides what appears to be a fine description of a broad range of virtuous acts suitable for individuals of different gender, age and status in society.

The stratagem, used by Socrates to begin a process of conceptual change in Meno, is in today's language referred to as a process of elicitation, that is, a process that stimulates the reactivation of an individual's understanding of a concept.

Socrates and Meno then engage in a dialogue considering the "swarm of virtues", as Socrates puts it, provided by Meno. Socrates is ever ready to engage in dialogue and to apply his *elenchus* strategy. Consequently during the ensuing dialogue, Meno is made aware that there are significant contradictions in his account of virtue, and of the undesirable consequences of these for his line of argument. Meno is, however, sorely tried by the intense feelings aroused naturally by the *elenchus*:

> Meno. Socrates, even before I met you they told me that in plain truth you are a perplexed man yourself and reduce others to perplexity. My mind and my lips are numb, and I have nothing to reply to you. Yet I have spoken about virtue hundreds of times, held forth often on the subject in front of large audiences, and very well too, or so I thought. Now I can't even say what it is.

> In my opinion you are well advised not to leave Athens and live abroad. If you behaved like this as a foreigner in another country, you would most likely be arrested as a wizard.
>
> (Guthrie, 1956, p. 80, 345-A, B)

It is clear from this quote that Meno's emotional reaction to perplexity is considerable and this leads him to project his feelings onto the apparent source of his perplexity. Interestingly enough Meno does not identify the source of his perplexity as simply lying in the concepts themselves and their inner contradictions, but instead identifies the source as lying in Socrates. The powerful emotional impact of the Socratic *elenchus* upon the hapless individuals to whom it was directed, eventually had serious consequences for Socrates. We are told by Plato, in later dialogues, that Socrates is tried by the State, is sentenced to death and this leads Socrates to taking his own life. It is relevant then for teachers to note the contiguous nature of learning, in that if perplexity is present in a student, as anything or anyone directly associated with it may very well become tarred with the same emotional brush:

> Socrates. It isn't that knowing the answers myself, I perplex other people. The truth is rather that I infect them also with the perplexity that I feel myself. So with virtue now. I don't know what it is. You may have known before you came into contact with me, but now you look as if you don't. Nevertheless I am ready to carry out, together with you, a joint investigation and inquiry into what it is.
>
> (Guthrie, 1956, p. 128, 80-D)

In an attempt to distract Socrates from questioning him further, Meno attempts to challenge him with the then already well-known Sophist's learning paradox, an argument regarding the futility of any inquiry into what one does not already know:

> Meno. But how will you look for something when you don't know in the least what it is? How on earth are you going to set up something you don't know as the object of your search? To put it another way, even if you come right up against it, how will you know that what you have found is the thing that you didn't know?
>
> (Guthrie, 1956, p. 128, 80-D)

Socrates, however, replies to Meno's challenge rhetorically, with a description of the then commonly held religious belief that all humans possess an immortal and all-knowing soul. Importantly for our understanding of Plato's position on this religious belief is that Socrates is careful to distance himself from it, in that he argues he will not "take his oath" upon its veracity. This fact underscores the rhetorical purpose of the story, and it proves sufficient to dispatch Meno's diversionary tactic:

> Socrates. Thus the soul, since it is immortal and has been born many times, and has seen all things both here and in the other world, has learned everything that is. So we need not be surprised if it can recall the knowledge of virtue or anything else which, as we see, it once possessed. All nature is akin, and the soul has learned everything, so that when a man has recalled a single piece of knowledge – *learned* it, in ordinary language – there is no reason why he should not find out the rest, if he keeps a stout heart and does

> not grow weary of the search: for seeking and learning are nothing but recollection.
>
> (Guthrie, 1956, p. 129f, 81-C, D)

The real purpose of this story is to undermine the Sophist's attack on the value of effortful and wide-ranging philosophical thought. The Sophists' widely professed doctrine against the possibility of discovering new knowledge through philosophical analysis was, Socrates argued, a:

> contentious argument...It would make us lazy, and is music to the ear of weaklings...The other doctrine produces energetic seekers after knowledge.
>
> (Guthrie, 1956, p. 130, 81-E)

2.2 Eliciting the New: The Second Phase of the Socratic Method

Socrates, having managed to defuse Meno's argument, indicates his willingness to help Meno inquire further into the meaning of virtue. This represents a second phase in the Socratic method. The first phase of the method, the *elenchus*, seeks to achieve perplexity. The second phase attempts the resolution of the conflict through the presentation and elicitation of ideas new to Meno. These new ideas are supplemented with opportunities, albeit of a limited nature, for reflection, comparison and differentiation of the conflicting views. In this second phase, Socrates directs his questioning technique in a new way:

> His questions bring into the light of day ideas which were latent in the other's mind, or to use his own metaphor, they assist the delivery of ideas with which the other was pregnant.
>
> (Guthrie, 1956, p. 108)

First, however, Meno requires of Socrates a demonstration of his skills and understanding of the processes by which one may come to recollect, and thus repossess, an aspect of the knowledge intrinsic to one's immortal soul:

> Meno. I see, Socrates. But what do you mean when you say we don't learn anything, but that what we call learning is recollection? Can you teach me that it is so?
>
> Socrates. I have just said that you're a rascal, and now you ask me if I can teach you, when I say there is no such thing as teaching, only recollection. Evidently you want to catch me contradicting myself straight away.
>
> Meno. No, honestly, Socrates, I wasn't thinking of that. It was just habit. If you can in any way make it clear to me that what you say is true, please do.
>
> Socrates. It isn't an easy thing, but still I should like to do what I can since you ask me.
>
> (Guthrie, 1956, p. 130, 31-E)

He requests Meno for the assistance of one of his many personal attendants. A slave boy, born within Meno's own household, is chosen to assist Socrates in his demonstration. Meno is able to assure Socrates that the boy has had no formal education in geometry, although it quickly becomes evident that the slave boy already understands the concept of "area" and has some basic computational skills. After

Socrates assures himself that the slave boy is capable of conversing in the Greek language, the dialogue with him begins.

The task that Socrates sets out to achieve is to elicit, from the slave boy, the correct answer to the following question: "What is the length of the side of a square double the area of a given square the side of which is 2 metres long?" (Nola, 1997, p. 58). By most skilful questioning and significantly aided by the drawing of a progressive series of illustrative figures drawn in the sand, Socrates guides the slave boy along the required path of reasoning. The dialogue with the slave boy progresses quickly until, after two confident but incorrect responses, self-contradiction becomes evident to the slave boy, and he too enters a state of perplexity:

> Boy. It's no use Socrates, I just don't know.
>
> Socrates. Observe, Meno, the stage he has reached on the path of recollection. At the beginning he did not know the side of a square of eight feet. Nor indeed does he know it now, but then he thought he knew it and answered boldly, as was appropriate–he felt no perplexity. Now however he does feel perplexed. Not only does he not know the answer; he doesn't even think he knows.
>
> Meno. Quite true.
>
> Socrates. Isn't he in a better position now in relation to what he didn't know?
>
> Meno. I admit that too.
>
> Socrates. So in perplexing him and numbing him like the stingray, have we done him any harm?
>
> Meno. I think not.

> Socrates. Do you suppose then that he would have attempted to look for, or learn, what he thought he knew (though he did not), before he was thrown into perplexity, became aware of his ignorance, and felt a desire to know?
>
> Meno. No.
>
> Socrates. Then the numbing process was good for him?
>
> Meno. I agree.
>
> (Guthrie, 1956, p. 135, 84-B, C)

From this section of the dialogue, we can conclude that Socrates and Meno are now agreed that perplexity is actually a good thing, so long as one can identify what it is that one is experiencing. It would appear then that the mental states of confusion and perplexity are necessary conditions for achieving conceptual change, that is, a change in personal understanding. We must remember, however, that perplexity is a necessary condition for conceptual change not a sufficient one. Powerful emotions are aroused in the state of perplexity, ones which educators must be prepared to address:

> Socrates. Now notice what, starting from this state of perplexity, he will discover from seeking the truth in company with me, though I simply ask him questions without teaching him. Be ready to catch me if I give him any instruction or explanation instead of interrogating him on his own opinions.
>
> (Guthrie, 1956, p. 135, 84-D)

It can be argued that we have already caught Socrates "teaching" in the conventional sense of the word, for example in Socrates' use of related questions and progressive figures drawn in the sand. Without these it would, understandably, have been more

difficult for a naïve individual to follow the complex line of reasoning used. In a less significant example, in section 85-B, he aids the dialogue with the boy by giving him the technical name "diagonal" for the line in question at that point in time:

> Socrates. The technical name for it is "diagonal"; so if we use that name, it is in your personal opinion that the square on the diagonal of the original square is double its area.
>
> Boy. That is so, Socrates.
>
> (Guthrie, 1956, p. 137, 85-B)

This casual definition of an object is certainly distinct from any attempt to elicit the term from the slave boy's supposed intrinsic prior knowledge. In a more significant manner we also catch Socrates teaching when he defines the topic of the experience that the slave boy will have, and moreover by the very nature and choice of his questions. Had Plato permitted Meno a greater voice in this aspect of the debate the dialogue may have gone something like this:

> *Meno. Surely Socrates, I have caught you teaching this boy the name for this line, as you say it is a technical thing and not something he has provided of his own accord.*
>
> *Socrates. Ah Meno. You really are a rascal, I have sought only to expedite this matter and yet you trouble me with this trifle. Indeed, I have attempted to teach him this term, but as you will have time enough to see he will not remember this term on the morrow. It is only when he comes to understand the reason for the term that he will freely recall it. So now, let us return to the demonstration for, as you shall see, it is only through reasons that the recovered knowledge can be tethered and thus attain stability in our memory.*

Meno. Yes, very well then Socrates, continue with your demonstration for I seek to understand you better.

But now, let us continue with our considerations of the real *Meno*.

Socrates. What do you think, Meno? Has he answered with any opinions that were not his own?

Meno. No, they were all his.

Socrates. Yet he did not know, as we agreed a few minutes ago.

Meno. True.

Socrates. But these opinions were somewhere in him, were they not?

Meno. Yes.

(Guthrie, 1956, p. 137, 85-D)

Meno agrees with Socrates on his proposition that the slave boy appears to have new knowledge. The tone of the agreement, however, leaves us in doubt as to Meno's commitment to the view that this does represent evidence for intrinsic knowledge. Given that we have circumstantial evidence that Socrates was actually teaching the slave boy, the argument about implicit prior knowledge remains controversial. It is perhaps that the slave boy's new knowledge is just that and not the recovery of pre-existing or intrinsic knowledge. Perhaps what is intrinsic is the capacity to synthesize something new, something that was not mysteriously already in the mind waiting to be rediscovered, but none the less remarkable for being newly learned; a new idea built upon the elements of prior experience, novel experience and creative reasoning.

2.3 The Psychological Attributes of Knowledge and Belief

In the following selection from the *Meno*, Socrates metaphorically outlines the psychological attributes of knowledge and beliefs. Socrates also describes the process necessary for the progressive transformation of newly recollected ideas to the status of true opinion, and finally to that of knowledge:

> Socrates. At present these opinions, being newly aroused, have a dream-like quality. But if the same questions are put to him on many occasions and in different ways, you can see that in the end he will have a knowledge on the subject as accurate as anybody's.
>
> Meno. Probably.
>
> Socrates. This knowledge will not come from teaching but from questioning. He will recover it for himself.
>
> Meno. Yes.
>
> Socrates. And the spontaneous recovery of knowledge that is within him is recollection, isn't it?
>
> Meno. Yes.
>
> (Guthrie, 1956, p. 138, 85-D)

What does Socrates mean when he claims that the slave boy's newly aroused ideas or opinions have a "a dream-like quality"? The meaning of this claim becomes clearer in the following passage of the dialogue, where he emphasizes the necessity of the generalized practice of the "opinion" that the slave boy has newly recollected. By using the phrase "dream-like quality", Socrates reminds Meno and the reader of the common introspective observation that dreams are often rapidly forgotten. Dreams

are usually difficult to recall, and the act of attempting to describe or recollect them appears itself to interfere with the imagery and so further assists the forgetting process. We are not usually troubled by this natural phenomenon, however many people are troubled by a related phenomenon, that is when we sometimes forget, moments later, the names of people to whom we have just been introduced. Many people are genuinely perplexed by their apparent ability to readily remember faces but not so readily people's names. The direct relationship between these phenomena and that of the existence of an accelerated rate of forgetting (Underwood, 1957), the psychological cause of the "dream-like quality" of newly aroused ideas, will be pursued in some detail in Chapters 5 & 6.

Socrates is aware of the benefits of practice and emphasizes that any practice undertaken should not be of a simple repetitious nature. It should instead be of a varied and applied nature. Socrates tells us that if the slave boy were to practise his new "knowledge" in a correct manner, then it would lose its dream-like quality, and so become more readily, and more fully, remembered. The slave boy's knowledge would then appear as accurate as anyone else's knowledge. However, he goes on to say that this is mere appearance, and does not really amount to real knowledge. The slave boy, through this additional effort, would only develop a "true opinion" about the matter.

> Socrates. True opinions are a fine thing and do all sorts of good so long as they stay in their place; but they will not stay long. They run away from a man's mind, so they are not worth much until you tether them by working out the reason.
>
> (Guthrie, 1956, p. 154, 98-A)

From the above we can conclude that, although practice of newly formed beliefs will transform them in memory so that they will no longer have a dream-like quality, the long-term benefits of this practice are transient. The tendency of the human mind to forget what it has learned through practice alone is now well known. Almost all students, and certainly their teachers, are familiar with the phenomenon which has been referred to as the normal rate of forgetting (Underwood, 1957, 1964; Slamecka & McElree, 1983). This notion will be developed and contrasted with that of accelerated forgetting in the description of the theory of conceptual mediation in Chapters 5 & 6 of this treatise.

It is however the final stage of the process of transforming belief into knowledge that is the most significant of all, the process of tethering in understanding the newly formed and practised opinion:

> Socrates. That process, my dear Meno, is recollection, as we agreed earlier. Once they are tied down, they become knowledge and are stable. That is why knowledge is something more valuable than right opinion. What distinguishes one from the other is the tether.
>
> (Guthrie, 1956, p. 154, 98-A)

2.4 A Summary of the Socratic Method

So, to summarize Socrates' position, that which constitutes human knowledge or understanding has the quality of always being clear and stable in memory. New experience, however, is fragile as it is always subjected to a rapid rate of forgetting.

Practice of newly aroused opinion leads to the loss of the dream-like quality of memory for these ideas and gives the appearance of knowledge, but the real test of knowledge lies in the long-term stability of these opinions in the individual's memory.

We are told that it is necessary for true opinions to be tethered in memory and hence for them to develop the attribute of stability of recall that is seen as a fundamental quality of knowledge. The most significant aspect of the transformation of true opinion into knowledge lies in the *reasons* that form the tether!

It would seem by this that Socrates is making strong distinctions between belief, true opinion and knowledge. The distinctions are based on the empirical attribute of the stability of knowledge compared to that of beliefs or even of true opinions. Newly aroused beliefs have a transient dream-like quality; practised beliefs or, in other words, true opinions still have the characteristic of running away from the mind. It is not practice alone then that tethers knowledge, it is the reasons or, in other words, it is what the individual understands that determines the stability or otherwise of their beliefs:

> Socrates. Well of course, I have only been using an analogy myself, not knowledge. But it is not, I am sure, a mere guess to say that right opinion and knowledge are different. There are few things that I should claim to know, but that at least is among them, whatever else is.
>
> (Guthrie, 1956, p. 154, 98-A, B)

It is relevant to return now to Nola's critique of radical constructivism:

> Surprisingly Plato's tether of reasons goes almost unmentioned in constructivist accounts of knowledge: merely constructing beliefs is often regarded as sufficient for knowledge. By omitting the third condition for knowledge constructivists conflate the definition of knowledge ...with the process whereby a person comes to know. As the episode with the Boy illustrates, the process of eliminating errors and arriving at knowledge by employing reasons has constructivist elements. In contrast, however the definition of knowledge is not a process of constructing; rather it concerns the final product, a state of knowledge, which results from a properly constructed reasoning process.
>
> (Nola, 1997, p. 60)

In recommending Plato's epistemology Nola emphasizes that the *Meno* doesn't represent Plato's final word on knowledge. In the *Theaetetus* a further development of the concept of knowledge appears that ends somewhat inconclusively, as do many of Plato's other dialogues (Taylor, 1960). However, what is developed is a significant distinction between normative philosophical debate and the strictly empirical or descriptive nature of psychological inquiry. This leads to the important rationalist perspective on the impossibility of a purely descriptive, psychological criterion for knowledge (Taylor, 1960). I will at this point then leave to philosophy the task of evaluating the ultimate truth of any claims to knowledge and be satisfied in this work to present an account of certain psychological attributes of our personal understanding of the world.

2.5 Issues Arising from the *Meno*

Socrates applies his method to his opponents or his students in a deliberate sequential manner in order to facilitate the individual's accomplishment of conceptual change. In every case, Socrates attempts to bring about a change in the individual's understanding, never attempting to simply provide information that can be learned by rote. He has no doubt that learning by rote without understanding can and does occur, and further that this goal is believed to be a sufficient and pragmatic one by the group of educators known collectively as the Sophists. Sophists were sceptical that philosophy could ever attain its goals and were opposed to its practice on the grounds that it was too effortful a task and hence a waste of time. There were, they effectively argued, cities to rule, wars to be waged, a multitude of businesses to be run, and lives to be lived to the full. It is within this context that Socrates and his group of students, which included Plato, saw their purpose as being true guides to wisdom and facilitators of change through the practice of rigorous philosophical debate.

The following phases and contingent mental states can be identified in the Socratic method for conceptual change, that is, for a change in one's understanding:

(i) The *elenchus*, or first phase of the method, is a dialectical strategy aimed at creating a mental state of perplexity in an individual.

(ii) Two main conditions must be realized for perplexity to be aroused. The first is the deliberate elicitation of the individual's understanding of the concept or

concepts involved. The second is that the individual must then become consciously aware of the existence of conceptual conflict as distinct from simply developing a dissociated feeling of confusion.

(iii) Perplexity is a necessary but not sufficient condition of change. It represents a state of awareness of conceptual conflict and naturally motivates a need for some resolution of this conflict.

(iv) The primary motivation, however, is simply for the elimination of the state of perplexity itself. The individual is motivated to re-establish conceptual equilibrium or continuity. This is clear from the fact that any newly aroused change in belief is not stable in the individual's memory, as it is always subject to forgetting.

(v) A second phase of this dialectical process, a collaborative process of investigation and inquiry into the nature of the problem is necessary. Socrates himself refers to this phase as "mental midwifery". The metaphor emphasizes the difficult nature of changing beliefs into knowledge and the need for assistance in this process.

(vi) Assistance is required for the "birth" of ideas that will form the tethering reasons necessary for the changing of belief or true opinion into knowledge. Such assistance is through opportunities for reflection, comparison, and differentiation of conflicting conceptions generated by the *elenchus*.

(vii) The main cognitive attribute of a newly aroused belief is its dream-like quality, which means that it is forgotten very quickly.

(viii) Generalized practice of such beliefs will give the appearance of stability. Despite such practice, a belief, even if it is objectively a true belief, will be forgotten, albeit more slowly.

(ix) The main attribute of knowledge is that it forms a stable memory. It is not subject to either a fast or slow rate of forgetting. The cause of this stability is that knowledge is tethered in the mind. The reasons for holding the belief itself are the substance of the tether.

A contemporary psychological explanation for the empirical phenomena so evocatively described in the *Meno* will be offered in the description of the theory and practice of conceptual mediation. The description of the Socratic method in the *Meno* fails to address fully the resolution of perplexity. Perplexity must not be left to itself, or otherwise any newly aroused knowledge will vanish like a dream. There is clearly something else that is required, and in the fact that Socrates refers to reasons as the substance of tethers, we come close to a viable solution to this problematic phenomenon of human learning and retention.

An additional necessary condition for transforming true opinion into knowledge will be proposed. It will be argued that this condition is the active conscious process of conceptual mediation and how this is to be achieved will be described in detail at both an empirical and a theoretical level.

3 THE EFFECTIVENESS OF REMEDIATION

Although conventional remediation produces significant short-term improvements in students' attainments it is evident that these, like many of the concepts taught to science students, are often not maintained in the long term. Within the literature and in practice, remediation is not distinguished from good teaching practice. There is a general belief that "remedial strategies involve no new principles of instruction" (Adelman & Taylor, 1986, p. 162) and thus "conventional remedial practice is not distinguishable from good teaching practice" (ibid., p. 176).

This belief is challenged here on both theoretical and methodological grounds. A reinterpretation of existing research on the phenomenon of proactive inhibition within the context of transfer of training will be proposed, and significant implications for the concept of learning difficulty are drawn. It will also be suggested that current methods of remedial practice are directly responsible for many of the symptoms associated with students' learning difficulties. An effective methodology having significant implications for curriculum design is described in Chapter 4.

3.1 Is Remediation Ever Effective?

There is ongoing concern within professional groups involved in therapy and remediation as to the effectiveness of their methods. Whereas short-term gains are

observed, the long-term effects of remediation are often impermanent. In a landmark study of the effects of remediation, Collins, who was at the time the Senior Educational Psychologist for Londonderry, Ireland, concluded that:

> remedial work may be likened to an overlapping teaching situation without essential change and, therefore, that it brought no useful positive forces into pupils' lives. (p.99)...The children in the research sample were given concentrated doses of what they had apparently missed in school. But this telescoped re-teaching was not effective.
>
> (Collins, 1961, p. 105)

Collins continued to be concerned by the growing evidence that re-teaching is ineffective and went so far as to denounce remedial educational practices as a "hoax" (Collins, 1972). Collins has attributed the ineffectiveness of remedial practices to a combination of developmental factors in the children reviewed and to the prevalence of the use of drill, or in other words, rote practice.

> Pupils who are not working up to their abilities need explanation, not exercise. They require attention to meanings, relations and understandings, not flash card drill. (Collins, 1961, p. 105)

His solution, however, to the problems he identified, is to propose radical changes to the institutional nature of schools (Collins, 1972), rather than to address the issue of why it is that re-teaching is so clearly ineffective. Nor does he give consideration as to how his own recommendations of learning for understanding can be realized in a new approach to remedial practice.

Sewell (1982), challenges Collins' emphasis on the role of maturation or a student's readiness for re-instruction. In its place, Sewell emphasizes issues of educational leadership by school principals, the value of intervention by experienced and well-intentioned teachers and the need for ongoing support within the curriculum for students once remedial education is withdrawn.

In his study Sewell reported that progress of the remedial students declined once they no longer attracted remedial support. This is in line with the results obtained by Collins. However Sewell noted a significant difference from Collins in that some students maintained their level of improvement compared to what he called a "borderline group". This group of students was borderline in terms of its attainment levels and was not of immediate concern to their teachers. As such, they were not referred for remedial support. They cannot however be thought of as a properly constituted control group, and Sewell accepted that his results on this issue were open to question (Sewell, 1982, p. 27). Whereas in Collins' rigorously conducted study experimental groups received remedial treatment for six months, Sewell's students were maintained in their remedial groups until it was felt by their teachers that they would cope, a somewhat subjective decision. Some students were maintained for twelve months, some for two years and others for three years. It is interesting to note that students maintained for one year showed the most rate of progress while those maintained for two years showed the least rate of progress (Sewell, 1982, p. 28f).

Sewell's conclusion that "considerable progress could be made by low expectation pupils in remedial education" (ibid., p. 30) is not fully supported on the evidence presented. Sewell himself indicates that:

> It is arguable that these figures show that there are groups of children who fail to benefit even when they are taught by staff who are generally conceived to be especially competent and child orientated.
>
> (Sewell, 1982, p. 29)

The prevalence of methodological flaws in this area of research is understandable given the complex nature of education. Adelman & Taylor (1986) undertook a review of research published between 1965 and 1980 that followed the progress of former remedial students. Of some thirty articles only thirteen were considered reviewable, the others being rejected on methodological grounds. Eight of these studies report negative results, two are equivocal and three report good long-term outcomes. Adelman & Taylor cite Spreen (1982) who had reviewed numerous long-term studies on the effectiveness of remediation and had found that:

> most children who are referred to a clinic for a learning or reading disability do not catch up. In fact their disability is likely to become worse with time. In addition, remedial instruction has not been shown to improve the prognosis for these children.
>
> (Spreen, 1982, quoted in Adelman & Taylor, 1986, p. 76)

There have been some attempts to balance this pessimistic view on the outcomes of remediation by an appeal to experimental design. It has been argued that these negative outcomes are often due to major faults in the processes of data collection, for example, the lack of appropriate control groups, and perhaps, most importantly, to the preconceptions of the investigators influencing the types of outcomes measured (Adelman & Taylor, 1986).

There is then convincing evidence that although students initially show improvement in their basic skill levels these are, for some reason, impermanent. This dilemma represents a major challenge to all educators. While some researchers argue about whether it is experimental design or students' maturation that is the main factor explaining the ineffectiveness of remediation, it will be argued in this thesis that it is the way remedial teaching is conducted that accounts for the impermanence of students' learning.

3.2 Maintenance, Generalization and Transfer

The failure of conventional remedial methods to have long-term benefits has now become incorporated within the concepts of maintenance, generalization and transfer (Adelman & Taylor, 1986; Ashman & Conway, 1989; Cole & Chan, 1990). There are, however, significant differences in the use of these terms by these authors.

For Cole & Chan, the concept of maintenance generally refers to the issues of the long-term retention of information and the ability to recall it. It is understandable to argue that:

> the teacher who puts a new method into place wants to be sure that its effect on learning is likely to last and that the learning achieved by students will be retained for a long time.
>
> (Cole & Chan, 1990, p. 20)

Ashman & Conway present a similar view:

> It seems important that children integrate the newly acquired information into their knowledge bases (or schemata) where it can be retrieved as desired and applied when appropriate. The storage of knowledge for future use refers to maintenance.
>
> (Ashman & Conway, 1989, p. 72)

However, the concept of maintenance, while being descriptive and reasonable at an intuitive level, is actually a value-laden concept when referred to remediation. The concern is whether or not the student will retain what is newly taught to them by the teacher as distinct from what they already know. It is driven by the empirical phenomenon of frequent difficulties in students' recalling a newly acquired but conflicting concept. What concerns the educator clearly, is the need for change in, for example, letter formation, a reversal, the spelling of a word, an algorithm or perhaps in more complex concepts such as mass and volume. What concerns the child is trying to cope with the demands of the change process.

A child, for example, who has developed a tendency to spell words the way they sound may spell the word "said" in a number of different ways. Given that it could be "sed", "sead", "siad", "seade" or some other sound/letter combination, the teacher will be led to present the child with the correct spelling and encourage its practice. The common experience of remedial teachers however, is the failure of the child to maintain the correct spelling. The notion that a student has failed to maintain a piece of information or has failed to maintain a skill over time must be placed within a non-judgmental framework. The evidence implying that something has not been

maintained, for example, that the student has not recalled the correct spelling of "said" is often the performance of something that *has* been maintained. The student has recalled his or her *own* way of spelling that word. What has been retained is of course the student's original way of spelling that word. The inherent bias in viewing the problem from the special educator's perspective is not particularly conducive to acknowledging the importance of personal knowledge as a relevant variable in the process of change (Ausubel, 1968; Lyndon, 1989). These intuitive definitions and desired outcomes are not in themselves sufficient to enable us to distinguish maintenance from a number of important and related phenomena. These are: the normal rates of forgetting of newly acquired information (Underwood, 1964, 1972; Slamecka & McElree, 1983) and the important phenomenon of accelerated forgetting (Underwood, 1957). Accelerated forgetting, it will be argued, arises as a consequence of conceptual conflict caused by remedial methods that are analogues of the negative transfer and the proactive inhibitory paradigms used in verbal-learning research. These concepts and issues will be fully developed in later sections of this thesis.

That students continue to perform incorrectly in the face of remedial education is important evidence of the powerful influence of prior knowledge on memory and performance. It is possible to avoid the difficulties raised by the use of the term maintenance through the appropriate use of the existing terms generalization and transfer. Further analysis of these two concepts will be necessary in order to achieve a satisfactory conceptual framework regarding the facilitation of the process of change.

3.3 Transfer and Generalization

An observation made by Collins in respect of the reading performance of his experimental group is that:

> the results suggest that remedial reading does produce immediate improvements in word attack, but there is less transfer and generalization of these skills than has formerly been believed.
>
> (Collins, 1961, p. 59)

The issues of transfer and generalization are fundamental concepts with long histories of research. They arise however from very different psychological paradigms. Despite these differing perspectives there has been an active assimilation of these terms into general discourse on the effects of learning on change.

The concept of transfer originally derived its meaning from research into the transfer of training, that is, the influence of one learning task on the learning and recall of another. Research in this area was divided into the study of facilitative factors in recall, that is, positive transfer, and inhibitory factors associated with recall, that is, negative transfer. The initially broad conceptualization of transfer referred to that which was "carried over" from one experience to another. The notion of the positive transfer value of some learning arose from the "faculty psychology" paradigm:

> Faculty psychology was explicitly developed by Christian Wolff in the eighteenth century. It emphasized that individual differences are developed and that people are born virtually equal. The central thesis of

> faculty psychology is that each person has a single unitary mind; this mind has several specific faculties, such as memory, will, and reason; and the strengths of these faculties depend upon the degree to which they are exercised. Within this pattern of thinking individuals might be construed as the result of different amounts of exercise of the various faculties of the mind.
>
> (Bigge & Hunt, 1962, p. 112)

The faculty perspective was used to support the belief, held by many educators of the day, in the improvement of mind through formal discipline, for example, through the teaching of classical subjects such as Latin and geometry. The challenge to these notions begun by James (1890), and extended by the work of psychologists such as Thorndike and Woodworth, led to a closer scrutiny of the phenomena associated with transfer (Andrews & Cronbach, 1969). For Thorndike the likelihood of positive transfer was dependent upon the presence of identical elements in both the original and the new learning situation. A protracted debate, on the nature of learning and its transfer carried on by Thorndike and Judd saw the concepts of transfer become intertwined with that of generalization. For Judd, a generalization was seen as an understanding of the relatedness of events or ideas permitting future experiences to be more effectively managed. For Thorndike it represented the more specific issue of similar circumstances stimulating the appropriately connected responses from the individual (Bigge & Hunt, 1980).

Later behaviourist perspectives equated the concept of transfer with that of stimulus generalization and also made a distinction between stimulus generalization and response generalization. In stimulus generalization, an existing response is produced

to a new stimulus, usually similar to the original stimulus. With response generalization, the individual produces a number of differing responses to the same stimulus.

Response generalization has a dual character in that it can be both adaptive and maladaptive. In its maladaptive guise, response generalization presents as a state of confusion. More than one response is presented to the same stimulus. For example many students have experienced having more than one way of spelling a word and not being sure which is correct. It is in the area of problem-solving that we find the adaptive side of response generalization. When confronted by a problem it is usually better to be flexible in our responses. To have more than one response to a difficult problem may, in fact, lead to the resolution of that problem.

Ashman & Conway present a cognitive perspective of special education, and describe generalization as:

> the transfer of learning from the training environment and or the task to other tasks that are conceptually distant from those used in training.
>
> (Ashman & Conway, 1989, p. 72)

This is similar to Cole & Chan's perspective. In their review of methods and strategies in special education they talk of both generalization and generalizability:

> Generalizability refers to the degree to which the learning will be used outside the setting in which it was acquired.
>
> (Cole & Chan, 1990, p. 20)

Transfer, as a concept for these authors:

> refers to the extent to which the learning will be adapted and applied to other areas, domains and settings.
>
> (Cole & Chan, 1990, p. 21)

There is then a considerable degree of overlap in the terms generalization and transfer as used by these and many other authors. There is however, no explicit distinction drawn between stimulus generalization and that of transfer of training. This degree of overlap of terminology is unwarranted and only serves to confuse the distinction between transfer and generalization. An attempt will be made in the next section to conceptually distinguish these concepts.

3.4 Positive and Negative Transfer

The concept of transfer has two dimensions, that of positive and that of negative transfer. It may be acceptable to equate stimulus generalization with the specific concept of positive transfer without too much loss in meaning, although this would involve a distinct narrowing of the traditional concept of transfer as carry over from prior learning. We cannot however also apply the same concept of generalization to the issue of negative transfer, as this would be contradictory. We do not speak of positive or negative generalization because generalization is not normally defined within the context of the influence of one learning situation on another. It is instead applied to the description of a natural phenomenon associated with learning and its

subsequent application by an individual, one that is influenced primarily by the similarity of stimulus conditions.

This point is made particularly clearly by the work of Pavlov in the field of classical conditioning. Here the phenomenon of generalization is noted as an inconvenience to the researcher who must first facilitate differentiation of the relevant conditioning stimulus from those stimuli to which a subject attends. It was noted in experiments on animals that often very dissimilar stimuli would evoke the same response. It was then necessary for these "sensory generalizations" to be extinguished. Pavlov described generalization and differentiation as complementary phenomena, which had to be taken into account during the conditioning process (Hilgard & Bower, 1966, p. 53).

3.5 Generalization or Transfer of Training?

If we then consider a situation where a change in concept or performance is required, that is, a response substitution in behavioural terms, how are we to describe this? Should this be described as a case of response generalization, as one of stimulus generalization or as a case of transfer of training? Where the intervention has been successful, we can speak of a positive transfer of training, and it would then be anticipated that the generalization of this change is likely. Where the intervention is unsuccessful, it may be best to describe the result as being due to negative transfer, rather than being due to a failure to generalize a new, though alternative, concept.

From a theoretical perspective, neither behavioural nor cognitive approaches posit generalization as being problematic, yet we find that speech pathologists and educators alike have claimed that they are regularly confronted by students who fail to generalize what has been newly taught (Ashman & Conway, 1989; Cole & Chan, 1991; Fey, 1988; Johnston, 1988; Kelly & Moore, 1989).

Concern regarding the impermanence of remedial intervention in the field of speech pathology has taken on major proportions. There it is referred to as a failure of the client to generalize the desired knowledge or skills. Fey (1988) expresses grave concerns for the future of the profession if the problems evident in this area are not taken seriously and a concerted effort made to resolve them. For Fey, no other problem presents "so many practical, theoretical and even ethical problems for the interventionist." (Fey, 1998, p. 272). Concerns therefore for the effectiveness of remediation, incorrectly expressed as a problem of generalization, are not limited to the educational profession:

> The practical problem of generalization is well known to all clinicians. Is there anything more frustrating than observing a child produce a new conversational act, language form, or sound pattern within a clinical context only to find that the behaviour is rarely or never produced elsewhere? This state of affairs occurs much more frequently than most of us really care to admit. But the problem will not just go away. The speech-language pathologist must deal with it on a daily basis. (Fey, 1988, p. 272)

There are two immediate problems which must be addressed. Firstly, applying the concept of generalization within a framework of conceptual change confronts the

same problem as was faced by the concept of maintenance. To say that a child has failed to generalize what has been taught must be put within the objective context of what the child is actually doing. If, in fact, the child is continuing to perform as he or she was before the intervention then the child is continuing to apply a pre-existing approach to a class of events. The child is in fact generalizing.

Secondly, it is commonly observed that children are able to generalize only one type of response, rather than another. For example they are able to spell the word "said" as "sed" consistently across a range of applications of the word in sentences, and yet fail to generalize an alternative response, that is, the correct spelling of the word. However, with regard to this problem, it is helpful to think in terms of negative transfer and proactive inhibition, that is, the influence of prior knowledge on the learning and subsequent recollection of a conflicting new response to an old stimulus. The child's prior knowledge, that is, in spelling the word "said" as "sed", affects his or her ability to learn and to recall the conflicting, although correct, response "said". Thus we could say that the child who is apparently unable to apply the correct alternative shows the effects of negative transfer and proactive inhibition, rather than a failure to generalize a particular alternative spelling.

A consistent trend in the definition of generalization emerges from a comparison of the various perspectives discussed above. The construct of generalization is commonly applied to the situation where an individual's responses are gradually made more responsive to new stimuli. Thus, generalization results in an increased flexibility of an individual in relationship to the influence of environmental stimuli. This outcome is referred to as stimulus generalization.

Accepting this emergent view of generalization raises an important question: Is the empirical problem facing educators and remediators one of a failure to achieve stimulus generalization? I do not believe that it is. For example, is the educator attempting the task of having the learner generalize an existing old response to some new environmental stimulus or, instead, encouraging the learner to produce new responses to an old familiar stimulus? I would argue that it is usually the latter!

If that is so, then educators are faced with the problems associated with the phenomena of negative transfer and proactive inhibition. These are well-known problematic phenomena associated with the process of change, a re-evaluation of which is necessary for a better understanding of conceptual change.

3.6 Transfer and Transfer Paradigms

A convenient vehicle for the study of transfer phenomena has been paired associate learning. The main experimental structure of such research programs are represented as follows:

Subject group	Task X	Task Y	Retest
Experimental	Yes	Yes	Yes
Control	No	Yes	Yes

Here the experimental group is provided with two word lists of paired associates to learn whereas the control group only learns one list. If on the retest of Task Y the experimental group performs better than the control group then we have operationally

defined positive transfer. If on the other hand the control group performs better than the experimental group then we have operationally defined negative transfer. An operational definition differs from a literary or dictionary definition in that it describes a means of measurement of the phenomenon concerned.

When issues of similarity of stimulus and response items in learning word lists are investigated it is usual for there to be two sets of paired associates for all subjects including those in the control group to learn. Under this condition of learning there is *no* similarity between stimulus and response items in the two lists presented to the control group subjects.

The AB-AD paradigm is the traditional negative transfer paradigm used to study the effect on recall of changes in the response items being used. A list of say twelve word pairs are learnt to a set criterion of recallability and this is then followed by the learning of a second list of word pairs, also to criterion. All stimulus items (A) of the second list of paired associates (AD) are the same as for the first list (AB). None of the first list response items (B) are included in the second list response items (D). Subjects are then tested immediately for recall of the AD list. An example of this would be:

A	**B**	**A**	**D**
dog	iron	dog	falcon
cat	steel	cat	hawk
rat	gold	rat	eagle

An important variation on the AB-AD paradigm is the AB-ABr paradigm. This experimental structure varies from the AB-AD form in that only first list response items are used during re-learning of the second list. This involves a re-pairing of first list stimulus and response items. An example of the AB-ABr paradigm is:

A	B	A	Br
dog	iron	dog	gold
cat	steel	cat	iron
rat	gold	rat	steel

We know from previous research (Underwood, 1966) that the degree of negative transfer and proactive inhibition, occurring under the AB-ABr paradigm is significantly greater than that occurring under the AB-AD condition. The paradigms produce these differential effects on transfer due to the fact that under the AB-AD condition there is only one identifiable inhibitory factor, that of forward association, whereas under the AB-ABr condition we can identify two inhibitory factors. These are the factors of forward and of backward association. However, as we shall consider in following sections of this chapter, it is the existence of three positive transfer factors under the AB-ABr condition, compared to only one positive transfer factor under AB-AD, that is of the greatest significance in understanding the process of change.

3.7 A New Interpretation of the AB-ABr Paradigm

Although a frequently used experimental paradigm, AB-ABr has been considered to be of analytic interest only. Underwood has stated that there are very few examples of this paradigm in the real world (Underwood, 1966, p. 507). However, the assumption that examples of the powerfully inhibiting AB-ABr paradigm rarely occur in the real world merits careful reconsideration.

It is true to say that a single set of paired associates may be an example of AB-AD yet they may equally well be an example of AB-ABr. It is only the consideration of the context within which a particular set is found that permits us to distinguish between the alternative paradigms. The guiding principle for discriminating between them is that under AB-AD, no first list response item may be present as a second list response item. For example, it is possible to describe a *single* set of paired associates such as dog-iron / dog-gold, as belonging to the category of paired associates AB-AD. One cannot however, exclude the possibility that we are dealing with a case of AB-ABr until the other sets of paired associates are fully described. The *context* within which a set of paired associates is located is crucial to the degree of inhibition that can be anticipated. When the above set of paired associates are found in the following context:

A	B	A	Br
dog	iron	dog	gold
cat	steel	cat	iron
rat	gold	rat	steel

we are able to appreciate that we are dealing with an AB-ABr paradigm and thus we can anticipate a higher degree of negative transfer than if the association occurred within the context of an AB-AD structure, for example:

A	B	A	D
dog	iron	dog	gold
cat	steel	cat	silver
rat	lead	rat	bronze

In view of the importance of context in identifying a single paired association as belonging to either one paradigm or the other, it is argued that we be cautious in relegating the AB-ABr paradigm to an analytical status only. There is next a need to explore whether this paradigm has a direct real-world influence on re-learning, particularly concerning its relevance in remedial practice.

3.8 Remediation, Negative Transfer and Proactive Inhibition

Remediation is somewhat similar to list learning, as it is the remedial teacher's task to teach new responses to old stimuli. We can thus anticipate that a teacher who is attempting to correct the performance of a child confronts at the very least an AB-AD paradigm. Thus the traditional approach to remediation faces the problem of either negative transfer or proactive inhibitory effects.

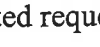
It is important to understand that negative transfer and proactive inhibition are fundamentally the same phenomenon. They are distinguished operationally only by the presence of a retention interval between the learning of the second list items and the testing of those items. Where testing for AD occurs immediately following the subject having learnt this list, the inhibitory effects measured are operationally referred to as negative transfer. However, where a retention interval (which may be hours or days in duration) is deliberately introduced between the learning of AD and testing for its recall, the inhibitory effects observed are operationally defined as being due to proactive inhibition. It is also important to understand that the degree of forgetting caused by proactive inhibition increases with the passage of time (Underwood, 1966).

3.9 Conventional Remediation and the AB-ABr Paradigm

Because teachers attempt to teach new responses to old stimuli, one can view the classical remedial setting as involving the negative transfer, AB-AD paradigm. This indicates that when attempting to learn the AD component, there is a known, natural inhibitory factor available (that of the forwards association of A to B) to account for the lack of success of conventional remediation. This factor alone would seem insufficient to account for the pervasive problems faced by students with so-called learning difficulties. There is however, due to the issues of meaning and context, the possibility that we are dealing with the more powerfully inhibiting AB-ABr paradigm. This paradigm has two natural inhibitory factors available; the forwards association of A to B and the backwards association of B to A, to account for the known problems associated with apparent learning difficulties.

Under laboratory conditions it is possible to ensure the learning of competing lists to a set criterion of recallability. In the real world of the remedial teacher the child has "lists" of paired associates already in place through prior experience or more importantly, developed over the course of remedial intervention.

Let us consider the following situation. A child has by experience come to use the reversed numeral two as his or her way of responding to the request to write that number.

Thus we have a self-initiated request, " Write two", and the response  .
At some future time the teacher responding to this "error" teaches the child the correct formation of the numeral. Thus we have the teacher-initiated request, "Write two", and the response  .

When taken together and presented in verbal learning paradigm form, these events represent an example of the negative transfer AB-AD paradigm.

A	B	A	D
Self-initiated "Write two"		Teacher-initiated "Write two"	

Let us next make the not too novel assumption that the child comes to associate these conflicting though meaningfully related experiences. We are then able to represent these experiences in paradigm form:

A	B
Self initiated "Write two"	S
Teacher initiated "Write two"	2

In the above we have two elements of an AB list. Let it now be that, in response to some future request by the teacher to write the number two, the child responds with a reversed numeral. On some later occasion let it be that the child independently writes the numeral correctly. Such events are common enough in the real world for this line of argument to have face validity. Let us now present these events and the previous example together in paradigm form. We would have something like the following:

A	B	A	Br
Self / "Write two"	S	Self / "Write two"	2
Teacher / "Write two"	2	Teacher / "Write two"	S

The above is an example of the AB-ABr paradigm rather than an AB-AD paradigm as second list stimulus and items are made up from the re-pairing of first list stimulus and response items.

Although remedial intervention may begin as a case of AB-AD (because of the intention of the teacher to change the child's response to a correct one), due to the phenomena of association and response generalization the paradigm rapidly changes to the more powerfully inhibiting AB-ABr form.

It is plausible to view the AB-ABr verbal learning paradigm as an analogue of conventional remedial practice. This paradigm does in fact predict major learning difficulties for anyone exposed to such an experience, these being readily observable in normal experimental subjects. Such learning difficulties are then the natural outcomes of *methodological variables,* not simply psychological ones.

Many other examples of students' errors can be readily placed within an AB-ABr paradigm form: the common b for d reversal problem, the spelling of words using sounds and letters e.g. "sed" for "said", idiosyncratic algorithms in mathematics (Baxter and Dole, 1990; Dole, 1991, 1993, 1995) and the prevalent and well documented misconceptions in science (Rowell, Dawson & Lyndon, 1990; Dawson & Lyndon, 1997).

It is evident that verbal learning research paints a gloomy picture for conventional approaches to remediation. As proactive inhibition is weakest immediately after the learning of the alternative and steadily increases to its maximum level thereafter, where a retention interval is introduced into the situation the degree of forgetting increases with the time interval. What is witnessed is in effect an accelerated forgetting of the newly taught information (Underwood, 1957). Fortunately, verbal learning research also points the way to a new and effective remedial approach.

3.10 Facilitating Positive Transfer for Effective Remediation

Because in conventional remediation teachers seek to teach new responses to old stimuli they initially confront a single inhibitory factor, that of forwards association.

As they continue the instruction, a second inhibitory variable arises naturally due to the processes of association and response generalization, that of backwards association. The remedial process has become an example of the AB-ABr paradigm form. Consequently, during instruction the child experiences considerable confusion and thus attentional problems. Following instruction, the child experiences accelerated forgetting as the child's proactive inhibitory mechanism operates to maintain the recallability of the original concept and/or its representation.

Conventional theories posit the existence of an unspecified learning disability to account for what are the well-known learning outcomes associated with the AB-ABr paradigm. These disruptive effects upon the recall of newly acquired associations are due to the fundamental and normal phenomenon of proactive inhibition. The powerful affective and interfering effects of normal proactive inhibition must be acknowledged and taken into account in our attempts to understand the problems associated with conventional remediation and so-called learning difficulty.

As noted earlier, research into the transfer of verbal learning was divided into the study of facilitative factors in learning and retention, that is, positive transfer, as well as the inhibitory factors associated with learning and recall, that is, negative transfer (Underwood, 1966). A comparison between AB-ABr, AB-AD, and the AB-CD control group in respect of variables associated with positive or negative transfer factors is worthwhile. A summary of these factors is presented in Table 1 below.

Table 1

Transfer Paradigms and Variables Associated with Positive or Negative Transfer

TRANSFER DUE TO	AB-AD	AB-ABr
Stimulus discrimination	+	+
Response discrimination	=	+
Response practice	=	+
Forward associations	–	–
Backward associations	=	–

SYMBOL	MEANING
=	This variable does not differ from the control group AB-CD
–	A negative effect when compared to the control group
+	A positive effect when compared to the control group

Source: (Adapted from Underwood, 1966, p. 525)

From this summary we are able to show that, if remedial activities were only represented by the AB-AD condition, then we would find only one positive transfer factor available, that of stimulus discrimination. Consistent with this paradigm it is known that students receiving remedial support are more likely to show signs of positive transfer within the remedial setting or simply in the presence of the teacher than when working independently. This can now be accounted for by the fact that the teacher or the room itself becomes a discriminating stimulus for that student and a particular response. Clearly, this is unsatisfactory, as there is little flexibility for either the teacher or the student under these circumstances. Consequently, removal of the discriminating stimulus leads to the recurrence of the original error. The student's resultant dependency on the teacher is an unfortunate outcome of normally effective teaching practices being used as the basis of remediation.

It is argued here that any remedial situation is better represented by the AB-ABr paradigm. We are then able to list three factors known to facilitate positive transfer. From the summary presented above, these factors are: stimulus discrimination, response discrimination and response practice.

Despite the fact that using this paradigm produces maximal negative transfer it also offers the opportunity to effect major positive transfer. At the same time that an individual is confronted by the greatest potential for negative transfer and, over time, for increasing proactive inhibition, we also have the highest potential for positive transfer. A method incorporating all three positive transfer factors offers significant opportunities to effect change. Such a method has been designed by the author and is known as Old Way/New Way (Lyndon, 1989, included as Appendix 2).

The method differs from conventional remediation in the importance placed on the individual's representation and elicitation of personal knowledge. In conventional teaching practice errors serve as a signal that the student does not know something. Consequently the response by teachers has been to teach or re-teach what they believe the student needs to know. This often involves considerable additional remedial time both in lesson preparation and in presentation. Unlike the conventional approach when using the Old Way/New Way method the error represents what the student does know. The teacher must first elicit the student's relevant personal knowledge and then with their consent engage them in a mediational procedure which incorporates all three positive transfer factors, stimulus discrimination, response discrimination and response practice.

4 EMPIRICAL ISSUES ASSOCIATED WITH CHANGING HABITS AND SKILLS USING THE OLD WAY/NEW WAY METHOD

Twenty-six years of experience with a method generally known as Old Way/New Way (Baxter & Dole, 1990; Dole, 1991, 1992; Baxter, Lyndon, Dole, Cooper, Battistutta, & Blakeley, 1997; Lyndon, 1989, 1995; Rowell, Dawson & Lyndon, 1990) in a wide variety of applications have successfully demonstrated its relevance in many areas of human learning where stable changes in habits, skills and concepts are required. Students' use of this methodology has been shown to have positive results for their conceptual development, skill acquisition, and self-esteem:

> Results of this study showed that O/N (*Old Way/New Way*) was superior in correcting students' systematic errors in computation and in promoting students' confidence and self-esteem; it was efficient in terms of teachers' time and effort, and students also showed increased conceptual knowledge of subtraction. After completing one O/N trial with each student the students were willing to work as a group, exploring the legitimacy of the subtraction algorithm with concrete materials, and building other subtraction knowledge and skills such as the use of addition to check subtraction calculations, how subtraction links to the real world, and the use of estimation skills to approximate answers. In an earlier study (Baxter & Dole, 1990), students exhibiting systematic errors in subtraction computation were randomly assigned to three treatment groups: conventional remediation, O/N, or the

> control group. O/N proved far superior in overcoming students' systematic errors over both the conventional and control groups.
>
> (Dole, Cooper & Lyndon, 1997, p. 13)

The methodology was, due to its widespread and successful use by teachers, formally approved as a remedial methodology by the South Australian Department of Education (Education Gazette, South Australia, 1983). The method has, according to Westwood (1997, p.162f), achieved the status of being a common-sense method for improving the spelling skills of students with special educational needs.

The method however is more than a simple corrective procedure for the improvement of spelling. The Old Way/New Way method is a cognitive program that has provided the majority of individuals who have learned the method with the means to control the process of change. This is an empirical statement, not a theoretical one. The reasons as to why this method is capable of producing rapid and permanent change in habits, skills and concepts is the subject of this dissertation.

The greatest challenge that this method creates is always a personal challenge. Indeed the biggest challenge to teachers is the challenge to stop over-generalizing their skills of teaching. Teachers generally understand that learning means change. However, they also need to understand that to change what is already known places special demands on the learner that far exceed the demands of learning something new.

4.1 Intuitive Beliefs

An intuitive belief is a type of habit, a collection of simple associations and/or ideas, generally based on the casual repetition of experience. The reasons for holding an intuitive belief are not necessarily capable of being easily articulated by their holders, as these beliefs arise through organizational processes that are not the subject of an individual's conscious awareness (Hasher & Zacks, 1979, 1984; Brainerd & Renya, 1990; Brainerd & Renya, 1993). An interesting example of an intuitive belief held by teachers that the author has regularly contended with in his work as a psychologist in schools, is that the errors produced by students in their schoolwork are idiosyncratic and random in nature. A number of early studies in the area of mathematics, such as Ashlock (1986), Brumfield & Moore (1985), and in spelling by children considered to have learning disability (DeMaster, Crossland & Hasselb, 1986; Lyndon, 1989) have found, however, that student errors were constructions that appeared regularly and consistently in their work rather than being random in nature. What was it then that led to so many teachers presenting with the same intuitive preconception about the nature of students' errors? Giving teachers holding such beliefs the opportunity to review each individual student's performance from the data available in their school work, and to then openly discuss their intuitive belief in the randomness of student errors, was found to be beneficial in changing this view. Some teachers, given this opportunity, have concluded that a combination of insufficient in-class time to evaluate students' errors and their cumulative experience of working with different classes, and thus many different individuals, was most likely the cause of their false beliefs.

The false premise, that students' errors are often simply random, leads via apparently rational processes to intuitive and yet incorrect theories about the nature of students' learning difficulties.

4.2 Error Analysis

The previous chapter outlined the significance of the AB-ABr paradigm for understanding the difficulties faced by someone wishing to learn a new but conflicting response to an old stimulus situation. From the broad perspective on proactive inhibition presented so far it is clear that a natural method of achieving change is available to any individual. Given that there are three positive transfer factors predicted by the research described above, the question raised is: what is the optimum strategy for following the recommended actions of stimulus discrimination, response discrimination and response practice?

This question has been answered at an empirical level through the development and extensive field trialling of the Old Way/New Way method. In an approach to "remediation" that was initially influenced by epistemological issues, that is, what it means for someone to know something and conversely what it means to describe someone as not knowing something, the following procedural outline for a remedial approach was prepared for use by teachers (Lyndon, 1979). It was entitled "Error Analysis", mainly in order to attract teachers' attention to the value of carefully evaluating the inner consistency of student's responses, rather than be concerned at an intuitive level by the apparent random nature of the errors.

Error Analysis

Errors are not produced by a random process, they are an example of what a child knows. A teacher or some other person can evaluate this knowledge as being wrong or incorrectly applied. The teacher, however, must not conclude from incorrect results that knowledge about the process does not exist; e.g., we do not conclude that the student doesn't know how to do it. The only conclusion that logically can be drawn is that he or she may know how to do it but that doing it in that particular way will lead to an incorrect result.

The child in many instances is not in a position to evaluate his or her own performance without assistance. This means that often the child is unable to know if his or her performances are right or wrong. He or she simply knows the procedure.

How to overcome the problem of incorrect knowledge

- It is important to understand that the child knows how to do it "wrong".
- Discover, by analyzing the errors and by talking to the child as required, how the child thinks about the procedure.
- Get the child to perform the task his/her way.
- Model the correct way of performing the task.
- Specify the difference between the two ways of performing the task.
- Ask the child to perform the same procedure three to five times, and ask him or her to specify the difference between their original performance strategy and the new performance strategy.

- The child then completes, for example, five similar examples in maths or for spelling puts the word into different sentences.
- Where an error occurs following a trial, do not simply state that an error has occurred, and do not simply "cross out" the work. Review the situation in the same way as for the original error analysis. In other words briefly go through the differences again.

(Lyndon, 1979)

The above procedure emphasizes the point that for "remedial" students to achieve a relatively permanent change in their habits, it is necessary for them to consciously elicit and re-elicit their own, although incorrect, way of responding during the progressive differentiation of the incorrect and correct performances.

During early trials of this approach the use of questioning as a strategy for eliciting the individual's own way of spelling a word, generally resulted in a positive response, which then permitted the presentation of an alternative or new way of spelling that word. It was, however, clear that the presentation of the correct information was a source of confusion for many students. In order to avoid unnecessary value-judgements by students as to the correctness or otherwise of their own spelling, the terms old and new were used to describe the alternative spellings. Furthermore, the recognition of confusion as a source of natural interference led to the use of the counter-intuitive learning strategy of re-eliciting the error.

The next step of eliciting from the student the correct alternative, however, did not resolve the confusion. Instead it initially created a state of heightened confusion or, in other words, a state of perplexity that required resolution. At first, students would

be effortful in their recall of the correct procedure, and would resort to checking back to the correct spelling, which was always available for them. It was noted that whereas differences between the alternative spellings may have been obvious to the teacher, this was not so for the student. The continued re-elicitation of both the old and the new spelling was associated with a progressive improvement in the ability of individuals to articulate differences between the competing alternatives.

What proved fundamental to the continued development of the procedure was that, most commonly, on the third differentiation between their old and new ways of performing, a fundamental change in both performance of, and satisfaction with using the new way, would occur. Before this, individuals would express dissatisfaction with the new way but after this, they expressed dissatisfaction with the old way. Before this, the individuals found it easier to write the word in their old way, and after this time they found it easier to write it their new way. Individuals expressed strong feelings about the continued elicitation and writing of the old way; for them it had begun to feel uncomfortable and now the word itself began to look "wrong". It was the consistency of this transformation of student affect and performance that led to a search for a theoretical model to account for these robust observations.

A relatively early psychological theory of learning and retention, known as associative interference theory, was found to be the most appropriate model in terms of its ability to predict outcomes, to describe events and, in great part, to explain them. Despite the theory's already well-known shortcomings, associative interference theory provides a valuable description of phenomena and concepts that

are relevant to an understanding and evaluation of this new method. A renewed interest in interference theory (Underwood, 1966, 1983) and the continued field testing of the Error Analysis procedure (Lyndon, 1979) had, by 1981, led to the development of the Old Way/New Way method (Lyndon, 1989). As this latter article provides some relevant background information to this treatise, it is presented as Appendix 1.

4.3 The Three Phases of the Old Way/New Way Method

To demonstrate the effectiveness of the Old Way/New Way method to groups of students, parents and teachers, it has been necessary to use examples that can be readily linked to their personal attempts at changing habits. The widespread occurrence of individual problems with English spelling, has led to this being the main exemplar used. It is however important to dissociate the exemplar both from the method and from the phenomena contingent on its use. This is necessary if we are to achieve a correct understanding of the process of change and how best to facilitate this fundamental process. The method is a reflection of the necessary conditions for learning when there is a conflict between prior knowledge and any new experience. It is important to emphasize that the method is not a program for improving spelling skills, or for improving one's ability to solve quadratic equations. It is a cognitive procedure that can be applied to anything that one has already learned and that one wishes to change.

The procedure of the Old Way/New Way method is the same irrespective of the intended content of the learning. There are three distinct phases to the method; these

are the initial preparatory phase, the mediational phase and the final application phase.

In the preparatory phase it is necessary, first of all, that both the old and new ways are identified. The learner must then elicit the old way and where necessary the relevant elaboration of this old way must be undertaken. Then comes the task of learning a new way and also actively differentiating between the competing alternatives. Sometimes this aspect of the process can take some time, depending of course on the nature of the new skill or concept involved.

It would, up to this point in the description, be apparent that there is not necessarily anything new here, in that it can be argued that this is simply a description of effective teaching practice. The next step in conventional remediation is for the individual to practise or apply this new skill or concept as broadly as possible. This "natural" approach to learning is based on the belief that practice of a new skill or the generalized application of a new concept always improves the retention of what is being learned. It is conceded that this belief is generally true of the relationship between learning, practice and retention of a new and non-conflicting skill or concept. However, this is not the case when we are attempting to change existing habits, skills or concepts.

After the preparatory phase, the next step is for the re-elicitation of the individual's old way. This is then followed by the elicitation or in other words the voluntary performance by the individual of the proffered new way. What comes next is perhaps the most significant aspect of the process in that the individual is required to

reflect upon the differences between the alternative courses of action or of thought. It is this process, of eliciting first the old way and then the new way, followed by their comparison and differentiation, that is called mediation.

The next important difference between conventional remedial approaches and the new procedure is that having completed the first mediation, the process is repeated. The individual re-mediates, that is, they re-elicit the old way and then the new way and again differentiate between them. This process is repeated fully five times and it is a characteristic of this method that individuals become more able to articulate similarities and differences between the competing alternatives as they progress through the mediational phase. Thus, the resulting differentiation develops in a progressive manner rather than arising from the rote learning of any relevant differences.

The third and final phase of this program is common to all other methods of teaching and learning. The application phase permits the individual an opportunity to generalize or apply their newly developed skill or concept.

It is the counter-intuitive elicitation and re-elicitation of the old way during the mediational phase of this method that sets it aside from conventional practice. Importantly for the method, what also sets it aside from the conventional approaches to remediation is that it successfully facilitates transfer of new learning when other methods do not. However this fact alone has not proved to be a sufficient reason for teachers to change their remedial practices. Reactions to the method have been varied, from that of seeing the program as a revelation (Lyndon, 1995, included as

Appendix 3) to simply experiencing consternation, or is that better described as perplexity?

4.4 Phenomena Associated with the Use of Old Way/New Way

Extensive use of this re-medial method over many years has brought about an awareness of certain robust phenomena. Of these, perhaps the most significant phenomenon is that of the affective attributes of the process of change:

> Man, however, does more than perceive his environment and think about it: he also *feels* about it. He feels elated, glad, sorry, grieved, angry or afraid. He feels excited or depressed. He feels in many other ways. It is difficult to separate feeling from thinking, and as a matter of fact, most of our terms which purport to describe purely the way we feel really describe ways of thinking rather than ways of feeling. Nevertheless, the facts remain that we do feel, and that there are different ways of feeling.
>
> (Dunlap, 1949, p. 4)

The issue of how students feel during attempts to assist their learning of new ideas and skills is of considerable importance to all educators, and given the counter-intuitive nature of scientific theories it is of particular interest to science educators. Prompted by Posner et al's (1982) emphasis upon learning being a rational process, the critical role of feelings in the process of conceptual change was raised in a short though challenging paper by West & Pines (1983):

> Is conceptual change a purely rational process? Is it appropriate to isolate the rational component of conceptual change while noting but ignoring the aesthetic or non rational?...We want to argue that non rational components are intrinsic to conceptual change in the individual, and that these should not be excluded in investigations of conceptual change.
>
> (West & Pines, 1983, p. 37)

Whilst acknowledging the importance of viewing learning as a rational process, West and Pines argue that there is a significant emotional component of conceptual change that had not been addressed by researchers:

> The process of conceptualization, be it intelligibility, plausibility, etc., taken separately or together, involves the learner's feelings. Does the student feel good? or proud? or satisfied? or alternately, bad? demeaned? dissatisfied? We are claiming that this is what learning *is*, and not simply motivational, attitudinal, or affective antecedents upon which learning depends.
>
> (West & Pines, 1983, p. 38)

One of the most prevalent empirical phenomena associated with learning in the face of conflicting prior knowledge is that when students are presented with "correct" but conflicting information, the correct information actually feels "wrong"! Students feel confused, and sometimes even frustrated, when they are shown to be wrong, and usually project these feeling states onto their hapless teachers. This is so even when they come to realize that they are, in an objective sense, actually incorrect. These feelings are major sources of disruption in all classrooms. The affective component of recognizing perceptual or conceptual conflict, which following Socrates we may

call perplexity, is a significant functional and motivational element in the continuity or change of an individual's errors. The outcome, whether continuity or change, it is proposed, depends entirely on the choice of method used conjointly by the teacher and the student to resolve the state of perplexity aroused by such conflict.

4.5 Demonstrating Confusion and Perplexity: The Stroop Charts

It is important for readers to personally experience the "power" of the emotional states of confusion and subsequent perplexity. This is readily achieved by undertaking the following activity, which presents a version of the Stroop Colour Charts (Stroop, 1935) designed by Lyndon (there being no standard form available). The new version of the Stroop Colour Charts is inserted following page 77. The associated activities will serve as an illustration of both the initial phenomenon of confusion and then that of perplexity, which arise from a continuing powerlessness to control one's own performance on an apparently simple task.

Chart 1 presents a series of six coloured rectangles arranged and re-arranged in a specific order. On Charts 2 and 3 the coloured rectangles are replaced by coloured words, with the same colour sequence being used on all charts. Simple consonant-vowel-consonant blends are used for the words on the second chart, while the words chosen for the third chart are the actual names of the six colours used for all charts. It will become readily apparent from using the charts, that there is an escalating level of difficulty in performing Tasks 1 to 3. Chart 3 is used twice during the activity, being the stimulus card for the fourth task. Initially in Task 3, the chart is used to demonstrate the powerful effects of perceptual conflict on affect and performance.

This same chart is then used in Task 4, to illustrate the ease of performance that follows when, due to the nature of the task, the perceptual conflict is removed.

Please follow the instructions printed on the back of each card carefully and pay particular attention to how you feel while performing the various tasks. Using a stopwatch, time yourself or have someone time you as to how many seconds it takes to complete the performance of each task. Keeping a written record of the various times taken on the four tasks provides a useful reminder of your performance and how it varies under the different conditions and tasks of the activity. It is helpful to the performance of Task 4 to take a one minute break after completing Task 3.

Task 1, the naming of the colours in the sequence, is not as easy a task as it might first appear. The main purpose, however, is to establish a baseline of performance on the naming of the colours on the chart. All charts have an identical colour sequence.

Task 2, the naming of the colour of the ink in which simple words, such as bat, mat and sat are printed, illustrates that although there is no major sense of conflict or perplexity, there is none the less an increase in the cognitive load of the task. There is also an occasional tendency for individuals to say the word rather than name the colour. The activity undertaken on this chart requires more effort than on the first.

Task 3, is again, naming the colour of the ink in which a word is printed. On this chart however a deliberate conflict is introduced between the meaning of a word, for example "blue" and the colour of the ink in which it is printed, namely black. The task of naming the colour in which the word is printed is universally difficult. It

creates considerable amusement, confusion and perplexity in the majority of subjects.

Task 4, involves using Chart 3 again. This time, however, the task is to name the words themselves. When the individual is instructed to read the coloured words only, the task becomes relatively easy. These new instructions are in accord with our direct expectation of the required task. The perceptual conflict, the state of perplexity, is effectively removed, as one is able to simply read the words, rather than having to name the colour of the word itself. Some individuals show evidence of retroactive inhibition from Task 3 in that they continue to name the colour of the ink in which the target word is printed instead of reading the word itself. This is in part the reason for the recommended break between Tasks 3 and 4. It is however interesting that some individuals find that they are inhibited in a new task from the transient influence of a previous task.

Generally, researchers have used a separate card for Task 4, with the words printed in the standard pattern of black print on white paper (Jensen & Rohwer, 1966). I have found it more beneficial to be able to make a direct comparison between the times taken to complete Tasks 3 and 4 using the same stimulus card. The usual outcome is that subjects achieve their overall best time score on Task 4 and their worst time score on Task 3. The relative ease of naming coloured words compared to naming the colour of the ink used to print the colour names, while using the same stimulus card, has proven effective in demonstrating the phenomena of the proactive facilitation and proactive inhibition of human performance.

1

Name the colours, left to right, row by row, as quickly as possible.
Correct any mistakes.

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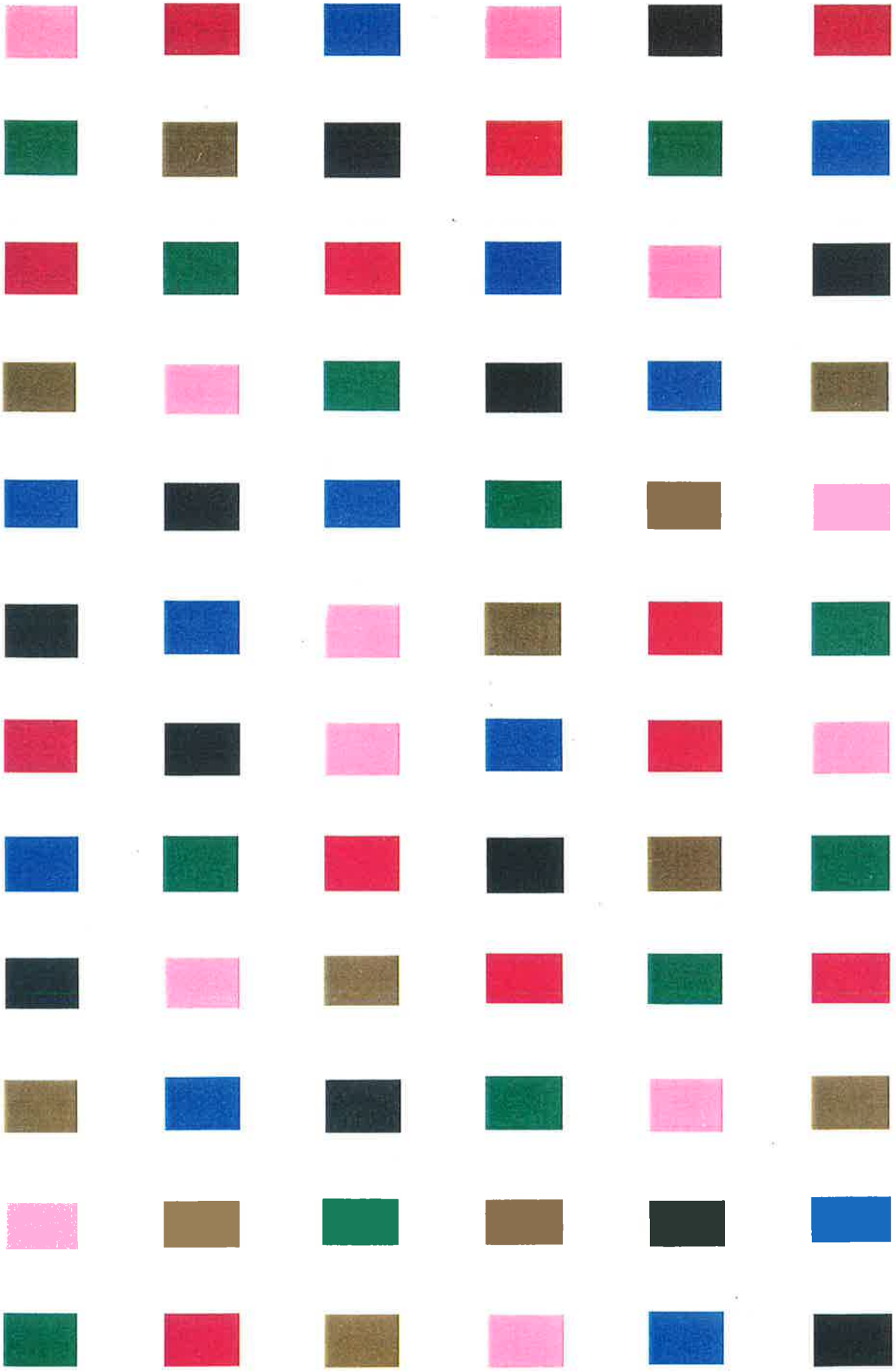

2

Name the colour of each word, left to right, row by row, as quickly as possible. Correct any mistakes.

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bat	fat	sat	cat	bat	mat
cat	mat	fat	bat	sat	rat
cat	rat	sat	fat	sat	mat
bat	rat	fat	bat	mat	cat
rat	cat	sat	mat	bat	fat
rat	bat	bat	sat	fat	cat
mat	rat	cat	fat	bat	sat
mat	sat	cat	fat	rat	rat
mat	rat	mat	sat	fat	fat
bat	bat	rat	mat	fat	cat
sat	mat	cat	rat	mat	sat
sat	fat	bat	cat	rat	cat

3

This is a demonstration of the interference caused by long-established habits.

Name the colour of the ink used to write each word, left to right, row by row, as quickly as possible. Correct any mistakes.

4

Say each word, left to right, row by row, as quickly as possible. Correct any mistakes.

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green	brown	black	blue	green	pink
blue	pink	brown	green	black	red
blue	red	black	brown	black	pink
green	red	brown	green	pink	blue
red	blue	black	pink	green	brown
red	green	green	black	brown	blue
pink	red	blue	brown	green	black
pink	black	blue	brown	red	red
pink	red	pink	black	brown	brown
green	green	red	pink	brown	blue
black	pink	blue	red	pink	black
black	brown	green	blue	red	blue

An interpretation that can be given to these experiences is that the confusion, and subsequent perplexity, felt on performing Task 3 is similar to how a student feels at the very moment they become aware of a conflict between what they understand and what is being taught. This powerful emotional state readily disrupts performance, and so it can be appreciated that the learning process is significantly influenced by this major affective factor alone.

It is possible to complete Task 4 only with considerable attentional effort or concentration, and with a contingent slowing of performance. The significant slowing of performance is a natural outcome of the increased cognitive load that is placed on the individual by the perceptually confusing nature of the task. It is a characteristic of students experiencing learning difficulties to display a similar slowness of performance and increased effortfulness in attending to the learning task. It is argued that perhaps these well-known attributes of students experiencing learning difficulties are caused by the same natural mechanisms that cause Task 4 to be so difficult. What is clearly illustrated by these demonstrations is that we are dealing with powerful psychological forces aimed at maintaining the perceptual and conceptual continuity of the individual.

4.6 The Attributes of Change

As was discussed in the previous chapter, a major attribute of conventional remediation is the transient nature of any learning that occurs. The major empirical characteristic of trying to change what someone already knows is that where this

change is attempted through the practice of the preferred new skill or concept, the learning that occurs is forgotten faster than normal.

In the preparatory phase of the Old Way/New Way procedure, it is initially easy to show someone the correct spelling of a word or demonstrate a better mathematical algorithm. Students can be shown a new way and be encouraged to practise it. However, if at this preparatory stage an individual is asked to report which of the alternatives looks or feels better, the great majority of individuals report that the old way still "feels" better.

This robust phenomenon has led to an interesting measure of the effectiveness of transfer to the new way. At the conclusion of the mediational phase of the method, students may be asked to say which of the two ideas "feels" better at this stage. This perceptual state of the individual has been shown to be a reliable indicator of the degree of transfer to the new way. Students who report that the old way still looks or feels better to them usually have greater levels of intrusion of errors during the generalization phase of the method.

It has also been noted that during the mediational phase, individuals develop and often report a change in their ability to perform both the old and the new way. The old way becomes harder to perform while conversely the new way becomes easier to perform. These changes in performance are often quite dramatic and with very young students are sometimes accompanied by a desire to avoid any further repetition of the old way. This change in ability to produce the new way with its associated inhibition of the old way has been observed to occur mostly on or

immediately after the third mediation. Individuals who have successfully transferred to the new way during the trial often report that the new way looks and feels "right" and that the old way now actually looks "wrong". This new condition represents a major change in the perceptual state of the individual.

The individual's old way is now subject to a specific and palpable process of retrieval inhibition (Anderson & Bjork, 1994; Bjork, 1989). Although an individual is still able to perform the old way, there is an attendant physical and emotional reluctance to do so. When an old way is produced there is associated with it a changed affective state; as mentioned above the old way now looks and feels wrong.

If, however, the individual's new way is not subject to use or, sometimes, even when there is only limited application, there appears to be a slow recovery or intrusion into performance of the old way over a period of two to three weeks. This intrusion however is in most cases self-monitored and is readily dealt with by a single additional mediation between the competing presentations. A similar observation has been widely made in psychological studies of conditioned learning and there it is referred to as spontaneous recovery (Underwood, 1957).

The learning that arises as a result of the Old Way/New Way procedure may still be subject to forgetting but now at a much slower rate, referred to as the normal rate of forgetting (Underwood, 1957; Slamecka & McElree, 1983). The new way is no longer forgotten at the accelerated rate associated with the proactive inhibition of new but conflicting learning. It is possible for an individual to move beyond this normal rate of forgetting to a condition of memory where no further practice is

required to maintain the memory in an active, voluntarily retrievable state. This is the notion of a stable memory associated with the development of knowledge in Socrates' epistemology.

A number of theoretical terms have been introduced above and will be discussed during a reinterpretation of associative interference theory to be developed over the next two chapters.

5 RECONSIDERING INTERFERENCE THEORY

Despite many decades of research into human memory within the functionalist paradigm a satisfactory account of the relationship between learning and retention has not been developed. Associative interference theory attempted to explain forgetting through a number of processes, namely retroactive inhibition (McGeoch, 1936; Müller & Pilzecker, 1900), unlearning (Melton & Irwin, 1940) and proactive inhibition (Underwood, 1957):

> The origin of associative interference theory is traceable to G.E. Müller, who introduced the ideas of associative inhibition (Müller & Schumann, 1894) and retroactive inhibition (Müller & Pilzecker, 1900). (Martin, 1971, p. 315)

Associative interference theory was proposed in contrast to an early, almost commonsensical, perspective that forgetting was caused by some form of decay of existing memory traces (McGeoch, 1936). The interference theory has, however, failed to provide a satisfactory explanation of forgetting based solely on a principle of momentary interference between contiguous associations.

> A relatively few years ago it seemed that a fairly comprehensive theoretical account of forgetting was close at hand, but that has slipped away. Some investigators have lost confidence in interference as a cause of forgetting, but none of the proposed replacements thus far has created a feeling that things are on a productive new track. But that will surely come.
>
> (Underwood, 1983, p. 262)

There have been many informative and comprehensive reviews of associative interference theory, (Baddeley, 1976, 1990; Crowder, 1976; Dempster & Brainerd, 1995; Martin, 1971; McGeoch, 1952; Postman, 1961, 1972, 1975, 1976; Keppel, 1968; Postman & Underwood, 1973). The more recent of these indicate the existence of inadequacies in the explanatory framework of the theory that had, for the most part, been identified by the interference theorists themselves (Baddeley, 1990). It is important to note, however, that the phenomena of proactive and retroactive inhibition have survived independently of interference theory, and are the subject of ongoing research particularly in the area of developmental psychology (Dempster & Brainerd, 1995).

There are relatively few theoretical constructs that have been proposed for empirical evaluation by associative interference theorists. Martin (1971), in a critical review of the theory, was particularly concerned with the almost "conversational" nature of the main theoretical constructs. In response to this major criticism Underwood cogently argued that at least interference theorists had not "overloaded the memory with mechanisms" (Underwood, 1972, p. 21).

The fundamental constructs of interference theory are retroactive inhibition and its corollary of reproductive inhibition, the principal of unlearning, and proactive inhibition with its defining phenomena of associative interference and accelerated forgetting. Underwood's research into the attributes of forgetting had led him to compare the accelerated rate of forgetting, when learning involves conflict, and a slower rate of forgetting when it does not. The latter phenomenon, referred to as the normal rate of forgetting, was not part of the original associative interference theory.

It was the theory's failure to explain this phenomenon that finally led to the abandonment of a theory based solely on interference as the single cause of forgetting. The alternative theory involving the existence of some endogenous forgetting mechanism has found support in Underwood's work.

A reconsideration of each of these main constructs and their interrelationship is necessary in order to clarify the relevance of associative interference theory to the theory and practice of conceptual change. This is not an attempt to resurrect interference theory. It is instead, an attempt to retain as much as possible of the empirical and theoretical insights gained over many decades of research into forgetting, by one of the most prominent psychological research programs to date (Crowder, 1976). Baddeley, in his noteworthy book on human memory, provides us with an important cautionary note on the status of interference theory:

> In the last decade, the interference theory approach to memory has undergone a very rapid decline. Psychology tends to have a depressingly short memory, and it would be a great pity if the awareness of the very powerful effects of interference were to be lost simply because they tended to be associated with a theoretical approach that became regarded as outmoded and somewhat sterile.
>
> (Baddeley, 1990, p. 248)

5.1 Forgetting and Retroactive Inhibition

There has always been major interest in the relationship between learning and retention, or memory. In fact, there is no possibility of learning without memory

and, consequently, psychology has been particularly concerned with describing the empirical facts of forgetting:

> The appearance of a general decrement after periods of no practice is one of the haunting annoyances of life outside the laboratory. The fact known yesterday eludes us now; the history or mathematics of which we were master ten years ago must be relearned; the happenings of yesterday are recalled but poorly today. (McGeoch, 1952, p. 400)

McGeoch (1932) proposed a model of forgetting based on the phenomenon of retroactive inhibition as an alternative to forgetting based substantially upon the decay of memory traces. He viewed the notion of forgetting based on a process of decay, taken to mean the actual loss or distortion of memory, as being of a questionable nature. McGeoch argued that if forgetting could be experimentally manipulated, as indeed it readily can be, then a ubiquitous process of memory decay was not the only variable at work, and if it were present then demonstrably it was not the most significant factor. The driving force behind McGeoch's proposal of retroactive inhibition as the principal cause of forgetting was primarily a logical argument against the decay of memory traces:

> It has sometimes been said, and often implied, that disuse is the fundamental condition of forgetting, i.e.; explains it. The reasoning is that learning occurs during practice or use, while during retention intervals, when there is no practice of the act in question (disuse of it), a decrement appears; therefore, the differential lies in disuse. It is not always easy to tell whether those who write of a law of disuse mean that disuse produces forgetting or only that, with

> disuse, forgetting frequently takes place. The latter merely states the fact...the former ...is unacceptable. (McGeoch, 1952, p. 401)

It is relevant to note that McGeoch was not totally against the idea that a process of neural decay was involved in forgetting. But decay alone he argued, did not appear to account for a number of well-known phenomena and so could not account for all examples of forgetting:

> If the law of disuse described forgetting as some root of the elapsed time, for example, no objection could be offered to it as a descriptive formulation, but the law of disuse has never been stated in this way.
>
> (McGeoch, 1932, p. 334)

McGeoch cited the phenomenon known as reminiscence, which is observed in the better retention of verbal learning material following a period of rest, than when retention is tested immediately after practice of that material. Another relevant fact was that a learning strategy known as negative practice appeared to cause forgetting of habits or skills, despite the apparent practice of those same habits and skills (Dunlap, 1928, see Chapter 6 for a detailed review). Furthermore, McGeoch raised the issue of the spontaneous recovery of conditioned responses following extinction, which was a common observation within classical conditioning experiments:

> The facts cited indicate that disuse does not always produce forgetting, that forgetting may sometimes be an accompaniment of use, and that there is a large class of abnormal phenomena lying wholly outside of the scope of disuse. It follows that disuse is not the general law that it purports to be. It

> might, in so far as the facts given show, be true in some or even in a majority of cases, but to be used accurately it would have to be modified and to have its limitations stated clearly. (McGeoch, 1932, p. 333)

McGeoch queried why a process of neural decay, if it existed, had not prevented these significant recovery phenomena of memory. This question makes it clear that McGeoch is taking here an extreme position on the idea of decay, equating decay with the permanent loss of a memory trace. This is distinct from his preferred alternative view that forgetting represents only the transient inhibition of a memory trace. For McGeoch forgetting was a dynamic process driven by the interaction of the individual and the environment, rather than a passive process determined by purely functional attributes of the nervous system:

> It is the general result of the work on retroactive inhibition that, when the interval between the end of learning and the beginning of the measurement of retention is filled with some non-learning activity, involving as nearly complete rest from mental activity as is possible, retention is much greater than when the interval is filled with learning.
>
> The considerations reviewed support, on the positive side, the hypothesis that retroactive inhibition, or interference from interpolated activities, is one of the major necessary conditions of forgetting, and that without the presence of inhibiting interpolated events forgetting would not, in most cases, appear. ... That forgetting is an active blocking rather than a passive decay is strongly indicated, also, by the cases of almost complete reinstatement, under unusual conditions, of material not recalled for years and supposedly completely lost. (McGeoch, 1932, p. 338)

Some twenty years later McGeoch had not changed his position on the conditions deemed necessary for forgetting, that is, that the major cause of forgetting was interference caused by some form of competition between alternative responses:

> Forgetting is a function of a number of major conditions. If we exclude the possibility that the major portion of forgetting may be explained by disuse or deterioration of the organic correlate of learning...there are three such fundamental conditions: (a) interference by intervening activities; (b) altered stimulating conditions; and (c) inadequate set at the time of recall. Forgetting occurs because of these conditions and not as a matter of passive decay.
>
> (McGeoch, 1952, p. 401)

5.2 Retroactive and Reproductive Inhibition

In his theory of forgetting, McGeoch introduced a distinction between two experimental conditions under which the general construct of retroactive inhibition, first introduced by Müller & Pilzecker (1900), could be differentially measured. The experimental conditions were distinguished on the basis of whether an activity, referred to as the interpolated learning which is any activity introduced between the learning and testing of a set task, did or did not conflict in some way with the performance of what was termed the original learning.

Where the experimental conditions *introduce a conflict* between original and interpolated learning, and a decrement in a subject's performance is measured, the interpolated activity is said to interfere with the recall of the original learning. The decrement in performance is attributed to a transient inhibition of the originally

learned associations. McGeoch referred to this readily observed phenomenon as reproductive inhibition, meaning that subjects are actively inhibited from reproducing, or in other words from retrieving, the original associations. On the other hand, where the experimental conditions *do not introduce a specific conflict* between stimulus-response items, and a decrement in performance is measured, McGeoch applied the term retroactive inhibition.

For McGeoch, then, retroactive inhibition arises simply as a result of the interference caused by day to day activity, and accounts for the forgetting of prior conscious activity. Significantly, it involves no notion of any overt conflict between these events:

> Retroactive inhibition is a case of forgetting which is experimentally produced by interpolating a second learning task between the time of original learning and later recall. This interpolated learning is the experimentally manipulated variable. With changes in it, decrements in retention are found to vary, and, in view of the fact that some learning activity is probably going on during all of one's waking moments, we may infer that retroactive inhibition is a general condition of forgetting. (McGeoch, 1952, p. 432)

Retroactive inhibition, then, is taken to be responsible for the forgetting of an intended action due to the distraction and the demands of a competing but non-conflicting task. For example, it had been my intention to ring the library in order to extend the loan of a book. As no telephone line was available, I could not ring the library there and then. I then noted and rehearsed the library's telephone number in order to more readily recall it when needed and decided that I would try to ring again

after completing another necessary though uncomplicated activity. The following morning, while thinking about the topic of retroactive inhibition, it occurred to me that I had forgotten to ring the library and extend my loan of a book. It was the act of thinking about McGeoch's definition of retroactive inhibition that reminded me that it was his book that I had forgotten to extend! I then effortlessly recalled the eight digit number I had earlier rehearsed, however, I was clearly not assisted in remembering to ring the library by rehearsing the telephone number itself.

From the above example it can see that my forgetting was not permanent, but certainly required reactivation by some related event. In this case it was thinking about retroactive inhibition that reminded me of the task. That there had been a retroactive inhibition of my intended action caused by interference from other activities is certain and appears to be a confirming instance of McGeoch's interference theory of forgetting.

The above example of forgetting is typical of the manner in which retroactive inhibition was originally conceived to be responsible for everyday forgetting. The fact that the inhibition caused was of a transient nature was seen as a positive feature of the phenomenon. The transient nature of forgetting caused by retroactive inhibition was taken as evidence that memory traces were functionally independent of one another. The probability that a particular trace was readily recalled at any point in time was, McGeoch proposed, determined by three factors. These were firstly, response competition, that is, the momentary dominance of one response over another. Secondly, the occurrence of a constant but natural change in environmental stimulus conditions accounting for what an individual would perceive at any point in

time. Thirdly, the learning set of the individual, that is, what it is that an individual already knows and is motivated by, and is thus consciously attending to, at a particular time (McGeoch, 1952, p. 437ff).

5.3 Reproductive Inhibition and Conflict in Learning

Retroactive inhibition has been extensively studied using paired associate learning because the degree of similarity between stimulus and response items can be easily controlled by the experimenter. Where a decrement in a subject's retention arises from introducing conflict as an independent condition of the experiment, McGeoch attributed this decline to reproductive inhibition:

> The phenomenon of retroactive inhibition has traditionally meant the decrement in retention of an original learned activity following interpolated learning. The phenomenon of reproductive inhibition has meant the decrement in the retention of an original learned stimulus-response sequence when one term of the original pair has, between learning and the testing of retention, been connected with another and different term.
>
> (McGeoch, McKinney & Peters, 1937, p. 131)

It had become clear that the degree of similarity between the original learning and the interpolated learning is of major significance in determining the degree of reproductive inhibition. It had also been long established that learning to make an old response to a new stimulus is significantly easier than learning to make a new response to an old stimulus (Bruce, 1933). The greater the conflict between the stimulus-response pairs the more difficult the learning becomes. The readily

observed and measurable difficulty that subjects face when learning a new, but conflicting, task was referred to as associative interference. It was believed that the cause of this learning difficulty lay directly with the influence of conflicting prior associations.

It is relevant to note at this point that McGeoch's idea of reproductive inhibition was conceptually related to the idea of the functional independence of memory traces. Learning something new did not of itself lead to a modification of any prior trace. Instead, an association or dissociation between the traces would be established. Which particular outcome, association or dissociation, is contingent upon the similarity or differences in both stimulus and response characteristics of the memory traces themselves. The notion that new learning could transiently inhibit the reproduction or retrieval of any old association was seen as a function of a momentary dominance amongst competing responses to a given situation:

> Inhibition is not thought of as a separate process but as a function of competition between responses with a resultant momentary dominance...of one response over another. Responses thus inhibited are not necessarily lost from the subject's repertoire, but are kept by other responses from appearing.
>
> (McGeoch, 1942, p. 495)

A robust fact confronting researchers however was that, although retroactive and reproductive inhibition could be readily demonstrated, the inhibition caused was always transient in nature and readily eliminated during relearning trials (McGeoch, 1952; Melton & Irwin, 1940; Underwood, 1949). This observation is central to an understanding of the practical implications of this early research into learning and

retention. The evidence was mounting that factors other than retroactive and reproductive inhibition were relevant to a complete understanding of the process of forgetting.

It is important to note that the overt distinction proposed by McGeoch between reproductive inhibition and retroactive inhibition, a distinction based on whether new learning involved conflicting responses to the same stimulus or not, has unfortunately not survived. Only the generic concept of retroactive inhibition is used today. It is also relevant to note that whereas McGeoch's theory had differentiated between reproductive and retroactive inhibition the possibility of a link between reproductive inhibition and proactive inhibition has not been drawn.

5.4 Unlearning: The Role of Dissociation in Conceptual Continuity

The inherent flexibility of the paired associate learning paradigm for the analytical study of learning and retention led to the development of an important construct, that of unlearning (Melton & Irwin, 1940). The term unlearning was used by Melton and Irwin to describe the active, though transient, inhibition of original learning that occurs during the deliberate practice of interpolated and conflicting learning. They considered this unlearning factor as additional to any simple competition among responses at the time of recall or relearning, this being the paradigm case of retroactive inhibition within McGeoch's theory of forgetting. It was a controversial concept and led to considerable research over the next twenty years culminating in a study by Barnes & Underwood (1959) that provided firm experimental evidence for the phenomenon.

To appreciate the importance of the phenomenon of unlearning requires an analysis of the relationship between retroactive inhibition and proactive inhibition. The phenomenon of associative interference is one of the two defining conditions of proactive inhibition. It represents the increased difficulty in learning a new, but conflicting, task relative to learning a new but non-conflicting task. The second and quite distinct factor defining proactive inhibition is the decrement over time in the recall of the interpolated learning as a result of the influence of original learning:

> By proactive inhibition is meant either (a) the retardation of the learning of an activity when some other activity has occurred as a prior condition or (b) the fact of poorer retention of an activity when some other activity has occurred as a prior condition of the original learning of that activity, than when a period of comparative rest preceded the original learning.
>
> (Melton & Irwin, 1940, p. 173)

Melton and Irwin presented data supporting the notion that there was a specific inhibition or unlearning of original learning during the practice of a competing response. In their study they had subjects learn lists of 18 nonsense syllables for five, ten, 20, or 40 trials, and then re-learn the original list to a criterion of two consecutively correct trials. They were particularly interested in the rate of intrusions from the interpolated lists and recorded all results verbatim. These intrusions represent the degree of associative interference present at various stages in the learning. There were generally few intrusions of an overt kind and although covert intrusions remained a possibility the method of recording subjects' responses did not support this potentially confounding issue to any great extent. An important aspect of the original data was that subjects faced intrusions or associative

interference from the original learning on mainly the first five learning trials of interpolated learning. This was irrespective of the degree of practice of the interpolated learning:

> There are overt signs of proactive inhibition of the learning of the interpolated list. That is, syllables from the original list occur as erroneous intrusions during the learning of the interpolated list. These intrusions occur for the most part during the first five trials on the interpolated list.
>
> (Melton & Irwin, 1940, p. 203)

It was also observed that retroactive inhibition increased with the degree of interpolated learning but that with overlearning of the lists (20-40 repetitions) a reduction in retroactive inhibition was noted although it was not statistically significant. For moderate degrees of practice (five to ten learning trials), retroactive inhibition remained high and continued to interfere with the experimental task of relearning the original associations. With over-learning of the conflicting associations however, a dual effect was observed. The first relearning trial of the original associations was subject to high levels of intrusion from the interpolated list; retroactive inhibition was, as expected, clearly present. Unexpectedly, however, this inhibitory effect disappeared very rapidly with subsequent relearning trials. These results led Melton & Irwin to conclude that:

> The theory of retroactive inhibition which attributes all the inhibitions to a competition of original and interpolated responses during the recall and relearning of the original response is, however, questioned. Since it can be shown that there is a large amount of retroactive inhibition on the first

> relearning (recall) trial after 40 interpolated trials even though there are very few overt intrusions on this trial, it is argued that some factor other than the competition of original and interpolated responses may be responsible for a portion of the retroactive inhibition.
>
> (Melton & Irwin, 1940, p. 203)

What is important to emphasize here is the fact that the intrusions from original learning occur early in the learning of a competing list. These intrusions, however, reduce in frequency as practice of the new list continues, although retroactive inhibition continues to increase over the entire period. There is, therefore, evidence for reduced response competition, which is indicative of a significant dissociative effect. So, although the over-learning of the interpolated associations initially results in a high level of retroactive inhibition, it is also the case that this inhibitory effect is rapidly dissipated:

> The decrease in retroactive inhibition with high degrees of interpolated learning is much more pronounced in the relearning trials (of original learning) after the first and in the number of trials required to relearn to mastery, which suggests that the retroactive inhibition produced by interpolated learning disappears during relearning more rapidly the greater the degree of interpolated learning.
>
> (Melton & Irwin, 1940, p. 202)

The significance of these observations for learning in the real world is that learning to change existing habits, skills or conceptions is initially difficult and requires deliberate effort. Attempts to facilitate this change through significant additional

practice of a new way will not necessarily be successful. Initially, of course, the new way will be learned and then with greater ease as the associative interference, that is, intrusions from the original associations are unlearned or inhibited. However, the dissociation of the old from the new that arises as a consequence of the unlearning process means that the old way is in fact more likely to be retrieved than one would normally expect from high degrees of practice of a new way.

The significance of the early intrusions from prior knowledge is that they represent a transient associative interference by the original learning with the interpolated learning which is restricted to the early stages of learning a conflicting activity. Initially then, the new but conflicting learning is subject to direct associative interference, but as learning continues these intrusions decline significantly. This phenomenon is attributed to an unlearning or dissociative factor.

Intrusions from prior learning and their occurrence during predominantly the first five relearning trials of conflicting learning are particularly significant from a mediational point of view. Where an individual chooses or is required to persist in practising a new activity, it is evident that the initially autonomous intrusions are transiently inhibited. It appears most likely then that it is the failure to mediate between competing responses when the opportunity presents itself, or at some more appropriate future time, that results in the continuity of an individual's habits, skills and conceptions.

5.5 Proactive Inhibition and Accelerated Forgetting

Proactive inhibition was first described as a phenomenon by Whitely (1927), with Whitely & Blankenship (1936) being the first to coin the term. It was Underwood (1957), however, who first confronted the inadequacy of retroactive inhibition and unlearning as an explanation of the substantial amount of forgetting observed within paired associate learning, and who proposed a central role for proactive inhibition in explaining what he called an accelerated rate of forgetting.

In his opening remarks for his presidential address to the Midwestern Psychological Association, St Louis Missouri in May 1956, Underwood said:

> I know of no one who seriously maintains that interference among tasks is of no consequence in the production of forgetting. (Underwood, 1957, p. 49)

Underwood was at the time one of the principal researchers in what was called the "Functionalist School", a group of psychologists who were mainly atheoretical empiricists. His paper, entitled "Interference and Forgetting" (Underwood, 1957) represents a milestone in the pursuit of understanding of the phenomena associated with forgetting. It was a revolutionary paper, setting on its head the psychological community's understanding and appreciation of forgetting, particularly in its relationship to paired associate learning. At the time the study of recall memory was conducted via rote verbal learning tasks. Underwood challenged the then conventional view that retroactive inhibition was largely responsible for the substantial reduction in retention observed in paired associate learning experiments.

The average reduction in the recall of a simple list of nouns or adjectives learnt to a criterion of one or sometimes two correct productions was 75 per cent measured over a 24 hour period. This substantial rate of forgetting was regularly observed following the learning of relatively simple tasks. Underwood's challenge to the interpretation of such results was fundamental in that the original research conducted by Ebbinghaus (1913) that established the existence of such a rapid decline in recall had been replicated numerous times. However, Underwood found it to be:

> an incredible stretch of an interference hypothesis to hold that this 75 per cent forgetting was caused by something outside the laboratory during the 24-hour interval. (Underwood, 1957, p. 50)

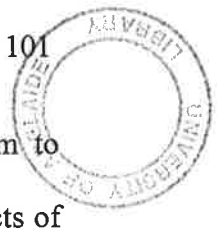
Underwood's important contribution was to convincingly demonstrate that the high degree of forgetting observed in Ebbinghaus's classical study, and in the numerous replication studies thereof, was actually the result of proactive inhibition. This powerful inhibitory phenomenon was due to the learning of lists of paired associates immediately prior to the experiment. Researchers had, it appeared, regularly provided practice lists in order to familiarize subjects with the task to be undertaken. In one such study subjects had been exposed to more than thirty lists prior to the one used as the experimental list. Once the variable of interference caused by conflicting prior learning, that is, proactive inhibition, was taken into account in the experimental design, the degree of forgetting that was then observed in subjects was effectively reversed. Instead of the research indicating a massive decrement in recall of 75 per cent in 24 hours, a less than 25 per cent reduction in recall was left to be accounted for after the same 24 hour retention period (Underwood, 1957, 1964).

What is particularly important from Underwood's research, however, is that the results obtained by Ebbinghaus are still valid in that they can now be clearly seen to illustrate that, where conceptual conflict is to be found, forgetting is accelerated by proactive inhibition. Of further significant interest is Underwood's conclusion that there are now implications for a view of memory that emphasizes, "greater homogeneity or continuity in memorial processes than hitherto supposed" (Underwood, 1957, p. 55).

5.6 The Normal Rate of Forgetting

Underwood's discovery of the significance of proactive inhibition represents one of his major contributions to the science of psychology. Because of his research, proactive inhibition was understood to cause the accelerated forgetting of conflicting new learning. His important proposals regarding what has come to be called normal forgetting (Slamecka & McElree, 1983) are of equal importance to our understanding of learning and retention. The term normal forgetting is used to describe the relatively slower rate of forgetting associated with the learning of things that are non-conflicting, that is, those that are novel and those that elaborate or simply confirm prior experience.

It is now accepted that Ebbinghaus's data showing logarithmic rates of forgetting are no longer typical of the rate of forgetting expected when the possibility of associative conflict is controlled. In the forgetting curves drawn today we see much more gradual rates of forgetting particularly in relationship to continuous motor skills (Baddeley, 1990). Underwood's success at explaining the majority of forgetting



shown under the conditions of paired associative learning conditions led him to investigate forgetting under more normal conditions, ones that avoided the effects of proactive inhibition.

Normal forgetting was studied principally through the method of using naïve subjects (ones that had not been used in verbal learning activities before) who learned and were tested on single lists of paired associates. It was this later focus of his research that was to create significant theoretical problems for a general theory of forgetting based on proactive and retroactive interference alone. It was Underwood's observation that subjects who learned only a single list of paired associates and were re-tested some 24 hours later showed only approximately a 25 per cent reduction in recall of the list learned. Underwood considered even this relatively low percentage loss of recall as probably an over-estimation of the actual loss (Underwood, 1957). Though the degree of forgetting was considered to be relatively minor, it still represented a major problem for the associative interference theory. Underwood and his associates attempted to account for this rate of forgetting in ways consistent with the theory that all forgetting was due to factors of associative interference alone. However, despite intensive and varied research efforts, the results were consistently unfavourable:

> The data that have proven so intractable to interference theory must be viewed with concern by anyone in memory, whether his sympathies lie with the interference approach or some other. Tasks in which a variety of encoding processes are used in establishing the memory are not forgotten at different rates. Lists of high meaningfulness, low meaningfulness, high similarity, low similarity and so on, are all forgotten at the same rate. Further, individual

> differences in rate of forgetting are minimal (Underwood, 1964). Do these facts mean what they appear to mean, namely, that a wide variety of mechanisms used in establishing memories, memories that must be encoded differently, have no consequence for long-term retention? Or does it mean that underlying all of these memories there is one, powerful, common constituent that is responsible for the observed constant rate of forgetting and that remains uninfluenced by particular manipulations suggested by extant theory? One cannot but conclude that the problem is of critical centrality and that its solution is no longer the sole responsibility of the interference theorist.
>
> (Underwood, 1972, p. 21)

This gradual rate of forgetting appears to be a significant factor of human memory. Extensive research by Underwood and his colleagues (Postman & Underwood, 1973) premised on the idea that normal forgetting was caused by proactive inhibition from prior language habits had proved unsuccessful:

> When the mechanisms and outcomes of implicit associative interference derived from laboratory studies were extended to incorporate associative attributes learned outside the laboratory, the data have given at best only scant support to the validity of the extension. More than a decade has passed since the generalized formulation was advanced (Underwood and Postman, 1960) (but) the anticipated variance in forgetting has not been shown. The rate of forgetting of single lists of different types do not have the variance expected by the theory.
>
> (Underwood, 1972, p. 19)

These results represent a significant challenge to a general theory of forgetting based solely on interference from proactive and retroactive inhibitory factors.

5.7 The Mystery of Normal Forgetting

The existence of a natural rate of forgetting of practised items has been given additional support by work undertaken by other researchers (Slamecka & McElree, 1983; Baddeley, & Nimmo-Smith, quoted in Baddeley, 1990). Slamecka and Baddeley, intrigued by Underwood's proposal (Underwood, 1964) that the rate of forgetting following learning was not dependent on the nature of the material being learned, and following an informal discussion on the matter, decided to investigate Underwood's claim. The researchers took different approaches to investigating this issue, with Slamecka's research followed the traditional verbal learning paradigm:

> The overall interpretation was that the forgetting of verbal lists is independent of their degree of learning. No current theories of memory predict these outcomes, but neither does the pattern of results disconfirm any theory. The argument is made that the present memory theorizing neglects almost entirely the central problem of normal forgetting.
>
> (Slamecka & McElree, 1983, p. 384)

In so concluding, Slamecka had drawn attention to a single though highly important addition to the list of factors that Underwood had indicated did not affect the forgetting of single, and therefore non-conflicting, lists:

> To that list of fundamental variables we can also add the degree of learning and thereby deepen the mystery.
>
> (Slamecka & McElree, 1983, p. 396)

The mystery referred to here is the existence of a constant rate of forgetting of that which is learned under a variety of conditions that exclude any conflict between original and new learning. This rate of forgetting is functionally independent of the nature of the material being learned and independent of the degree of practice of the material.

In a rather more complex though pragmatic investigation, Baddeley et al. investigated the rate of forgetting of knowledge of anatomy by students of physiotherapy:

> Physiotherapy students in Britain are required to take a national exam at the end of their first year in anatomy. One component of this used to be a multiple-choice paper. We were able to re-test students on the original paper after varying intervals of time, thus allowing us to plot separately the performance of students who did well on anatomy, as indicated by other parts of the examination, and students who did rather poorly. An item analysis of the examination had been carried out on a national basis, so we were able to plot separately the retention of easy and difficult items. We, like Slamecka and McElree, find that the number of items lost per unit of time does not depend on the level of initial learning.
>
> (Baddeley & Nimmo-Smith, quoted in Baddeley, 1990, p. 254)

The existence of an accelerated rate of forgetting of practised items was first evident in the results of research conducted by Ebbinghaus during 1890, but was only fully explained by Underwood in 1957. It appears, however, that not all involved in the study of memory have fully appreciated the import of Underwood's 1957 study which indicates that the forgetting shown in Ebbinghaus's study was specifically due to interference from prior learning:

> It is hard to escape the suspicion that the classic forgetting curve of Ebbinghaus that is shown in all the introductory psychology texts may be rather less universal than we tend to assume.
>
> (Baddeley, 1990, p. 242)

On the contrary, it would appear that Underwood's research has determined that the classic forgetting curve is clearly a universal curve. It is the forgetting curve that we should expect to derive from data collected in experiments on learning and retention where associative conflict is an independent variable and where proactive inhibition consequently causes the accelerated forgetting of the conflicting associations.

The main stumbling block for interference theorists was their opposition to the principle of the decay of memory traces. Underwood's research into normal and accelerated rates of forgetting effectively reopened the debate on the principle of decay. Baddeley (1976, 1990) found it necessary to propose a decay theory of forgetting and his model, without hint of conflict, necessarily included the phenomena of retroactive and proactive inhibition. Underwood (1983) chose not to pursue the path of integrating interference theory and the construct of decay for reasons best known to him.

The role of inhibitory mechanisms in long-term memory has been taken up more recently by Bjork (1989), Anderson & Bjork (1994), and Anderson & Spellman (1995). They have addressed the issue of the so-called decay of memory traces through the construct of retrieval inhibition:

> It is argued herein that inhibition plays an important role in higher-order as well as lower-order cognitive processes. One such form of inhibition for which there is accumulating evidence is retrieval inhibition, characterized by a loss of access to certain items that are, in fact stored in memory.
>
> (Bjork, 1989, p. 309)

There appears, however, to be little choice but to propose a theory of forgetting that incorporates both the principles of interference and the decay of memory traces but achieving such integration is not a straightforward matter.

As a general theory of forgetting, interference theory was challenged by its inability to account for three major issues. Firstly, there was the forgetting associated with the learning of single lists of paired associates, which was described earlier in this chapter. It was Underwood's research into normal rates of forgetting that finally exposed significant difficulties for a solely interference-based theory of forgetting. The constant though relatively slow rate of forgetting "in the range of 10-20 per-cent forgetting over 24 hours" (Keppel, 1972, p. 98) associated with learning via practice of novel information, strongly implied some ubiquitous process of retrieval inhibition. That there was, in addition, an accelerated rate of forgetting attributable to the factor of interference, was questioned only in regards to its relevance beyond paired associative learning:

> As is well known, the emphasis on interference as a focal concept in forgetting theory arose from the work on proactive and retroactive inhibition. It may not be fully realized that transfer effects in learning, and retroactive and proactive inhibition, are exclusively concerned with associative attributes of memory for memories that have been established in the laboratory.
>
> (Underwood, 1972, p. 19)

It is difficult to accept, however, that it has ever been the intention of researchers following the Ebbinghaus tradition of paired associate learning to restrict the interpretation of the results of their efforts to the area of paired associate learning. It has always been assumed that there would be a degree of transfer of the results of research to the real world. Otherwise, there would seem to be little point to the research apart from the activity itself. Therefore, the validity of Underwood's declaration that proactive inhibition is exclusively a phenomenon of verbal learning research is untrue. This has proven to be the case as continued research into the phenomenon in the area of developmental psychology has shown (Dempster, 1991; Dempster & Brainerd, 1995).

The second major challenge for interference theory was the failure to find significant retroactive and proactive inhibitory effects in experiments on meaningful learning. However, Dempster (1985, 1988) has demonstrated that both proactive and retroactive inhibition can be observed and that they are of influence within meaningful learning. In a series of carefully constructed studies using complex meaningful material he successfully showed that:

> previous failures to obtain RI (*retroactive inhibition*) with connected material were due at least in part, to various shortcomings of procedure and measurement, including relatively insensitive retention measures (Ausubel *et al.*,1959; Hall, 1955; J.A. McGeoch and McKinney, 1934b), insufficient amounts of interpolated learning (Ausubel *et al.*, 1959, 1968; Hall, 1955) and the use of very short retention intervals, of not more than a few minutes (Hall, 1955; Howe and Cavicchio, 1971; J.A. McGeoch and McKinney, 1934b). Several studies using connected material have found heavier retroactive losses following retention intervals similar to the ones used in the present experiments than those following much shorter ones.
>
> (Dempster, 1988, p. 109)

There is a point of logic that is particularly relevant here. If a person has an established habit, skill or knowledge and is confronted by the need to learn new but conflicting information this activity, we are now aware, may for a time interfere with the retrieval of the original learning. If, as defined, retroactive inhibition is a phenomenon that is measured by the reduction in recall of previously learned material, then there is a difficulty with a nil finding in any research. If there is no evidence for retroactive inhibition of previously learned material, then we may only conclude either that there was no conflict in the materials or that the materials were tested in a manner that failed to expose the retrieval difficulties that were there. It is of no surprise then that Dempster's results emphasize methodological considerations for the evaluation of the effects of retroactive inhibition:

> Even under more favourable conditions of procedure and measurement, RI is unlikely to be detected unless the conditions of relatedness meet at least two

> criteria. First, successive passages should share the same topic or general semantic category, otherwise it seems unlikely that the passage contents will be represented in some overlapping (i.e., potentially interfering) fashion in memory. Second, when analyzed in terms of the present classification scheme, more elements across each of the meaning structures should be different rather than the same in content.
>
> (Dempster, 1988, p. 109f)

In earlier research Dempster had tackled the important issue of proactive inhibition in meaningful learning. He reported that it had become the conventional wisdom amongst educators that proactive inhibition was not relevant to meaningful learning even though, as I have noted earlier, Ausubel had used the construct as the centrepiece of his proposals on "meaningful reception learning" (Ausubel, 1963). Dempster conducted two experiments which directly addressed the relevance of proactive inhibition for meaningful learning and drew the following most significant conclusions:

> Overall, these results add to the weight of evidence that connected meaningful material is susceptible to proactive interference. In addition, they extend the results of previous studies by suggesting that some forms of topic organization are more susceptible to proactive interference than others, and that individual differences in susceptibility to proactive interference are a source of differences in academic achievement. Moreover, the two forms of topic organization used in this study are representative of the way lecture and text material is often organized. Successive sentences in a subdivision or paragraph are usually about the same topic, whereas sentences in adjacent subdivisions or paragraphs are often about related topics. Accordingly the

> results of this study suggest that proactive interference may be a common cause of everyday learning problems, and are a first step in identifying the kinds of material that are most sensitive to proactive interference.
>
> (Dempster, 1985, p. 87)

As was the case for retroactive inhibition it is important to note that if an experiment is unable to demonstrate proactive inhibition, then this does no more than show that the new learning did not directly conflict with the individual's prior knowledge. Therefore there can be no implication drawn from such results that proactive inhibition does not exist within the context of meaningful learning. Such results are necessarily ambiguous. However, proactive inhibition has been demonstrated unequivocally in studies on paired associate learning and now more recently in the area of meaningful learning by Dempster (1985). It may be argued, however, from these studies that there is considerable flexibility in the interpretation given to meaningful learning, in that many potentially conflicting items are later shown not to be so. This result arises because of the very nature of the definition given to the phenomenon, that is, that proactive inhibition is the inhibitory effect on the recall of new learning by prior learning. The fact that prior learning may be neutral in its effect towards new learning should be of no surprise, nor should it be of concern that prior knowledge is often facilitatory. It is only when prior knowledge is in fact shown to be in conflict with new knowledge, because the prior knowledge is retained in preference to the new, that we have a relevant situation.

The third major challenge to interference theory was the continued evidence of proactive inhibition under conditions thought sufficient for its elimination. It should be emphasized again that interference theory has been the focus of one of the most

prominent psychological research programs this century (Crowder, 1976). Yet the task that interference theorists set themselves, of showing that all forgetting could be accounted for by proactive and retroactive inhibition, has not been accomplished. Perhaps the most surprising fact of all is that, despite more than fifty years of research into proactive inhibition, the researchers have failed to provide an acceptable explanation of the phenomenon.

> Our discussion of theoretical analyses of interference has been limited almost entirely to mechanisms of RI, and little has been said about PI (*proactive inhibition*). There are two major reasons for this asymmetry in the consideration of empirical results. First, experiments on retroaction have remained the major testing ground for alternative conceptions of interference. Second, and more important, there is today no coherent account of the conditions and characteristics of PI, and this state of affairs signals a major weakness of current theories of interference. Classical interference theory attributed PI to competition and failures of list differentiation. As we noted previously, recent studies have provided more impressive evidence for the decrements in recall than can be produced by the latter factor. The major interpretative difficulties stem from the fact that PI continues to be observed when competition and differentiation are ruled out or minimized as sources of interference...The results can be attributed to the recovery of the set to give earlier responses, on the assumption that the simultaneous arousal of two response repertoires generates output interference. Some independent evidence for this assumption was obtained in a study of long-term PI in free recall.
>
> (Postman, 1972, p. 178)

5.8 The Mechanisms of Forgetting: A Tentative Proposal

The difficulties that interference theory has had in accounting for forgetting, and in particular its failure to provide an explanation of proactive inhibition, leads to the proposal that perhaps proactive and retroactive inhibition are phenomena that are functionally independent of the two rates of forgetting proposed by Underwood.

It is suggested here that the accelerated rate of forgetting is best understood as the usual rate of forgetting that is activated when items are experienced but not practised. More significantly it is also the rate of forgetting of an item conflicting with some prior experience of the individual, that is, under the conditions necessary for associative inhibition and unlearning to become evident and for the resultant proactive inhibition to be later initiated.

Proactive inhibition appears to be a major unlearning process in its own right. It is important then to differentiate associative interference and proactive inhibition. Associative interference is a dual process of prior response presentation and of response dissociation, thus permitting the acquisition and retention of conflicting knowledge. Where the learner does not take the opportunity, presented naturally during the period of associative interference, to mediate between the conflicting responses, we find that the new learning is, over time, subject to an accelerated rate of forgetting or, in other words, it is proactively inhibited. This as we have seen leads to an approximately 80 per cent decrease in the probability of voluntary retrieval of the new learning over a 24 hour period.

It is proposed that the individual may consciously control this phenomenon in that, through the application of a cognitive strategy, accelerated forgetting is redirected from the new response onto the old, resulting in the retention of the desired new response.

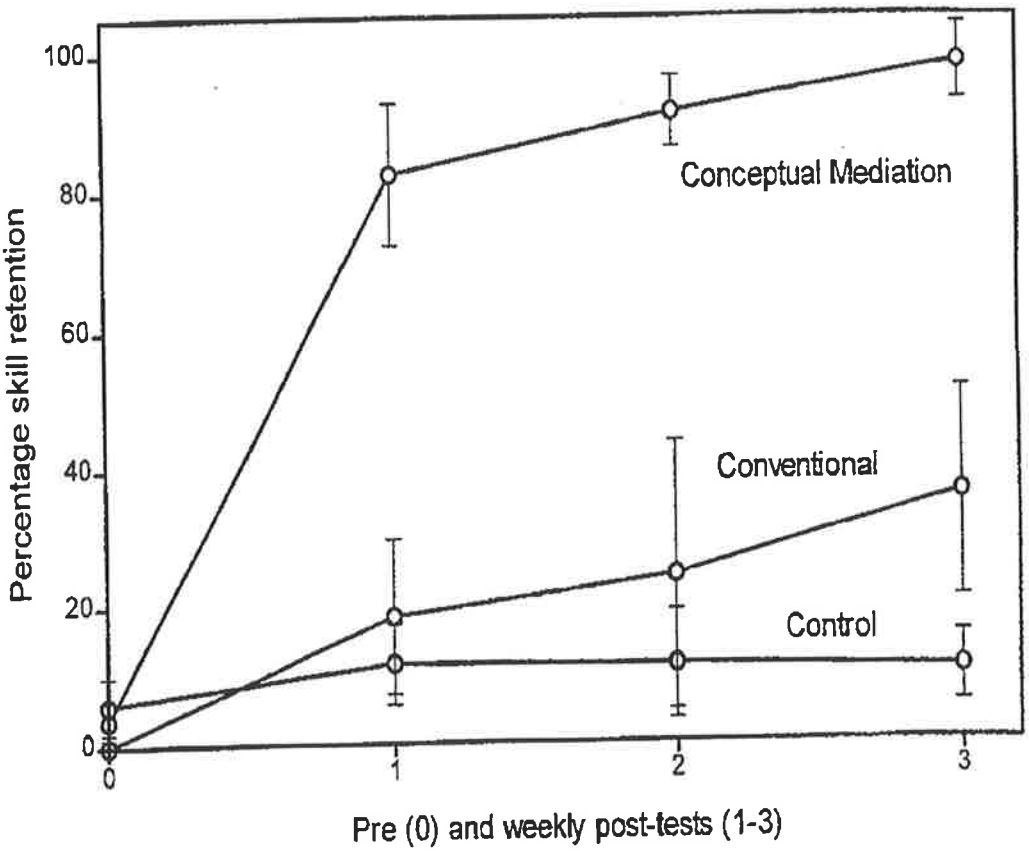
Interference theorists have in particular studied a phenomenon of learning in which the order of acquisition of information has a significant bearing on the learning and retention of conflicting information. Mediation facilitates learning of this kind in that there is an actual exchange of probability of presentation, through the increased probability of the reactivation of the new but originally conflicting learning. This kind of learning leads to a relatively permanent change in existing habits, skills and conceptions.

5.9 An Experimental Field Trial of Old Way/New Way

In a study funded by the Australian National Training Authority, a rigorous experimental investigation was undertaken of the relative effectiveness of skill correction in a group of vocational education students using Old Way/New Way compared with that obtained by conventional methods of remediation (Baxter et al., 1997). A copy of the completed report including descriptions of methods and results of the project is included as Appendix 4. The graph of the results of this controlled study, Figure 1, is of particular interest to us from both a practical and a theoretical point of view. The results illustrate that where students and their teachers used conventional teaching methods in an attempt to correct pre-existing skills, the rate of retention of the new skill, one week after remediation, was only 20 per cent.

FIGURE 1:

Improvement in skilled performance (mean ± se) using Old Way / New Way versus conventional error correction (based on all available subjects, n = 34)



Source: Baxter et al. (1997, p. 16)

This result is directly predicted by the research on the effects on re-learning of proactive inhibition. The students experienced accelerated forgetting of the new skill, that is, they showed an 80 per cent loss in retention of the new skill. Conversely the group of students who have used the Old Way/New Way method have demonstrated that they have only been subject to a normal rate of forgetting of the new skill, that is approximately 20 per cent loss of retention. This too is in line with the research presented on normal rates of forgetting.

What is also apparent from the results is that those students who had mediated between their conflicting skills were then able to progress to skill mastery over the following two weeks. During this time there was no additional teacher-initiated mediation on those skills. The graph for those students who had experienced conventional remediation similarly shows a slope of improvement over the two weeks from the low level of improvement shown at week one. However it is important to note the considerable variation in individual scores, as illustrated in the graph, obtained by students in the conventional group in comparison to those of the students in the mediational group. Only certain individuals of the conventional group demonstrate any reasonable degree of progress, whereas the entire group of students who mediated between their conflicting skills achieve skill mastery in the same period of time.

The students who had used the mediational learning strategy of Old Way/New Way, showed improved affect, improved self-detection and self-correction of incorrect skills. They also showed an improved understanding of the complex nature of the skill being learned, and developed an understanding of the value of the method for

accelerated skill development. Teachers who were involved in the study were impressed with the results and were highly positive as to its value in their field of education. It is also relevant to note that the treatment effectiveness of the method was not teacher-dependent. These results, described in Baxter et al. (1997), are significant in that they provide direct support for the method and more importantly for its theoretical underpinnings. We may conclude that the accelerated rate of forgetting of new learning, caused by conflicting prior knowledge, is transformed into a normal rate of forgetting by the use of a relatively simple cognitive strategy. Furthermore the original learning, the cause of proactive inhibition, is now itself subject to an accelerated forgetting effect, thus reducing its influence in future skilled performance to a controllable and thus more acceptable level. Individuals are now able to pursue the development of skill mastery or, within the field of conceptual development, the attainment of a stable level of knowledge representation that we may properly call understanding.

6 WHY ELICIT AND THEN PRACTISE THE OLD WAY?

A comparison of conventional re-teaching practices with the recommended Old Way/New Way method makes it clear that a major difference lies in the elicitation and practice of the old way during each step of the progressive practice of differences between the old and the new. This conscious and progressive differentiation of the old and the new is a necessary condition for the redirection of the accelerated forgetting effect (Baxter et al., 1997; Dawson & Lyndon, 1997; Lyndon, 1989).

> Our practical problem of learning may be summed up in one question: How can we learn most usefully?
>
> (Dunlap, 1949, p. 15)

In the past, where correction has been required, there has been a major tendency for teachers to re-teach the correct information while actively avoiding reference to the incorrect information. Where teachers do discriminate between the correct and incorrect responses, this is rarely managed in a progressive manner. By progressive it is meant that emphasis is placed on a gradual increase in the detail of the perceptual and conceptual differences between the "old" and the "new" being described. Where a teacher chooses to concentrate on differences between old and new, the resulting differentiation is rarely practised enough to overcome the proactive inhibitory effect and the accelerated forgetting it causes.

The main concern expressed by some teachers regarding the process of progressive differentiation is that it appears to be a form of "naïve" rote learning activity. Rote learning, however, is usually understood to involve the deliberate practice of a new activity without particular regard to the meaningfulness of the activity or its content, and specifically without regard to the individual's prior knowledge and beliefs.

Progressive differentiation is the complete opposite of "rote" learning. The differentiation process demands of the individual an active, meaningful involvement with the conflicting items, activities or concepts, with the express purpose of taking control of a powerful mechanism, namely that of accelerated forgetting.

6.1 Changing Habits Through Negative Practice

Evidence for the beneficial effects on learning of eliciting and practising a pre-existing incorrect response, although difficult to find, is varied and clearly unequivocal. The phenomenon of negative practice, although rarely mentioned in psychology textbooks today, is an important example. The originator and main proponent of the beneficial effects of negative practice was Dunlap (1928), then Professor of Experimental Psychology in the John Hopkins University:

> In 1928, Dunlap published a short paper in Science (3) in which he reported his now familiar observation that errors could best be corrected by practicing the error themselves with knowledge of their correctness.
>
> (Peak, 1941, p. 316)

The main point of Dunlap's publication in *Science*, was not simply that negative practice was an effective correctional technique, but more significantly that *not all* conscious and deliberate practice leads to the improved retention of a habit. In fact, he argued that the opposite condition, that of a suppression of a pre-existing habit was readily observable under certain conditions of practice. In particular, if there is an *intention to forget* an already established habit, then the so-called, negative practice of that habit, instead of strengthening the old response, actually leads to its suppression. This was an important observation, which challenged the basic proposition in existing learning theories that practice always leads to strengthening of a response and clearly demanded further investigation and explanation.

What is of particular interest in the experiments on, and practical applications of, negative practice are the instructions given to subjects, that in order to eliminate an habitual error one should repeatedly practise the incorrect information. Negative practice was generally performed in isolation from the physical performance of the correct procedure but with the clear expectation that, at a cognitive level, the individual was to reflect upon the differences between the old and new habit.

Dunlap was interested in the practical applications of negative practice and wrote a book entitled *Habits: Their Making and Unmaking*, an obviously very successful work that was originally published in 1932, and had its fourth and final reprint in 1949.

In this book, Dunlap provided a new perspective on habit change and learning, one that emphasized the importance of practice as a means of not only developing habits,

but also of eliminating them. When practice results in the development of habit, Dunlap referred to this as positive practice. He saw this effect as supporting the conventional view of learning as a process:

> These are the cases in which the learning appears merely to fix the practice responses, in a way conforming to the traditional description of habit formation. (Dunlap, 1949, p. 94)

Dunlap however was also aware that there existed research evidence of an opposite nature. This evidence was clear about the existence of a set of conditions where new learning resulted from the practice of old established habits. These were:

> the cases in which, by the repetition of a response which has already become habitual, the response is eliminated. (Dunlap, 1949, p. 94)

It is essential to note that positive practice is applicable only to new learning that is of a non-conflicting kind, which was labelled "alpha learning":

> Quite clearly, also, the *alpha* type of learning occurs only in the cases where the learning is really never finished, but the habit exists only as a continuous learning process. (Dunlap, 1949, p. 95)

Under the alpha condition we are not confronting the individual with a need to change an existing habit, skill, knowledge or belief. There is only the possibility of new learning, or of positive transfer, in the sense that what is being practised is consonant with prior knowledge, in other words we are dealing with proactive

facilitation. What the individual already knows facilitates or is elaborated by the new experience. It is only when some form of conflict is experienced that natural and autonomous inhibitory processes are brought into action.

In such conditions we may feel the conflict or the confusion, and may attempt to resolve these through re-learning or positive practice. However, as outlined by Dunlap and as confirmed in our own research program, this deliberate practice does not always lead to the desired or anticipated change. The old is retained and the new is inhibited, being forgotten at an accelerated rate when compared with the rate of forgetting of non-conflicting information, and this we now understand to be due to the mechanism of proactive inhibition.

Dunlap was critical of classical learning theories that pre-dated what he considered the "scientific" study of psychology which, at the time he first published his book on habit change, had been ongoing for some half a century:

> The effect of negative practice would be unintelligible from the orthodox point of view which regards learning as the mere increase in the tendency to a given response that is assumed to be produced through the response itself. As has been pointed out, however, a response may increase or decrease the tendency to its reproduction according to the ideational and affective features included in the response. The effects of negative practice, as described above, are in thorough accord with the fundamental principles of learning as we now understand them.
>
> (Dunlap, 1949, p. 164)

In many ways, Dunlap's approach to psychology was "cognitive" in nature, although the cognitive paradigm, with its particular emphasis on the information processing computer metaphor, was yet to emerge.

McGeoch (1952), also describes a series of studies on negative practice and its positive effects on learning. A significant example was an experiment conducted with students of typing, who were learning to transcribe from shorthand. They practised habitual errors under one of two conditions. The first involved negative practice of their errors and the other condition involved an equivalent amount of practice of the correct spelling. Subjects, who each had four habitual errors, were directed to type eight full lines of each of two incorrect words. The other two words were used as the control, and subjects were directed to practise the correct spelling of these words for an equal number of times. Of significant interest was the fact that the words practised "incorrectly" were not subject to error on retest, while ten out of eleven students who had practised the correct spelling were found to have made errors on retest. The latter result is a clear example of the influence on recall of proactive inhibition while the former result is an example of the positive effects on proactive inhibition of negative practice.

The most important outcome of the investigations into Dunlap's hypotheses of negative practice is that practice of the *incorrect* information is sometimes more effective as a corrective activity than practice of correct information. McGeoch concluded that the evidence for the positive effects of negative practice had been convincingly demonstrated:

> Practice of the wrong response has often been called *negative practice*, though it is negative only in the sense that it is aimed at the inhibition of an act. Such inhibition is as positive a process as any in learning.
>
> (McGeoch, 1952, p. 292)

We should note at this point that the terms "positive and negative practice" were used by Dunlap only as a convenient form of description. As defining terms they describe an outcome that is after the event; one type of practice is not positive and the other negative as if they were different colours or sounds. The individual carefully elicits and then repeatedly performs the particular activity and the outcome of this activity is then judged to be positive or negative.

The practice undertaken during the use of the Old Way/New Way method if viewed from Dunlap's perspective involves both positive and negative practice. As has been indicated above, the uniqueness of negative practice lies in the inhibitory effect that arises when a cognitive "set to change" precedes the practice of an undesired habit. As McGeoch, when referring to the issue of negative practice indicated, without a set to change there is no effect:

> The set of the subject not only directs him toward an attack upon a rational problem; it also determines to a considerable extent what prior knowledge he shall bring to bear on it and how he shall attack it.
>
> (McGeoch, 1952, p. 226)

The amount of practice of this habit under the conditions of the cognitive set to change varies quite considerably from very little negative practice in the case of

memorizing a person's name to considerable negative practice when dealing with the problem of a habit such as stammering. In this instance, practice is undertaken on a daily basis over a period of weeks. Certainly, Dunlap was aware of the limitations that negative practice faced when dealing with the resolution of complex skills and of social or behavioural problems.

Modification of the conditions of both such positive and negative practice, as in the Old Way/New Way method, facilitates the differentiation of the conflicting habits in such a manner that the inhibition of the old is achieved more effectively. Dunlap had himself seen the possibilities of applying both conditions to the resolution of more complex situations although he gave no indication that this was to be preferred. For example he provided the following thoughts:

> While emphasizing the importance of negative practice in the breaking of habits, and its indispensable function in many cases, we must not overlook the value of positive practice in these cases...We have seen that the relation of positive practice to negative practice is that negative practice begins the learning process and positive practice finishes it.
>
> (Dunlap, 1949, p. 227)

> In various types of learning, it may be possible that alternating of positive and negative practice may be a useful procedure.
>
> (Dunlap, 1949, p. 230)

It is of interest that Dunlap goes on to consider, briefly, the notion of gradual approximation in the development of a complex skill such as swimming. He does

not however pursue the possible relationship between the progressive differentiation of old and new habits and skills, and the process of change, although it is clearly implicit in the notion of gradual approximation in mastering a complex skill.

Negative practice involves the idea of a motivated learner who makes habitual errors and desires change. The learner practises their error while simultaneously holding in mind that this practice will be of assistance in changing to the desired new way.

> In negative practice the determining factors are the thoughts and desires involved in the practice.
>
> (Dunlap, 1949, p. 95)

> In making voluntary performance the practice material, it is obvious that the act must be voluntarily initiated, and that the involuntary act will not do. Yielding to the impulse to stammer, to bite the fingernails cannot be made the basis of negative practice. The patient must always "beat the impulse"; he must initiate the act voluntarily, at a time when there is no involuntary impulse.
>
> (Dunlap, 1949, p. 225)

Here we can see that the notion of the contiguous elicitation of both the old and the new formed a central role in the positive outcomes of the negative practice technique. In relationship to the Old Way/New Way method, the contiguous association of the old and the new are always explicit. But furthermore, the contiguous association becomes an opportunity for explicit discrimination learning. It is this latter factor, and its associated phenomenon of the redirection of accelerated

forgetting, that both functionally and theoretically distinguish Old Way/New Way from Dunlap's negative practice method.

As discussed above, the notion that repetition of a response necessarily leads to strengthening of that response, in the sense of increasing its probability of recall, is no longer tenable. That the elicitation of an error may actually lead to the inhibition of that error is a significant contribution to our thinking about learning and certainly informs our practice. Within this context it is important to consider what effect there would be on learning if the practice of "errors" were deliberately avoided. McGeoch (1952) reported an area of study that bears some relevance to the issue of eliciting and practising an error. The studies concerned maze learning activities where subjects used a stylus pen to complete the maze activity. It was found that where subjects were, at a particular point in their learning, physically prevented from making any further errors, their maze learning was significantly impeded relative to the learning of subjects who were permitted to learn by trial and error. It is clear then that this approach, which prevented trial and error learning, in effect was creating learning difficulties. The conclusion drawn from these studies was that:

> The wrong acts are eliminated, in part, by being performed - that is by frequency...in the sense that their elimination is positively correlated with their frequency.
>
> (McGeoch, 1952, p. 291)

The results of these studies are supportive of Dunlap and of his understanding of the importance of the practice of errors, whether this is through natural trial and error or by the repeated practice of errors as advocated by Dunlap.

Peak (1941) reviewed the theoretical status of negative practice and its relationship to the learning theories of the day, and provided an insight into a possible explanation of the effects noted by Dunlap that is germane to the main theme of this thesis:

> It has been suggested that the present discussion is related to the experiments on retroactive inhibition, which show that an increase in practice of an interpolated performance at first increases and then decreases the interference with a performance which has already been learned and is recalled following the interpolation. The most generally accepted theories of these results attribute the interference to a transfer of response tendencies from the interpolated responses to those learned in the original series. Melton and Irwin...have proposed that some of the retroactive inhibition results from unlearning of the original responses when they appear during interpolated practice. This unlearning is transferred to the situation in which the original material is recalled. It is possible, of course, that some such factors of transfer and generalization need to be considered in negative practice and that practice of an interfering response may at an early stage of practice weaken and later strengthen its antagonist. However, the situations are so different that it is impossible to do more than suggest the possible parallel.
>
> (Peak, 1941, p. 332)

In hindsight, one can see that Peak would have found it difficult to do more than be aware of the potential importance of the interference theory of forgetting as an explanation of the phenomenon of negative practice. Retroactive inhibition was studied within a restricted experimental paradigm as an example of experimentally

produced forgetting (McGeoch, 1952). The general aim of this research was to provide evidence opposing the notion that forgetting over time involves only some physiological process of trace decay. In the retroactive paradigm, as has been discussed previously, the practice of new but conflicting associations leads to the transient inhibition of the original learning.

In the case of negative practice, however, what is practised is in a sense the "original list" itself, something that would normally be expected to strengthen, and not inhibit or suppress, the performance of that list. Yet, within the conditions described above for negative practice, we find that practice of the old list creates an effective unlearning of that list and moreover its substitution by the new one. The link to interference theory had been made, if only tentatively, though there was no evidence of this in Dunlap's own writing on negative practice.

6.2 The Significance of Elicitation to the Process of Change

The idea of the elicitation or conscious reactivation of a memory trace has a common-sense feel to it. Most readers would accept the idea that a memory trace is in some form of storage or inactive state until the trace is retrieved by some means; it is reactivated, and brought back to a conscious state. What, however, is meant by elicitation and how does this differ from unconscious reactivation? Elicitation is here taken to be the voluntary recall and performance of a habit, skill or some aspect of knowledge. An elicited act differs from general performance only in the sense that not all actions that we perform are voluntarily accessed. Many of our day to day activities are automated responses and are cue dependent; they are reactivated simply

by re-experience itself. This is why, of course, we distinguish between habits and skills. The astonishing complexity of the perceptual process, as uncovered by psychological research, occurs in the blink of an eye and fortunately we are usually unaware of its facilitation of our activities. A child who has just reversed the letter "p", writing "q" instead, during the writing say of the word "postman", has usually reactivated the reversal automatically. For clarity of definition this would not be referred to as an elicitation. If we were to ask the child to now write the word "postman" again, and the child complied with this specific request, this would be an example of an elicitation. An elicitation, then, is a conscious or deliberate reactivation of a memory trace as distinct from an automatic and thus unconscious process. The important role played by the reactivation of memory traces in the process of change, whether these are consciously elicited or are simply associative in nature, will now be explored.

Studies by Gordon (1977) and Gordon & Spear (1973) on memory reactivation in rats indicate that reactivation returns a memory trace to a "dynamic" state which is then reprocessed in a manner similar to newly acquired experiences. The effect of this is confirmed by the fact that any reactivation of memory for prior events has a significant impact on the degree of proactive interference measured following the learning of a conflicting activity:

> These data are consistent with a growing body of evidence that newly acquired and reactivated memories share similar characteristics...One interpretation of such similarities is that once a memory is reactivated, it returns to an active or short-term state and is reprocessed in much the same manner as a newly acquired or 'short-term' memory. This type of model, first

> suggested by Lewis (1969), attributes to the mechanism of memory a dynamic character not present in a simple consolidation model (McGaugh, 1966)...But if reactivation causes a passive memory to return to an active state, there is a basis for understanding how organisms are able to continually add to, delete from, or otherwise modify memories that have been stored long ago.
>
> (Gordon, 1977, p. 241.)

In a significant contribution to our understanding of the processes of loss and distortion of memory traces in humans, Estes (1997) proposed an extension to his "perturbation" model of short-term memory to that of long-term memory. Perturbation is the term used for the complex of ideas that makes up Estes' perspective on the nature of recall from memory. Just as the word learning has come to mean the measure of change following practice or experience, perturbation refers to the reactivation of a memory trace as being a necessary condition for its change. If there is no reactivation, then the evidence collected and reviewed by Estes indicates that change either in the structure of the trace or in its probability of recall is unlikely. While this perturbation model was developed between 1955 and 1994 in the domain of short-term memory research, Estes has more recently been motivated to extend the application of the model due to the recent revival of interest in memory loss and distortion. This revival is:

> a consequence of widespread public concern with cognitive aspects of aging and with aberrations of memory in eyewitness testimony and recollections of childhood abuse.
>
> (Estes, 1997, p. 148)

However, at this point in our considerations we are particularly interested in what the integration of the extensive research reviewed by Estes has to say on the issue of reactivation of memory traces:

> Thus for perturbations of remembered attribute values to occur during any interval, it is evidently essential that reactivation of memory traces of to-be-recalled items be allowed to occur during the interval.
>
> The characterization of the perturbation process that seems to best fit all presently available evidence is as follows. Following the encoding of an event in a memory trace, the trace remains unchanged over even long intervals during which no similar events are experienced. However, when conditions that obtain following encoding of a trace do allow the perception of the same or similar events, the trace is reactivated to some degree when each such event occurs. Upon each reactivation, the trace is updated, that is reencoded, and there are many sources of support for the belief that both the original encoding of an item in memory and its reencoding are subject to random error.
>
> (Estes, 1997, p. 153)

Estes's model of change, loss, or distortion of a given memory trace is based in part on a mechanism of change that is "random in character" (Estes,1997, p.157). This idea is theoretically significant, although Estes recognizes that the model only accounts well for the characteristics of memory distortion in simple discrimination tasks and does not adequately account for conceptually complex situations. What is of significance in his model are the facts that he presents on the malleability of recall memory.

The emphasis here is on Estes' opinion that, for change in an existing memory trace to occur, a process of reactivation or elicitation is necessary. As is well understood, however, a necessary condition is by no means a sufficient condition for change. This is particularly so within the context of the classroom situation where conceptual exchange is the desired outcome of teaching.

In what way then are we able to take a necessary condition, that is, the reactivation of prior knowledge, and so construct the learning experience that we may maximize our probability that learning, that is, change, will occur? It has earlier been argued that accelerated forgetting, caused by proactive inhibition, is the major obstacle to the learning process. In what way then are we able to control the problem of conflicting prior knowledge, the proactive inhibition and subsequent accelerated forgetting, that follows naturally in the teaching of a scientific theory that is in conflict with an individual's understanding?

An answer at a practical level has been proposed in the use of the Old Way/New Way method. I have argued that the literature on verbal learning actually predicts the existence of such a method; so can specific support be found in the literature of associative interference theory for the model in action?

6.3 Associative Interference and Mediation

There are two major studies that relate directly to the issue of practising both the old and the new responses contiguously. These studies, conducted some seven years apart, were an attempt by one of the main proponents of associative interference

theory, Postman, to address the ecological validity of the study of forgetting using the technique of paired associate learning:

> When subjects have to learn new responses to old stimuli, as under the A-B, A-D paradigm of transfer, they may interpret the task demands in two different ways: (a) The old responses are no longer correct and the new ones must be substituted for them, or (b) The old responses remain potentially useful but the new ones have to be acquired in addition. The transfer task may thus be seen as calling for either response substitution or response accretion. The conventional experimental arrangements used in studies of negative transfer and interference encourage the subject to adopt a strategy of substitution because the occurrence of a B response during second list learning constitutes an error. Outside the laboratory, however, people are likely to think of different responses to identical or similar stimuli in terms of accretion rather than substitution. What was learned earlier does not usually become incorrect when new information is acquired. Hence, experimental arrangements fostering response accretion are probably more representative of normal conditions of transfer than are those inducing response substitution.
>
> (Postman & Gray, 1977, p. 255)

Postman and Parker (1970) conducted the first of the two related studies relevant to a mediational perspective. They investigated the effects on transfer and retroactive inhibition of the accretion condition where first list recall occurred during test trials of second list learning.

Their general conclusion was that, under an accretion condition, subjects can maintain first list associations during the second list learning condition without

seriously affecting their overall learning of the new associations. Moreover, the fact of continued practice of the old way significantly reduces the degree of retroactive inhibition. In other words, the transient suppression of old responses that normally accompanies the practice of a new response to old stimuli is significantly reduced. What this implies is that, when the learner actively differentiates between two conflicting lists, this facilitates the retention of both sets of information at the time of testing.

The one exception to their general conclusion, however, is of particular interest. Whereas unlearning was significantly decreased under certain paradigms, increased unlearning of first-list associates was in evidence for the A-B, A-Br paradigm:

> (The) decline in performance under the A-Br paradigm implies that specific first-list associations were progressively weakened as second-list learning continued. Clearly, the procedure of re-pairing makes it difficult to maintain both the first and the second response to a given stimulus. Thus, transfer learning may not progress to full mastery unless at least some of the first list associations are extinguished or suppressed. In agreement with this interpretation, A-Br was found in a previous study to be the only paradigm for which there was a significant amount of retroactive inhibition under conditions of multiple-choice learning - that is, when correct performance reflected the integrity of specific associations and was independent of response availability.
>
> (Postman & Parker, 1970, p. 179)

As indicated in the earlier analysis of the relationship of A-B, A-D and A-B, A-Br (in Chapter 3 of this treatise), we anticipate that in the real "meaningful" world, any occurrence of A-D, rapidly becomes an A-Br paradigm due to repeated factors of contiguity and meaningful association.

The significance of this experiment lies in the fact that under some experimental conditions, but not all, a reduction of a transient inhibitory effect, that of retroactive inhibition, can be achieved through a change in experimental procedure. The procedural change involves simply practising the retention of both the old and the new items during the learning of the second list. For the A-B, A-D paradigm we find that the effect is to reduce the degree of forgetting of the first list. Of greater significance however is the fact that it is not possible to reduce first-list unlearning under the A-Br condition.

Postman & Gray (1977) conducted an experiment that again considered the issue of accretion versus substitution. On this occasion, however, they investigated the effect that a change in learning condition would have on the degree of proactive inhibition observed. Proactive inhibition is known to cause accelerated forgetting of the learning of second list associates. Interestingly the picture provided by verbal learning research is one of an ebb and flow of inhibitory effect. At first the learning of a new, but conflicting, list of paired associates leads to a decrease in recallability of the items from the original list. This retroactive inhibitory effect is however transient, and is followed by a spontaneous recovery of the recallability of the original learning. A significant reduction in the probability of recall of the new leaning is concurrently observed and overall the effect is referred to as accelerated

forgetting. So it is clear that proactive interference is a most significant empirical phenomenon.

It is possible under the accretion condition, where practice of both the old and the new is maintained, that an increase in the proactive inhibition might occur. However, the researchers rejected this possibility on two counts. Firstly, they were aware that the degree of learning of the original list has only a slight effect on the level of proactive inhibition (Underwood & Ekstrand, 1996). Secondly, as had been shown to occur in the Postman & Parker (1970) study, the differentiation of the lists would be enhanced by the accretion procedure:

> These considerations lead to the prediction that maintenance of first-list associations during second-list learning will serve to reduce long-term proactive inhibition.
>
> (Postman & Gray, 1977, p. 256)

These predictions were supported by the study. The full significance, however, of this study had not been fully realized by interference theorists:

> Long-term proactive inhibition was reduced significantly when second-list learning was under the accretion rather than the substitution condition. The reduction in proactive effects was not very great in absolute terms, but it has to be evaluated in light of the fact that it occurred in spite of a substantial increase in the strength, and hence the competitive potential, of the interfering list. Furthermore, given the level of retention under the control condition, an appreciably larger separation between the substitution and accretion groups

> could have come about only if proactive interference were essentially eliminated for the latter.
>
> (Postman & Gray, 1977, p. 261)

The significance of this study lies in that fact that once again a relatively simple change in experimental methodology has led to the control of the most significant factor in the forgetting of conflicting new learning, that of proactive inhibition.

In the Postman & Parker (1970) study, under the A-C paradigm (which is functionally equivalent to our previously discussed A-D paradigm), it was found that retroactive inhibition was directly manipulated by the contiguous elicitation of both the old and the new information. In the Postman and Gray study the contiguous elicitation of the old and the new associations led to the control of the most robust of empirical phenomenon, that of proactive inhibition.

It is clear then that both retroactive and proactive inhibition can be controlled through the conscious and deliberate elicitation of the conflicting alternatives, which in part provides an answer to the question: Why elicit and practise the old way? The critically important answer is that we should do so because it permits us to control the effects on learning of both retroactive and proactive inhibition.

Extensive research in the field of science education has provided numerous examples of the accelerated forgetting of new concepts caused by proactive inhibition. In the following chapters I will outline the development of and specifically describe the conceptual mediation method for facilitating the cognitive process of conceptual change.

7 THE DEVELOPMENT OF CONCEPTUAL MEDIATION

In the preceding chapters I have attempted to show that a re-evaluation of teaching practice is required in relation to any approach in teaching for conceptual change. If, as is claimed by science educators, students must often become involved in major paradigm shifts to become scientists, or even to understand what it is to be one, then science educators are effectively involved in a major remedial undertaking. I have argued that conventional teaching alone will be ineffective in facilitating conceptual change due to the operation of a natural mechanism for conserving prior learning, that is, proactive inhibition. It is argued that any attempt to teach and, as is inevitably necessary, to re-teach a counter intuitive scientific theory will in effect lead to the construction of an AB/ABr paradigm and to its naturally associated accelerated forgetting phenomenon. Evidence was provided in the introductory chapter that this has been the experience of science educators since systematic research began in the early seventies. This state of affairs has led to considerable theoretical speculation amongst science educators about probable causes, and has also brought about the development of improved teaching strategies. The need, however, for a viable theory and effective methodology for conceptual change is still evident.

The revitalized perspective on the function and significance of proactive inhibition and the potential solution to the pragmatic problem of conceptual change, as outlined in the previous chapter, will be elaborated on within the context of the class-oriented

approach of Rowell & Dawson (1985), whose research was predominantly based on Piaget's theoretical model of equilibration (Piaget, 1970, 1971, 1977).

7.1 An Equilibrium of Piaget's Theory of Equilibration

Piaget's theory of equilibration was meant to be a general model of the progressive cognitive development of the individual. Whatever the shortcomings of the equilibrium model, and there are now acknowledged to be many (Brainerd, 1978; Karmiloff-Smith, 1993; Vuyk, 1981), it has performed for Piaget, and many others, one of the functions of a good theory: it has been very influential and has inspired a vast amount of valuable research.

Piaget's theory of equilibration (Piaget, 1983), given its emphasis on the active self-regulation of an individual's cognitive development, appears to be influenced by Kant's theory of apperception, as was Herbart's before him (Flugel, 1959):

> Although Kant's influence on psychology was much smaller than that on most other branches of philosophical study, he has nevertheless exercised an immense effect on the whole outlook and treatment of mental science...It was Kant who by his insistence on the unity of perception and the notion of an active self, which organizes experience with the help of the categories of space and time, was the forerunner of the modern schools of Function and Gestalt. Kant's "transcendental unity of apperception" is a complex and somewhat awe-inspiring doctrine to the novice in philosophy, but it led to a

> whole series of elaborate treatments of the psychological processes of apperception, from Herbart to Stout.
>
> (Flugel, 1959, p. 14)

As Boden points out, "Piaget's theory is praiseworthy for its 'Kantian' stress on self-organizing mental structures and cognitive transformations" (Boden, 1979, p. 154) and a reflection by Lorenz on his emergent understanding of Piagetian theory is noteworthy:

> All along I have thought that Piaget was one of those tiresome empiricists and only now, after studying Piaget's work on the genesis of the categories of thought, I have come to realize that he is really not so far removed from Kant.
>
> (Lorenz, quoted in Furth, 1969, p. 24)

A significant difference between Kant and Piaget however lies in the fact that Kant proposed innate categories of understanding, those of space and time, while Piaget sought to find a solution to the development of objective knowledge in a self-directed or autonomous construction of knowledge.

The central issue, which distinguishes Piaget's theory from rationalism, common sense and empiricist psychology, is that of the active construction of knowledge by the individual. A principal question for Piaget was how it became possible for an individual to overcome the imperatives of perception and egocentricity and so develop objective knowledge? His answer was to appeal to the notion of an active self-directed construction of objectivity, which he termed the process of

equilibration. For Piaget, cognition is not a mere sense-driven copy of the external world. It is instead a semiotic activity, in that we give meaning to what we see, hear and feel. All knowledge then, that the individual comes to have, is distinguished from the accretion of experience and is developed as a result of a progressive and conscious conceptual construction. Knowledge is therefore not imposed by maturation or simply by the influence of experience alone. All intelligent activity, all thought and all logic are self-constructed:

> Piaget's epistemology, therefore, is firmly committed to a constructivism: Knowledge does not pre-exist in some transcendent or transcendental realm, waiting to be discovered: it is generated by the individual in the course of its interactions with the natural world.
>
> (Kitchener, 1989, p. 155)

For Piaget the act of knowing is necessarily a transformation of the object by the subject. The knower is actively engaged in the generation of various kinds of abstract conceptual operations, transformations of existing knowledge by means of practical action in and on their physical and conceptual environment. Knowledge is no mere innate predisposition or sensory copy; rather, as we have seen, its development involves a dynamic semiotic activity. Because of this, Piaget felt it was necessary to explain the development of objective thought in the child in a new way:

> The traditional factors (maturation, experience, social environment) are not sufficient to explain development. We must therefore appeal to a fourth factor, equilibration, and we must do this for two reasons. The first is that

> these three heterogeneous factors cannot explain a sequential development if they are not in some relation of mutual equilibrium, and that there must therefore exist a fourth organizing factor to coordinate them in a consistent, noncontradictory totality. The second reason is that any biological development is, as we now know, self regulatory, and that self regulating procedures are even more common at the level of behaviour and the constitution of the cognitive functions.
>
> (Piaget, 1983, p. 120)

For many, equilibration has proved to be a difficult concept to fully comprehend. For Bruner the concept was of little value and he described it as "surplus baggage" (Bruner, 1959, p. 356). Boden (1979, 1982) argues that although the concept is vague and that it does not provide an explanation of cognitive development, she nonetheless believes that it does provide a necessary description of the problems of cognitive development:

> Piaget was right to identify autonomous differentiation as a very important, very general, and profoundly problematic phenomenon. There are great difficulties in conceptualizing coherent, progressive, self-regulated change, whether it occurs within cognitive structures, biological organisms, social systems, or scientific knowledge.
>
> (Boden, 1982, p. 167)

The difficulties that Piaget's theory presents for readers are perhaps because of the epistemological nature of the theory where the emphasis is not upon learning in the

traditional psychological sense but upon a new construct, that of equilibration (Kitchener, 1986, 1993):

> We never intended to substitute the model of equilibration for that of learning. The only question concerns the relation between them...equilibration is a precondition (necessary but not sufficient) of learning in the sense that every learning presupposes the intervention of activities not learned that bring about its equilibration...in fact every learning presupposes a logic and as this logic derives from a process of equilibration, equilibration is a necessary condition of learning.
>
> (Piaget, 1959, quoted in Furth, 1969, p. 237)

In this quote Piaget talks about the notion of things "not learned" bringing about equilibration. One way of understanding the notion of not-learned activities, is to view them simply as certain functional attributes of the perceptual process that results in learning. An important aspect of this however is to remember that the concept of learning itself refers to the measure of change in the individual that has already occurred; hence when we speak of the intervention of activities not changed, we are not only speaking of functional perceptual variables but also of the contribution to future learning or change, of the individual's prior knowledge. In this manner the influence of not-learned activities becomes more meaningful and presents a fair representation of what Piaget means here. It is also relevant to reflect on the notion that equilibration is a necessary condition for learning; but of course this is a special kind of learning. It is the change to existing assimilatory structures where the changes are not simply additions to existing structures but represent an accommodation or fundamental change of the assimilatory structures themselves.

Achieving accommodation, a change to a new understanding of a pre-existing concept, is demonstrably no simple achievement.

Equilibration then accounts for the autonomous and progressive development of knowledge from less well-organized to better-organized stages of conceptual development or in other words to a change in understanding. It is particularly important then to understand that, for Piaget, equilibration within the sphere of an individual's cognitive development represents a non-innate or learned process:

> In addition to maturational factors, social life or experience, which are those commonly put forward to explain development, we therefore have to take into account a factor of non innate coordination of acts, which operates during their actual functional unfolding and which may be called the equilibration factor.
>
> (Piaget, 1973, p. 45)

All knowledge that an individual develops, Piaget believes, is directly the result of a conscious, that is, self-directed and progressive process of conscious conceptual construction and reconstruction. Thus all intelligence, all thought and all logic are constructed and reconstructed by the individual, and this autonomous process is referred to as equilibration.

7.2 The Equilibration of Perception and Cognition

Piaget has however also proposed the existence of an equilibration of perception. Piagetian theory makes a distinction between the perceptual system and its

equilibration and the conceptual system and its equilibration. It is therefore necessary to distinguish between the biological auto-regulated processes of perception and the cognitive, self-regulated mechanisms of intellectual activity. A failure to make this distinction explicit leads to fundamental problems in understanding his theory:

> The fact that an equilibration of perception exists, and consequently a play of regulations characteristic of this field, is shown by the existence of certain perceptions useful for learning or improvement, which involve no recourse whatsoever to external reinforcements.
>
> (Piaget, 1978, p. 98)

That an auto-regulated mechanism of perceptual organization is a necessary condition for the operation and the development of an individual is readily acknowledged. The extent of this automatic regulation of perception is now recognized to be very considerable indeed:

> The now growing data on neonates and young infants suggests the existence of some innately constrained, domain-specific attentional biases or predispositions. The infant is not assailed by buzzing blooming confusion *a la* James (1892), nor by undifferentiated and chaotically assimilated input *a la* Piaget (1955). Rather from early infancy, special attention biases channel the way in which the child processes constrained classes of inputs that are numerically relevant, linguistically relevant, relevant to physical properties of objects, to cause-effect relations, and so forth.
>
> (Karmiloff-Smith, 1993, p. 593)

It is perhaps unfortunate then that Piaget has chosen to refer to this automated perceptual process as a form of equilibration, as there may be a tendency to confound two quite distinct constructs of equilibration. He does so, however, because of his commitment to seeing the development of the individual as being both of a biological and of a cognitive nature. The theory of equilibration, he tells us, cannot be understood unless we take into account the dependencies among three processes. The biological adaptation of the organism to its environment; the adaptation of intelligence, seen as in part dependent upon the equilibration of perception; and most important of all for his theory, to the achievement of a progressive cognitive development and functioning, also described as a process of equilibration.

For Piaget then there are two specific and complex processes that he calls equilibration. One is an innate biological and hence automatic process of perceptual organization. The second is a non-innate or learned process, the essential aspect of which is that it is autonomous or consciously self-directed. The latter process is the more commonly known and discussed construct of equilibration, which specifically addresses the development of cognitive functions by the individual.

7.3 Assimilation, Accommodation and Elimination

In Piagetian theory we begin and end with assimilatory structures, whether these are of a perceptual or of a cognitive nature. All development of an individual, whether physical or conceptual, is dependent upon the capacity of the organism to accomplish three activities. Firstly, to assimilate what it requires from the

environment and thus maintain its state of continuity. Secondly, to accommodate to the demands of the environment where necessary, that is, to change within the general constraints of the pre-existing assimilatory structures. Thirdly, and where necessary, to eliminate those aspects of what was originally assimilated that are unmanageable or not required by the system. Thus, clearly, accommodation is not a process as such but rather is the term given to the fact that specific measurable changes to the assimilatory structures have occurred and that they do so via the self-directed process of equilibration.

The terms assimilation and accommodation are used in a broad manner, characteristic of Piagetian constructs. For example, a child involved in imaginary play may creatively assimilate various objects to represent cars or planes; or sand from a sandpit may be used to represent the tea in a plastic bucket "teapot". Such imaginative and transient conceptual transformations of objects to meet the needs of the individual are described as involving a process of assimilation. We may be more inclined to think of assimilation as principally the activity of an individual making sense of some immediate new experience, but this is clearly not the defining example. A significant aspect of assimilatory structures however is their role in the continuity of the individual both physically and cognitively:

> If assimilation alone were involved in development, there would be no variations in the child's structures. Therefore he would not acquire new content and would not develop further. Assimilation is necessary in that it assures the continuity of structures and the integration of new elements to these structures.
>
> (Piaget, 1983, p. 107)

> The term accommodation, generally taken to mean a measurable change in the individual's assimilatory structures, is extended to include imitation of the action of an object or another individual. Thus a child may for the first time, imitate the sound of a dog or a cat, or use a new word and be described as having accommodated to the models provided. Yet this very broad use of the terms is also only meaningful within the context of what it is possible for the individual to actually imitate. This being so as a consequence of a principal role of assimilatory structures, which is the continuity of the structures themselves.
>
> (Piaget, 1983, p.708)

Piaget's model of equilibration offers disequilibrium, and that includes the disequilibrium caused by conceptual conflict, as the motive force of change (Piaget, 1978). It is experiential or conceptual conflict that leads to disequilibrium, and it is the resulting affective component of this tension that motivates a resolution, and so initiates conceptual adaptation through the self-directed process of equilibration. Conflict is seen to provide a motivating force, which is moderated by the developmental needs and interests of the individual:

> In our interpretation of the connections between any cognitive construction and outside disturbances with their resultant compensatory reactions...it goes without saying that an essential place should be reserved for need and consequently for interest. On the one hand, interest is the motivating force or value in any assimilation scheme...On the other hand, need is the expression of a schema's momentary non-functioning, and from the cognitive viewpoint, it thus corresponds to a gap or deficit.
>
> (Piaget, 1978, p. 83)

Piaget discusses three possible reactions to disequilibrium arising out of a challenge to an individual's assimilatory structures. One of these, and perhaps a base form of reaction, is the act of ignoring or avoiding the confusion caused by an experience. This behaviour is fundamental to the notion of elimination that Piaget offers as a necessary condition of any cognitive process of assimilation:

> When a new fact arises, it can, depending on the situation, produce no modification in the system (for example an additional object in a classification system prepared to receive it) or, on the contrary, it can constitute a disturbance...When a new characteristic is incompatible with a previous discernment, the subject, though perceiving it , will neglect it or will pretend to consider it but distort it in order to adjust it to the scheme retained for the discernment.
>
> (Piaget, 1978, p. 66)

A second reaction is effectively to try again in the sense of attempting to assimilate the conflict in a more deliberate way:

> (A) casual explanation contradicted by an unexpected fact will be completed or replaced by another explanation which takes the new factor into consideration.
>
> (Piaget, 1978, p. 67)

A third reaction is characterized by a continuing state of equilibrium brought about by the individual being capable of contiguously:

> anticipating the possible variations which, as foreseeable and deducible, lose their disturbance characteristics and establish themselves in the potential transformations of the system.
>
> (Piaget, 1978, p. 68)

This last possibility only makes sense when we look at how Piaget defines the state of equilibrium. Equilibrium in the cognitive sense is a special state of preparedness for equilibration or change and is distinguished from the imbalances of assimilation and accommodation that are possible in this complex theory.

> But as long as assimilation and accommodation are in equilibrium...we can speak of cognitive behaviour as opposed to play, imitation, or mental imagery and we are back in the proper domain of intelligence. But this fundamental equilibrium between assimilation and accommodation is more or less difficult to attain and to maintain depending on the level of intellectual development and the new problems encountered. However such an equilibrium exists at all levels, in the early development of intelligence in the child as well as in scientific thought.
>
> (Piaget, 1983, p. 108)

It is relevant to distinguish the perception of conflict from the actual accommodation or successful adaptation to the conflict at a cognitive level. It is one thing to register the conflict, but what happens if there can be no assimilation to, or accommodation of the existing knowledge of the individual? Here is where we anticipate the impact of the equilibration of perception to be noticeable, through the elimination of the conflict as a biological stimulus for the individual. The conflicting stimulus is eliminated as a consequence of the perceptual mechanism of accelerated forgetting.

The resulting retrieval inhibition permits both the ignoring of the perception and the continuity of the assimilatory structures of the individual's knowledge. The dual nature of equilibration is suitably illustrated by this common situation.

An illustration of the second kind of reaction to conflict is to be found in any attempt to write about Piagetian theory itself. This, of course, is only possible as a result of a process of assimilation and accommodation of the theory. It represents an adaptive change in the writer's assimilative schema as a result of an autonomous or self-directed equilibration. In the case where one is unable to initially comprehend an aspect of Piagetian theory this leads to disequilibrium and to a potential elimination of the concept or concepts, which may be critically relevant to an understanding of his theory.

Given the significant limitation to cognitive adaptation which the concept of elimination represents for many people, it is of interest to note that in the many reviews of Piagetian work, during the period of his greatest influence, the concept of elimination is not addressed (Donaldson, 1978; Boden, 1979; Flavell, 1963; Furth, 1969). Of all the reviews of his work Piaget considered Vuyk's (1981) to be the most concise and definitive work on his theory of genetic epistemology. Even in this work, however, the significance of conceptual elimination goes unrecognized, and is effectively eliminated in a few lines:

> If an object cannot be assimilated there are two possibilities. Either it is too far outside the range of what is "assimilable" and it is therefore just left aside by the subject. Or it is close enough to assimilable objects for the scheme to

> be changed so that, ultimately, assimilation becomes possible. This change is called accommodation.
>
> (Vuyk, 1981, p. 66)

Perhaps it is possible to set aside conceptual elimination without detracting overall from Piaget's theory. Perhaps, on the other hand, the inclusion of this dimension, that of the limits of assimilation and accommodation, is central to a clearer understanding of the process of equilibration and hence to a better understanding of Piaget's theory.

Piaget's formula for the process of assimilation (Piaget, 1983) is of special interest in that he defines the process of assimilation as involving both the integration and the elimination of certain aspects of the environmental offering. In outlining the process at the biological level of the organism it is presented as follows:

$$(T + I) \rightarrow AT + E$$

The symbol T, represents the individual and a particular cognitive structure; while the symbol I, represent the integrated substances or energies, this leading to the outcome represented as AT. In the formula, A represents the strengthening or change of the structure T, which may be in terms of the efficiency of T. Finally, we have E which represents the eliminated substance or energies. Piaget draws the analogy between the process of elimination of waste in biological systems and the elimination of conflicting aspects of experience in the process of human cognitive development:

> Hence, cognitive adaptation, like its biological counterpart, consists of an equilibrium between assimilation and accommodation. As has just been shown there is no assimilation without accommodation...In the same way, cognitively speaking, the subject is capable of various accommodations, but only within certain limits imposed by the necessity of preserving the corresponding assimilatory structure. In Eq1 the term A in AT specifies precisely this limitation on accommodations.
>
> (Piaget, 1983, p. 708)

This of course leaves *E*, elimination, which is described as "whatever in the stimulus situation is excluded in the structure" (ibid., p. 707). Conceptual structures that are not assimilated or may have been transiently assimilated but did not lead to accommodation, are eliminated so that they are no longer capable of being a biological stimulus for the individual.

Many students and teachers of science are most familiar with this phenomenon of elimination and would like to know what to do about the large amount of eliminated knowledge this represents. Piaget provides us with a descriptive metaphor for the difficulties of conceptual change but does not provide a solution to this pressing problem. Instead, he only gives reassurance of the necessity of the elimination process. The conceptual mediation strategy, which is derived from the work of Lyndon (1989) and Rowell, Dawson & Lyndon (1990), directly addresses the problems of elimination and hence conceptual change or accommodation:

> A major feature of Lyndon's theoretical framework for Old Way/New Way is his introduction of an unconscious brain function, which he calls

> proactive inhibition (PI), a feature additional to and not directly recognized by Piaget. Lyndon argues that PI varies in strength between individuals and that it operates to prevent the association of conflicting ideas; inhibiting recall of new knowledge in conflict with prior knowledge. The result is that subjects may have more than one conflicting explanation for an event, each likely to be tied to different specific cues. Lyndon's theorizing is potentially far reaching, and deserves careful examination. Within his expanded framework, PI is the "survival mechanism" apparent in the conservation of knowledge, and against which equilibration must battle for progress. And such facts as the retention by children of their own science, together with school science (or some poorly equilibrated melange of the two), and each accessed according to its own cues, are to be expected...Lyndon suggests the reason that Old Way/New Way is effective in promoting change is that it serves to reduce the effects of PI, and to promote retroactive inhibition (forgetting; lowering accessibility to the generator) of the "old" knowledge.
>
> (Rowell, 1993, p. 131)

7.4. Science Learning and Conceptual Conflict

The teaching and learning of science, due to the fact that it deals with an abstract representation of the world, is conceptually based rather than based in experience itself. In many ways science explains away our direct sensory experience. This fundamental perspective was an innovative "construction" of ancient Greek philosophers:

> The natural philosophy of the Ionians, simple as it is, comprises two elements. There is an element of observation and an element of thought. In

> order to explain the phenomena of the senses they had to invent a system of abstract ideas.
>
> (Farrington, 1949, p. 50)

Scientific explanations constantly challenge "common sense" and so confront the proposed mechanism of perceptual and conceptual continuity, that is, proactive inhibition. What this means from the perspective being presented is that the teaching of science is not achievable simply by the presentation of sound logical argument and appropriate empirical demonstration, even those eliciting conflicting interpretations. Whereas these are necessary conditions for learning about science they are not sufficient in themselves. What is also needed is a removal of any obstacle to conceptual change.

The facilitation of conceptual change becomes achievable only after it is recognized that common sense or intuitive knowledge must be treated as prior knowledge which will, due to the normal functioning of the proactive inhibitory mechanism, cause the accelerated forgetting of any conflicting, albeit "scientific", way of understanding the world. We have then the twin obstacles of personal intuitive knowledge and that of a mechanism of conservation. That these twin obstacles to conceptual change may be managed by using appropriate methods, and are not the result of any dysfunction in an individual's capacity to learn is a central theme of this thesis. As a well-known Australian science educator has written:

> Those who have been involved in this sort of research might believe that poor understanding is readily overcome by remedial teaching, but it turns out to be far from as simple as that. Attempts to alter misconceptions have

> found that beliefs are very stable, and that although it is easy to add new information to students' knowledge it is much more difficult, almost impossible, to get them to resolve contradictions between prior beliefs and what is being learned now. That is much learning is superficial, being done without deep reflection. Appreciation of this point leads to recognition of the need for training in meta-cognition.
>
> (White, 1986, p. 4)

It may seem counter-intuitive that the very teaching of science is fundamentally a remedial process. The frustration experienced by science teachers and their students at the apparent opaqueness of scientific thinking has attained for science educators the status of folklore. It may, however, appeal to the progressive science educator, that the teaching of counter-intuitive science itself involves the use of counter-intuitive pedagogical methods. It is, of course, conceptually easier on the sensibilities of science educators to refer to the process of the teaching of science as involving conceptual change rather than involving remediation. The notion of remediation has evolved a highly negative, value-based, profile. It has been argued, by a number of my own teaching colleagues, that the teaching of science to our brightest students must not be compared to the activities undertaken for remedial students.

For remedial students, it is "understood" that intellectual or environmental factors account for their lack of progress, and so specialist teachers and special methods are deemed appropriate. For science students, however, only the best teaching methods will do. There is of course no dispute with the argument that only the best of

teaching methods will suffice, but I question what such best practice might actually look like.

The teaching of science necessarily involves conflict between intuitive knowledge and accepted theoretical knowledge. Understanding that this interaction is moderated by proactive inhibition, which functions to maintain prior knowledge irrespective of its epistemological value, has significant implications for the construction of an effective science curriculum.

That students are creative and capable of developing intuitive theories is a main tenet of the constructivist perspective (Driver, 1982; Osborne & Wittrock, 1983; Pope & Gilbert, 1983). Students are, importantly, no longer seen as merely passive absorbers of formal scientific knowledge. As emphasized by Driver (1989, p. 481) there is a "compelling reasonableness" in the young students' "constructed" understanding and explanation of natural phenomena.

The role that reasonable, though limited, explanations or justifications play in the persistence of individuals' beliefs in the face of contradictory evidence has long been of interest to science educators. (Karmiloff-Smith & Inhelder, 1975; McCloskey, Washburn & Felch, 1983; Rowell & Dawson, 1983). The construction by students of a logical rationale for their views, in the face of formally presented conflicting evidence, has been seen by some science educators as majorly responsible for the remarkable persistence of particular misconceptions:

> Reasoners often dismiss contradictions by arguing that they (the conflicting events) address a different phenomenon and are not applicable to the event they were designed to contradict.
>
> (Burbules & Linn, 1988, p. 67)

From the perspective outlined in the previous chapters, such intuitively based, though reasoned, explanations or justifications would indeed, having been constructed by the individual, be protected from conflicting evidence or alternative explanations and so be conserved by the action of the organizational process of proactive inhibition. In the light of this perspective the use of "conflict" to facilitate conceptual change, although intuitively powerful and logically necessary, must be carefully reconsidered. Intuitions, reasoning, intuitive theories, conflict and proactive inhibition are odd conceptual companions.

7.5 The Significance of Discrimination Learning for Conceptual Change

An argument supporting the formal use of mediation and remediation in the facilitation of conceptual change was presented across the previous chapters. It follows from this argument that an understanding of the function of the proactive inhibitory mechanism would dissuade teachers from simply using re-teaching as the strategy of choice when they wish to teach for conceptual change. It is argued here that we may take control of the accelerated forgetting process to the degree that we can target a particular concept by the use of both stimulus and response discrimination. The use of the generic cues of "old and new" have been found to be of value affectively, but they are in this regard neither necessary nor sufficient

variables in the facilitation of conceptual change. What is apparently both necessary and sufficient to the process of conceptual change is the mediation of the differences between the alternative concepts, a notion of progressive differentiation, followed by a sufficient opportunity for the generalization or application of the preferred or "new" concept.

It is relevant to our discussion then to trace the occurrence of discrimination learning, that is, conceptual differentiation, in the works of Piaget (1978, 1979), Kuhn & Phelps (1982), Kuhn (1989), and Rowell & Dawson (1985), who all advocate disequilibrium or conceptual conflict as a motivating agent for conceptual change. These approaches will later be compared with the new method of approaching conceptual change being advocated here, one which has been empirically trialled by Rowell, Dawson & Lyndon (1990). An attempt is made to show that the progressive conceptual change evident in the above experimental situations is due in large part to the influence of discrimination learning on the degree of positive transfer of new knowledge.

7.6 Precocious Conservation: An Example of Precocious Equilibration

A particularly interesting experiment conducted by Piaget and Inhelder produced evidence of the possibility of what Piaget referred to as precocious conservation (Piaget, 1979). This precocious conservation, representing as it does a significant and developmentally unanticipated equilibration, was observed following an apparently minor change to the normal experimental procedure associated with the study of conservation by Piaget and his co-workers.

It is indicative of Piaget's broad ranging style of "model" building that an entirely new area of study in mathematics, that of correspondences and morphism, led him to an important revision of his understanding of the development of cognitive functioning:

> For a long time (some 50 years) transformations seemed sufficient for explaining cognitive development and sufficient for practical action, because a practical action always consists in modifying reality...But the study of correspondences and of morphisms has shown us that comparisons are quite necessary...Even though as comparisons they transform nothing by themselves, these comparisons are necessary for the discovery of transformations, because in order to discover transformations it is necessary to know the data and in order to know the data it is necessary to begin with a system of comparisons. But this comparison, essentially amounts to searching for resemblances...Differences do not give rise to correspondences.
>
> (Piaget, 1979, p. 26f)

Differences, that is, discrimination learning, may not give rise to correspondences or morphisms but they may indeed give rise to precocious transformation. Piaget's interest in this new area of mathematics led him and Inhelder to modify the procedure of a traditional conservation experiment in the following manner:

> Instead of deforming the little ball (of clay) into a sausage simply by pulling or pushing by hand, we take off a piece and we ask the children if the same amount of clay is in the ball. All the children tell us, "No, you have taken something away, there is less." Then the piece that was removed was placed

> on the other end...thus; a small piece was taken away on the left and placed on the other end on the right. The children were asked, "do we have the same quantity of clay as in the small ball before the transformation was made?" Now a very interesting thing happens- after the age of 5 1/2, on the average, three fourths of the children say immediately, "It is the same thing, you took it away and then put it back and it's always the same quantity of clay." Thus after age 5 1/2 these children arrive at a stable conservation. If instead of taking away and adding again, the traditional experiment in which a small ball is pushed into another shape is performed, the children tell us, "But that is still the same quantity, you have only stretched it."...There is a notable advance of the discovery of conservation due to this technique of taking away and adding again...(a) precocious conservation.
>
> (Piaget, 1979, p. 21f)

The change in procedure from the traditional experiment was minimal though significant. The opportunity to discriminate between a series of transformations of the ball of clay, prior to them being presented with the traditional transformation of the clay, permitted the children to confirm the conservation of the amount of clay despite the normally troublesome nature of such a transformation. Piaget, however, was himself not so interested in the importance of the issue of discrimination learning in this instance, despite his awareness of its relevance to his model of cognitive development. Piaget concluded the paper by pointing out that:

> We have, while working on this problem of correspondences and morphisms, glimpsed an aspect of cognitive development that for the most part had escaped us until now.
>
> (Piaget, 1979, p. 27)

Discrimination learning was a significant aspect of the procedure that led to the "precocious conservation" described by Piaget, but it appears to have been overshadowed by his consideration of the implications for an additional form of equilibration, that of correspondences.

7.7 Discrimination Learning During Problem Solving

Another example of the implicit importance of discrimination learning is that of Kuhn & Phelps (1982). In this study, Kuhn & Phelps proposed and trialled a problem-solving method, the aim of which was to facilitate the study of the process of conceptual development. They contrasted their problem solving approach from conventional training studies on the basis that they provided individuals with problems to solve and an opportunity to solve them. Conventional approaches, they felt, offered solutions or perhaps preferred strategies leading towards the desired solution. The development of this method had been influenced in part by the work of Inhelder & Piaget (1958) who had studied the ability of subjects to construct solutions to problems involving chemical reactions.

In the Kuhn & Phelps (1982) study, students in their fourth and fifth grade were asked to discover which of three liquids was responsible for a chemical reaction that was evident either by a change in the colour of, or the occurrence of a precipitate in, a reagent liquid in which all three test liquids had been mixed. Kuhn & Phelps made a number of significant observations during this study.

(i) They considered that they had provided data, which could be framed within a number of theoretical perspectives, data that any theory would need to be capable of explaining.

(ii) Some individuals showed evidence of very rapid change from what were termed inefficient to efficient strategies. The majority of pre-adolescent subjects, however, displayed a pattern of strategy change which:

> involved an extended period of highly variable performance in which valid and invalid strategies were used in conjunction with one another and appeared to compete with one another for dominance.
>
> (Kuhn & Phelps, 1982, p. 39)

The observation by Kuhn & Phelps that achieving change involved extended periods of confusion, is in contrast to the study conducted by Piaget & Inhelder (1979) described above. The opportunity to experience a series of deliberately ordered transformations of a ball of clay leads to precocious conservation. These were simple discriminations, e.g. after a small piece is removed from the ball of clay, the question is asked, "Is there the same amount of clay left in the ball?". Yet, left to their own devices, students in both the traditional test of conservation and in the Kuhn & Phelps study, only changed to more efficient strategies with great effort. This result highlights the need for teachers to present ordered experiences, rather than to just provide opportunities for their students to discover, and practise discriminations, which hypothetically, permit the facilitation of conceptual change.

(iii) Knowing the correct answer after an experiment was not sufficient to change a student's approach in novel or slightly modified problems. Changes to the context or detail of the experimental situation would, even when an individual had previously been successful on a similar task, usually lead to the recurrence of previously inefficient strategies. There was, then, strong evidence for a lack of transfer of the newly acquired strategies. Kuhn & Phelps considered this event to be a "most remarkable" aspect of the variability of strategy use shown by the students. From the mediational perspective being proposed here, however, such a lack of positive transfer would be linked to the factors of stimulus discrimination, response discrimination and response practice, none of which, under the conditions imposed by the study design would have been readily available to these students. The students were not offered a better theory or strategy to follow. They were instead only offered an opportunity to discover an effective strategy and to develop the associated metacognitive rationale for this.

(iv) Only frequent attempts at problem solving in which students applied "anticipatory schemes" led to what was termed "mastery of the problem". Such trial and error activities necessarily involve discrimination learning.

Two related achievements were identified as necessary in the attainment of performance mastery. For Kuhn & Phelps these were firstly the "need to perfect, or consolidate, the utilization of advanced strategies" and secondly to achieve "the abandonment of old ones." The latter problem was considered by these authors as both counter-intuitive and a considerable challenge to science educators who, in the main, concentrated on the development of new strategies:

> Virtually all the attention of developmental psychology has been devoted to the development of new strategies or behaviors, rather than the abandonment of old ones. The present findings, however, suggest that the second of these two achievements may pose the more formidable challenge, which is the reversal of the way we usually think about development.
>
> (Kuhn & Phelps, 1982, p. 40)

This challenge is central to the arguments presented in the previous chapters of this thesis. The change to a new way of performance is very much dependent on the functional abandonment of the old way. The manner in which this can be achieved, however, is only through the use of the very same "old way": which for many is a totally counter-intuitive strategy. It is not until individuals elicit and progressively differentiate both the old and the new way, that they are able to redirect the powerful accelerated forgetting effect associated with the operation of proactive inhibition.

(v) An interesting finding by Kuhn & Phelps, given the problems with conceptual change faced by science educators and students, is that the "exercising of existing cognitive strategies is sufficient to effect their modification." (Kuhn & Phelps, 1982, p. 36). The term "sufficient" usually refers to the notion of a sufficient condition for something, and is best juxtaposed with the terms necessary and necessary condition. It is for example a necessary condition of mammalian life on this planet that there is an appropriate level of oxygen present in the atmosphere. In itself however the presence of oxygen is not sufficient for such life. It follows logically then that the observation of mammalian life on this planet is a sufficient condition to infer the existence of an appropriate level of oxygen in the atmosphere. To say that the practice of existing strategies is "sufficient" to effect their

modification is a more powerful claim than to suggest that such exercise was simply necessary for their modification. The one certainty about these "exercises" is that they involve the individuals in complex discrimination learning. These complex discriminations arise between the various action strategies available to the individual, and the evaluation of their respective outcomes which are distributed over the course of the "repeated encounters" found to be necessary for task mastery.

Kuhn & Phelps, however, only present us with a description of extended periods of confused strategy use, changing from moment to moment in response to internally constructed anticipations. Furthermore, subtle changes in context permit the recurrence of inappropriate strategies, despite the apparent development and availability of more appropriate ones. It is relevant to note that it was Kuhn & Phelps' intention to observe the natural development of conceptual strategies within a non-directive problem-solving environment. So the notion of exercise is one that assumes that what are being exercised, at least initially, are the individual's pre-existing strategies. There was also the explicit assumption that there were to be natural opportunities to observe strategic changes:

> The subjects...are approaching the age when the particular cognitive strategies we are focussing on have been observed to emerge.
>
> (Kuhn & Phelps, 1982, p. 3)

(vi) The notion of the "sufficiency of exercise", has been a theoretical cornerstone of Kuhn's research. This construct is found in Kuhn & Angelev (1976), Kuhn & Phelps (1982), Kuhn, Amsel & O'Loughlin (1988), and also in Kuhn (1989).

> My thesis is that during this period of variable usage, subjects are not only gaining practice in the use of the more advanced strategies but they are also gaining in the metacognitive understanding of them. That is, why they are the most correct or efficient strategies to apply, what their range of application is and so forth.
>
> (Kuhn, 1989, p. 686)

That, during this exercise or "period of variable usage", the differentiation of possible strategies, in relationship to desired successful outcomes theories, is a fact which is implicitly recognized by Kuhn as important to progressive conceptual change. Further the notion of the sufficiency of exercise, although still retained, is somewhat attenuated. Kuhn points out that although the exercise of existing strategies may lead over time to progressive changes there may be better ways of achieving this end:

> The fact that our microgenetic research has shown exercise to be a sufficient factor to induce change allows certain inferences but not others. It does not imply that exercise is necessarily the optimal means for inducing change.
>
> (Kuhn, 1989, p. 687)

Kuhn's awareness of the limitations displayed in the development of the reasoning of some subjects, including their inability to differentiate between theory and evidence, and in the persistent recovery of less efficient strategies following minor changes to the experimental conditions, led her to two major conclusions. Firstly, that there was a real need to investigate the mechanism of transfer of newly constructed skills

across contexts, and secondly, that there was an important role for science educators in proposing and facilitating the development of alternative theories:

> What may need to be contributed from an external source, however, is the possibility of alternative theories. As noted subjects often cannot conceive of the possibility of an alternative theory to their own. Once alternatives are established and the subject is engaged in relating evidence to each of them, the contradictions inherent in applying different standards for different theories may eventually come to be recognized.
>
> (Kuhn, 1989, p. 687)

7.8 Teaching a Better Theory

Rowell & Dawson (1985) have effectively pre-empted Kuhn's (1989) conclusion that there was a need for the teaching of a better theory as a means of providing a facilitation of conceptual change. In this they were guided by the proposals of philosophers of science (Lakatos, 1974), who had pointed to the reluctance of scientists to abandon an accepted theory simply on the basis of a few anomalies that often arise during the collection of empirical data. Such unanticipated results were often taken to be indications that either the theory needed some adjustment or that perhaps some error had occurred in the measurement of the event. Lakatos's notion included the view that any research program has negative heuristic, which identifies certain basic assumptions representing the "hard core" of the program that are to be immune from attack. This is extended by the notion of a positive heuristic, which aims to guide the development of the theory in response to an empirical challenge to this hard core. It is only when a better theory is developed, and is proposed in order

to explain the anomalous results, that the scientific community is apt to consider change:

> There is no falsification, before the emergence of a better theory.
>
> (Lakatos, 1974, p. 119)

Rowell & Dawson (1985) successfully modified equilibration-based instructional strategies to make them more relevant to the world of practising teachers. This approach was based on four theoretical premises.

(i) Following the work of Kuhn (1962) and that of Lakatos (1974) they proposed that an individual's personal knowledge or intuitive theory will only be abandoned if a better theory is available.

(ii) The construction by an individual of a better theory is possible without having to confront the individual with the conflict between his own intuitive or overly simple theory and the better alternative.

This assumption arises in contrast to another equilibration-based and class-orientated approach to science teaching, that of Nussbaum & Novick (1981). Their approach was to use a "critical situation" or in other words an interesting though counter-intuitive experiment to stimulate the intuitive or simplistic ideas of the students. Having been elicited, these ideas are gradually brought into conflict with the alternative though "correct" framework, through a co-operative class discussion process:

> Our task as teachers is to expose pupils' alternative frameworks and attempt to create situations which will enable them to achieve accommodation with the scientific frameworks we would have them adopt.
>
> (Nussbaum & Novick, 1981, p. 772)

These two approaches differ in that Rowell & Dawson's method does not involve the use of conflict or confrontation until after the students have a viable alternative theory that they are able to articulate.

(iii) Students must have had sufficient experience with the better theory to permit them to recall significant aspects of the theory during the co-operative debate phase of the procedure.

(iv) The process of cognitive change involves the construction of both strategic (the how to) and the meta-strategic (the why it is so) aspects of the better theory. These conceptual categories are not required to be constructed concurrently. This is in contrast to the notion that strategic and meta-strategic knowledge is constructed concurrently, a feature of the approach used by Kuhn & Phelps (1982).

Is the concurrent construction of strategic and meta-strategic knowledge in any developmental sense natural? Rowell & Dawson do not believe that it is, and perhaps it is not what Kuhn & Phelps have concluded either. It might be argued that they have emphasized this point, and that therefore it is what they mean, but is it what they actually say? Regarding meta-strategic knowledge, which they suggest is gained over a lengthy period of problem solving practice (within a restricted domain), they in fact only speculate that the meta-strategic knowledge:

> played a strong role in the subject's eventual stabilization at the level of valid efficient strategy usage and, in particularly, in the subject's abandonment of the less adequate, invalid strategies.
>
> (Kuhn & Phelps 1982, p. 47)

As has been argued earlier there is no need to speculate about the role of metacognitive knowledge or about the role of the extensive periods of exercise, which, from a mediational perspective, are necessary but not sufficient conditions for conceptual change. I have argued that these observations are best interpreted from the functionalist, associative-interference perspective. Stimulus discrimination, response discrimination and the practice of the new response are all factors which will facilitate positive transfer of the new and alternative concept. Certainly, the meta-strategic consideration of the reasons why one theory is better than another is significant in a process of conceptual mediation.

What then is the significance of Rowell & Dawson's suggestion that the "better theory" should be presented prior to the introduction of deliberate conceptual conflict?

For practical reasons the better theory presented to students, is based as much as possible on their prior knowledge. This approach then presents a most significant opportunity for the reactivation of intuitively held opinions, beliefs and procedures that relate to a specific body of knowledge. Providing an opportunity for stimulus discrimination, response discrimination and response practice necessarily requires the construction of a better theory. This necessary condition for change may occur naturally over extended periods of exercise, as proposed by Kuhn & Phelps (1982),

or alternatively, and more efficiently, in the provision of a ready-made better theory as in the case of Rowell & Dawson (1985).

The question to be asked in relation to the latter approach is how it differs from the conventional approach used by classroom teachers when they provide students with a better theory. As a comparison between the two methods will show, the essential difference lies in the opportunity students are provided to differentiate between their original intuitive or simplistic theories and the proffered better theory.

Rowell & Dawson outline a six-step strategy, which they recommend be followed in order to facilitate the process of equilibration. It is referred to as the alternative scheme, AS, and is contrasted with a more conventional, or orthodox approach, O. In the orthodox approach it is assumed that there will be no deliberate attempt to separate strategic from meta-strategic knowledge.

(i) Rowell & Dawson's first step is to establish the extent of the personal knowledge that students possess relating to a particular concept. They refer to this generically as "Questioning" however it contains many elements including written responses to specially devised questionnaires. Many teachers avoid this important task, claiming that it is too time-consuming to collect and evaluate the "alternative" ideas held by their students.

This data collection is important in a number of ways. Firstly, due to the course of natural forgetting, it provides both teacher and student with written reminders of each individual student's beliefs. Secondly it provides the teacher with a valuable data

base from which to plan future interventions. It is important for teachers to be able to classify the various forms that student beliefs take in order to ensure that they are discussed during the intervention phase of the program.

(ii) Where ideas are presented by students as solutions, these are acknowledged and accepted as a possible way of responding to or solving a problem. It is the purpose of this step to specifically avoid conceptual conflict. The recording, by students, of these possible solutions is necessary to provide what Rowell & Dawson refer to as a "paper memory".

(iii) It is indicated to the students that a new theory is going to be presented which may provide a solution to a particular scientific problem. They are encouraged to take part in the construction of the new theory, it being suggested that their "help" is required to achieve this aim. It is also indicated to them that the new theory will later be evaluated against the range of possible solutions put forward earlier by the students themselves. It is at this point that it becomes clear that the alternative strategy specifically involves the construction of discrimination between the student's own solutions and the preferred solution.

(iv) The new theory is then taught to the class following the general principal of "linking it to basic knowledge already available to the class" (Rowell & Dawson, 1985, p. 335). This is done in the belief that, if such a method is followed, the new theory will be more meaningful and thus more memorable. Opportunities are provided for the practice of problem solving using the new strategy. If errors are evident in the construction of the new theory these are pointed out to the student.

The challenge however at this stage is not so much to the spontaneous or intuitive beliefs of students but rather to the rationality of the construction. It is only the logic of the reasoning that is challenged.

(v) Students are then tested on their ability to apply the new theory in action. It is important at this stage to maintain a record of their attempts at novel problem solving as this information will be used later to evaluate student progress.

(vi) A teacher-guided opportunity, that is a co-operative debate, is provided for the students to compare and contrast their original and their newly constructed theories. Making the students' records of their previous written comments and test results readily available to them assists this process of conceptual differentiation:

> The function of the teacher is to act as chairman and, if necessary, as *agent provocateur*. This ensures that any unnoticed knowledge gaps inherent in erroneous spontaneous beliefs are brought to light and pursued.
>
> (Rowell & Dawson, 1985, p. 336)

From the description of Rowell & Dawson's alternative teaching strategy it is clear that the central core of the method involves students learning to differentiate between their original and their newly constructed theories. When this approach was tested, however, the alternative strategy was limited in its success. The results provided only tentative support for the propositions that the separation of strategic and meta-strategic elements together with the use of conflict via co-operative debate would lead to improved learning and retention of the scientific perspective. This led to a re-evaluation of both the procedure and the theoretical rationale adopted by Rowell &

Dawson (1985) presented in Rowell, Dawson & Lyndon (1990), and more recently in Dawson & Lyndon (1997) which is presented in Appendix 5.

7.9 Changing Misconceptions: A Challenge to Science Educators

The Rowell, Dawson & Lyndon (1990) paper arose from a challenge presented to Rowell and Dawson by Lyndon during a discussion of the problems faced by science educators in facilitating conceptual change. Lyndon argued that a weakness of the co-operative-debate approach lay in the fact that there is an insufficient opportunity provided for students to overcome the conservative influence of proactive inhibition. The learning difficulties displayed by science students, it is argued, are psychologically identical to those experienced by students in other subject areas including those undertaking remedial work. Perhaps, by using the paradigm associated with the successful change of habits and skills, they might also improve the learning and retention of scientific concepts.

Adopting a mediational perspective meant that it was necessary for Rowell and Dawson to replace the informal and relatively unstructured co-operative debate strategy with the more formal mediational phase of the Old Way/New Way method. This phase of the method specifically involves a progressive elicitation and re-elicitation of the old concept and its differentiation from the new concept. Within this phase the activities of eliciting the old, eliciting the new and progressively differentiating between them is fully repeated five times. From his work in applying the method to the mediation with spelling and simple mathematical problems,

Lyndon has established that the method is still effective when due to practical considerations a group of students share the task of describing the progressive differentiation of the old from the new. It is fortunate for both teachers and their students that the mediation with a new way by a group of students sharing a similar old way is almost as effective as mediating with individuals on a one to one basis. There are, of course, natural limitations to any group-learning process. The direct relationship between learning and a student's voluntary attention, and the greater opportunity for individuals to be distracted within a group setting compared to individual instruction, are major examples of such limitations. These practical difficulties are true of learning in classrooms in general; however it has been noted that students using the mediational strategy display a strong interest in the performance of their peers. This social phenomenon has the effect of actually improving the attention of students to the subject under discussion by the group.

To test Lyndon's claim that a method for changing habits and skills could be adapted to facilitate conceptual change, a study was conducted by Rowell, Dawson & Lyndon (1990), the full details of which are presented in Appendices 7 & 8:

> Does Old Way/New Way work? More to the point, does it work any better than co-operative debate? To make a start on answering this question we chose as our topic the explanation of displacement volume, and obtained the assistance of a local primary school with three, non-streamed classes of Year 7 students. On the basis of knowledge gained from previous work with volume (for example, Rowell & Dawson 1983), we predicted that many students at this year level would have

> misconceptions concerning the explanation of displacement volume. We were not disappointed.
>
> (Rowell, Dawson & Lyndon, 1990, p. 170)

In this study three separate teaching approaches were applied and evaluated:

> To test the efficacy of Old Way/New Way in comparison with co-operative debate, three teaching strategies were devised and randomly paired with classes. Class A was taught the better theory, that object volume explains displacement, and followed this with co-operative debate of selected questions. Class C was taught the better theory, and followed this with the Old Way/New Way strategy. Class B was given the Old Way/New Way strategy only.
>
> (Rowell, Dawson & Lyndon, 1990, p. 171)

The results of this study were significant in two main ways. Firstly, the replacement of the logically structured but informal co-operative debate with a formal mediational strategy, directly tied to specific components of the students' preconceptions, led to a significant improvement in learning and the retention (five weeks later) of the scientific concept:

> What has been illustrated here, however, is a striking additional effect achieved by requiring students to go through the sequence of mental actions needed for the equilibratory replacement of their misconceptions.
>
> (Rowell, Dawson, & Lyndon, 1990, p. 74)

The two classes A and C, that had been presented the better theory, differed only in the strategy used to follow up the initial differentiation of the competing concepts. The co-operative debate class, class A, showed an overall 36 per cent retention of the new understanding of the relationship between object volume and displacement volume. Class C, which had mediated between their specific preconceptions and the new concept, following the presentation of a better theory, showed an overall 73 per cent retention of the new concept.

These results are significant from the theoretical perspective being developed here as there is a direct parallel between the results of the Baxter et al. (1997), study presented earlier in Section 5.9, and this study of conceptual change. Retesting of the Year seven students had been deliberately delayed for five weeks in order to provide an opportunity to observe the long-term retention of the concept taught. Like the vocational education students who had received conventional remediation, class A demonstrated accelerated rates of forgetting of the new concept. Although certain individuals had transferred to the new way (seven of 19 students from class A), the quasi-mediational nature of co-operative debate places this result within expectations. The more positive results obtained by class C on retest, were similar to those obtained by the vocational education students using the Old Way/New Way method (Baxter et al., 1997). The results from both groups showed that accelerated forgetting had been successfully redirected by the inclusion of a mediational phase in the teaching strategies used. In class C, 11 out of 15, or 73 per cent, of the students, showed long-term retention of the new concept of volume. This illustrates that the group had only shown the degree of forgetting associated with normal rates of forgetting, that is, the rate of forgetting of information which has been practised but

is not in conflict with prior knowledge or experience. Taken together, the results of these studies support the claim that the use of a mediational learning strategy can control the phenomenon of accelerated forgetting normally associated with the learning of a conflicting activity or concept.

A second and equally significant aspect of this study was the fact that the use of an Old Way/New Way strategy without the initial teaching of a better theory is generally ineffective. Only one student out of 16 had retained the new concept on retest following the five-week retention interval. Despite the use of the method to mediate between specific exemplars of the new concept and the students own views, that was undertaken with class B, the Old Way/New Way strategy was insufficient for the long-term retention of the new concept. On the surface this may appear a surprising result. When an individual mediates between habits or skills using the Old Way/New Way strategy it is anticipated that there will be approximately 80 per cent transfer to the new way. This has been the consistent experience at an empirical level for many years (Baxter et al., 1997; Lyndon, 1979, 1989, 1995). The general effectiveness of Old Way/New Way with habits and skills demonstrates that we are, under these circumstances, usually able to control the effects of accelerated forgetting.

Why then, were the results of class B, which used the Old Way/New Way strategy, so poor in comparison to their peers? The answer to this question lies in the fact that, in a mediational paradigm, what must be elicited and then progressively re-elicited is the student's specific prior knowledge, not merely examples of its application. In the case of class B there was no effective elicitation and re-elicitation of the students'

prior understanding of volume. Despite numerous demonstrations of both conflicting and consonant events being presented and discussed with these students in a formalized mediational setting, there was no real opportunity for the students to sufficiently reflect on their own prior knowledge or on the new concept itself. This opportunity was provided to both class A and class C. These students received twenty-five minutes of detailed better theory presentation that provided a natural opportunity for the elicitation of their own understanding of object volume and its relationship to displacement volume.

It was the failure of students in class B to retain the new way, compared to the success of students in class C, that highlights the distinction between Old Way/New Way as a method for changing habits and skills, and its application to the more complex activity of conceptual change. Although the steps of the two procedures are effectively the same, with conceptual mediation it is the old concept itself that must be elicited and mediated against a conflicting but better conceptual framework. The use then by science teachers of conflicting exemplars can be seen only as a necessary but not a sufficient condition for conceptual change. As both Kuhn (1989) and Rowell & Dawson (1985) have independently concluded, there is an important role for science teachers both in presenting new theoretical frameworks and in so teaching them that they facilitate the learning and the retention of these better conceptual frameworks.

Where someone mediates between the different spellings of a word, they are not usually attempting to change the meaning or concept that the word represents. The spelling of the word "said" as "sed" does not imply that the individual

misunderstands its meaning. Instead, it is the habitually incorrect spelling, that is, the representation of or sign for a particular idea, which they wish to change. For example, with commonly misspelled words like: sed (said), seperate (separate), accomodation (accommodation), Wensday (Wednesday), etc., there is no sense in which the meanings of the words are changed by adopting the new spelling.

The spelling of homonyms, or near homonyms, words that have similar pronunciations but different meanings (for example there, their, they're; which, witch; practice and practise) obviously cannot be learned without knowing which meaning is intended. It is therefore necessary to include in mediation a context which indicates the meaning.

Let us take as an example of the relatively common problem of the homonyms there and their. In the primary years of schooling many students substitute one of these homonyms for the other. Usually it is a case of the over-generalized use of one of the pair to represent both meanings, rather than a complete substitution of one for the other. So for example a child may write: "Look, there it is. It is a really nice house and it is theirs!" Dealing with such an over-generalization demands that the problematic words be placed into a meaningful context. Whereas with the spelling of a word the elicitation simply requires that the individual spells the word his or her own way first, when dealing with the correct choice of a word the elicitation requires using the word in context. Hence a suitable sentence containing the target word is elicited. The new spelling is then substituted for the old spelling within the sentence and the two sentences and word meanings are then differentiated.

The above preparatory phase is followed by the mediational phase (five repetitions of the old and new and the differentiation between them) which in turn is then followed by the application phase (six generalizations of the new way of applying the word "their"). The individual writes six novel sentences applying the correct usage of the word. With this example, the sequence would be as displayed in Table 2 below.

The point of this illustration is that unlike the case where an individual mediates between the habitual spelling of a word and its correct spelling, the *meaning* of the word itself becomes an essential aspect of the mediational learning process. It is no longer just the spelling of the word alone that is relevant. It is the specific meaning of a particular spelling that must be differentiated from the competing alternative spelling and its meaning. The use of sentences to provide the necessary meaningful context for the mediation between the conflicting representations is analogous to the conditions necessary for the mediation between any conflicting concepts.

Extending this notion to the mediation between commonsense views of the world and the rigorous conceptual structures of science, for the learning and retention of scientific concepts to occur it is necessary for there to be an active and comprehensive elicitation of an individual's prior knowledge. And as Kuhn (1989), Rowell & Dawson (1985) and Rowell, Dawson & Lyndon (1990) have found, this elicitation is considerably facilitated by the presentation of a better theory that is in conflict with an individual's prior knowledge. Not only is the initial teaching of a better theory valuable in the elicitation of the student's own understanding, it is also a necessary condition for conceptual change.

Table 2

Mediating a "there" for "their" spelling substitution.

ELICITATION	PRESENTATION	DIFFERENTIATION
It was there house.	It was their house.	"There" refers to place while "their" refers to ownership.
OLD WAY	NEW WAY	MEDIATION
It was there dog.	It was their dog.	Describes the differences
It was there car.	It was their car.	Describes the differences
There cat was purring.	Their cat was purring.	Describes the differences
There house was big.	Their house was big.	Describes the differences
It really was there car.	It really was their car.	Describes the differences

GENERALIZATIONS
It was their turn to do the shopping.
Their house was right next door to the shop.
Look over there, is that their missing dog?
Have you seen their brand new car.
I really like their new house.
Their cats are always chasing the birds.

Unless an individual is confronted by conflicting experience or by a conflicting alternative perspective, there is no psychological impetus for change. The presentation of a better theory thus plays a dual role in the process of learning for understanding. It is both a facilitatory factor in the elicitation process and a necessary though not sufficient condition for conceptual change. Having established that there is a need for change, one is then confronted by the necessity of overcoming the natural obstacles to change, these being associative interference, unlearning, transient retroactive inhibition, and proactive inhibition and the accelerated forgetting that results from its operation. These natural processes all contribute to the mind's tendency to maintain its conceptual continuity. The emotional states of confusion and, more significantly, of perplexity indicate the operation of these mechanisms. However, if left to themselves, these emotional states are resolved by the mind reverting to its pre-confused or pre-perplexed state.

This is the story of associative interference and proactive inhibition and, significantly, it is now clear that any individual has the freedom of choice to control the mind's natural tendency for conceptual continuity. Through the cognitive process of mediating between the conflicting alternatives, the probability of conceptual change is considerably enhanced. The process of conceptual mediation permits the majority of individuals to control the natural but psychologically complex process of conceptual change.

8 CONCEPTUAL MEDIATION IN A SCHOOL SETTING

Conceptual mediation has been used as a learning strategy in the teaching of science and mathematics at William Light R-12 School (formerly Plympton High School) since 1994. In that year, with the support of the Principal, Mr. R. Henderson, Lyndon and two experienced science teachers, Lloyd and Wilkinson, began a collaborative action-research project into the application of Lyndon's theory and method of conceptual change. This ongoing action-research project has come, in a generic sense, to be referred to as the Conceptual Mediation Program (CMP).

Over this time Lyndon, Lloyd and Wilkinson collaboratively explored many of the complex pedagogical and psychological issues that were raised in the practical applications of conceptual mediation. Lyndon's early role was in providing the teachers and their students with a working model of learning for conceptual change. A wide-ranging series of discussions were held on many fundamental issues associated with science education. The topics of these discussions ranged from basic classroom management practices to the practical problems associated with the preparatory and mediational phases of the method to consideration of the implications for science curriculum that such a new approach to learning for understanding presents for science educators:

> As a teacher of mathematics and chemistry of many years experience, I have found it professionally exciting to observe the changes in my students as they have taken on board this new approach to learning and have achieved

> standards far in excess of my expectations. Because the students are more subject literate and less confused, their reading and problem solving skills are far superior. As they come to realize that success in maths or science is a reality rather then an improbability, they become more "on-task", there are few discipline problems, and attendance improves. There has been a major turnaround in student attitude – from one where they expected to be entertained to one where they see that effective application to their work leads to predictable success – and the reward is the thrill of understanding.
>
> (Wilkinson, 1999, p.15)

Over the past five years this group has also been involved in professional development of many science educators within both public and private secondary schools across South Australia (Lloyd, 1999; Lyndon, Lloyd & Wilkinson, 1995, see Appendix 8) and also more recently in the Australian Capital Territory at Canberra and Lanyon High Schools. Over this time, we have received considerable support from science teachers for the continued practical development of the theory of conceptual mediation:

> It is apparent the CM (*conceptual mediation*) theory "makes sense" to peer teachers in providing both a theory of identifying obstacles in instruction, and techniques students can use to attack these obstacles.

> The CM team have conducted (teacher in-service) sessions which have been well-received by peers. This is indexed by evaluations conducted upon conclusion of the workshops, as recorded on anonymous feedback sheets. We have read these sheets and can comment that the feedback is strikingly positive and unambiguous. The CM team should be commended

> for constructing in-service sessions that meet a strong need amongst our teachers, and for developing successful communication strategies in this connection.
>
> (Yates & Biggs, 1998, p. 7)

It is clear from our discussion with many science teachers with whom we have worked that there are many practical obstacles to the teaching of science for understanding inherent in the design of current curriculum, and these obstacles must be addressed as a matter of priority.

8.1 General Procedural Sequence

As a result of our collaboration, a general sequence that the teachers would follow in introducing conceptual mediation, and in its application to specific topics, was established and is presented below:

(i) A learning model that explains the need for mediational learning strategies is presented to students. Students are encouraged to develop competency in the recommended cognitive strategies, which they should apply to the learning for understanding of science concepts. A version of the teacher/student handbook, modified for use as a general mediational learning training manual (Lyndon, 1998), is included as Appendix 9.

(ii) Having selected a topic, the teacher elicits the students' associated knowledge, beliefs and ideas raised by this issue. This can be achieved in a variety of interesting ways such as small group or whole-of-class brainstorming sessions, small-group discussion and poster preparation (for later class presentation), the

preparation of concept maps or more simply by the written response of students to a pre-test on the topic. The construction of a suitable pre-test can be guided by the review of students' misconceptions in Driver, Squires, Rushworth, Wood-Robinson (1994). The records of these activities are retained by the students and/or the teacher for use during future preparatory and mediational phases of the program.

(iii) Prior to the presentation of any new topic, particular attention is given to the scientific terminology that will be presented. Wilkinson argues that it is essential that students' personal understandings of important terms be elicited and clearly differentiated from the scientific use of these terms. Wilkinson's position was derived empirically during his twenty-five years of teaching prior to his involvement with conceptual mediation, and his perspective is clearly supported by the research of Gilbert, Watts & Osborne (1985), Vygotsky (1987) and Sutton (1992). The active differentiation of words used in a scientific manner from their common sense usage is an important aspect of the process; it is considered to be a necessary condition for the successful mediation between students' understanding and the scientific concepts associated with a particular topic. For example, students' problems with the general notions of force and motion are greatly facilitated by the prior differentiation and mediation between their own and the scientific use of terms such as acceleration, speed and velocity. Some teachers find it an unusual step to present word lists as a pre-condition for the teaching of a new theoretical framework. However, in this we are also guided by Ausubel's notion of advanced organizers (Ausubel, Novak & Hanesian, 1978). In this instance we are applying the notion very broadly to include the terminology that students will meet in the teaching of the new concept, and that we anticipate they will find confusing.

(iv) Next, the teacher explicitly teaches the new concept and provides opportunities for students to rehearse important aspects of it. This enables later comparison with old perspectives that are initially presented to the class by the students themselves. The fact that we have explicitly taught the new concept and also differentiated the appropriate scientific terms from their commonsense foundations is no guarantee that the students will be freely able to recall the relevant scientific ideas. The problem is not one of teachers having inadequately taught the scientific concept, it is instead a problem arising from a conflict in understanding; it is this conflict which leads to the accelerated forgetting of the new concept. This significant problem can be resolved by the use of the conceptual mediation method.

(v) There are three separate phases in the conceptual mediation process: the preparatory phase, the mediational phase and the application phase. In the preparatory phase the teacher facilitates the re-elicitation of the students' old concept and its comparison and differentiation from the new scientific concept. At this stage the material collected during the original elicitation of students' ideas can be presented again to facilitate discussion of their old perspectives. It is essential for the resolution of the natural phenomenon of accelerated forgetting that the students learn to differentiate between the conflicting perspectives. The students' perceptually constructed preconceptions and alternative conceptions must necessarily be re-elicited at this stage and again during the mediational phase.

In the mediational phase of the method the recall of the new concept, and its active differentiation from the alternative perspectives, is fully repeated, in a progressive manner, five separate times. The term "progressive" means that when this reflective process is undertaken by the class or by an individual there is a growth in the

individual's awareness of how the alternatives differ. There is importantly, also, a corresponding increase in the capacity of the individual to articulate any such similarities and differences. As has been observed in other applications of the mediational learning process (using Old Way/New Way to change habits and skills), at least three progressive differentiations are necessary for the re-direction of the accelerated forgetting effect to be initiated. This re-direction of the accelerated forgetting from the old to the new knowledge is then consolidated over the following two differentiations.

Once the mediational phase is completed, the new concept is then generalized to at least six novel applications or problem solving situations.

(vi) The use of a formative test/summative test evaluation strategy has proved to be a useful way of demonstrating to students the value of mediational learning. Students readily observe the difference in learning outcomes of using either practice or the relevant mediational learning strategy (Old Way/New Way or conceptual mediation) for correcting errors made during formative testing of a subject. The independent use of mediational learning strategies by students, during homework, to deal with conflicting habits, skills or concepts is encouraged. Specific recommendations regarding homework and its important role in learning are presented in the training manual (see Appendix 9).

The mediational learning methods of Old Way/New Way and conceptual mediation and the explanatory learning model offers students the opportunity to adopt a metacognitive perspective and to learn specific cognitive skills that facilitate learning for understanding.

8.2 The Influence of Conceptual Mediation on Learning

An independent evaluation of the influence on student learning of conceptual mediation was commissioned by the South Australian Department For Education Training and Employment late in 1998 and Yates, a psychologist from the University of South Australia, was appointed to undertake this review. This ongoing study has to date investigated the general impact of conceptual mediation upon students' attitudes to learning. Yates' decision to concentrate firstly on this more general aspect of the program's goals was motivated by his interviews with the principal and teachers in the school and also with feedback from visitors to the school.

> The primary goals of CMP involve helping young people to acquire scientific knowledge with greater facility and to achieve a deeper level of understanding in their studies. However, in the course of developing the program and encouraging students to use CM procedures as consistent mental aids, the teaching staff began to be impressed by the feedback they were receiving in the area referred to as *positive learning attitudes*. It was felt that students who had participated in classes in which CM procedures had been employed continued to display and maintain high levels of interest and engagement within their studies. This feedback appeared to emerge also in discussions with school visitors; i.e. visitors were apparently impressed with high levels of motivation and task engagement within classes being taught via CMP.
>
> (Yates, Henderson, Higgs, Lyndon & Wilkinson, 1999, p. 2)

While this aspect was the major focus of this first evaluation, Yates plans a further investigation, which will focus more specifically upon the comparative changes in

students' understanding of scientific concepts as a result of their use of conceptual mediation.

Due to a variety of practical constraints the conceptual mediation method and its explanatory learning model has not been introduced to all students at the school. Its introduction was restricted to those classes taught by Lloyd and Wilkinson and supported by Lyndon. Of the total of 177 students involved in the study, 73 students from Years 8-10 have been taught by these teachers. This circumstance provided Yates with what he termed a quasi-experimental situation:

> We were able to capitalise on the fact that by the end of 1998, almost one half of the students in Years 8, 9 and 10 had participated within CMP classes. The other half of the students in those levels had not experienced CMP teaching and therefore constituted a natural comparison group. The CMP had been administered to intact classes. Although it cannot be claimed that student allocation to classes is ever a "random" process, the different classes were not ability streamed, and to our awareness the classes can be viewed as directly comparable. (Yates et al., 1999, p. 2)

The results of this relatively large cross-sectional study of all the students from Years 8 to 10 demonstrated that the project has, over time, an unanticipated and beneficial effect on student attitudes to learning and to school:

> We can interpret the current data as indicating that CMP is associated with highly desirable educational outcomes of benefit to young people striving to adjust to the demands of current schooling pressures. We submit that

> any educational procedure or curriculum innovation that can claim to be associated with positive motivational indices, reduced school hostility, and less malaise, has to be taken very seriously.
>
> (Yates et al., 1999, p. 8)

Another significant result noted by Yates was the effect upon students' voluntary attention to the learning task:

> My...student and colleague, Geoff Higgs, conducted classroom observations of a Year 10 Science class using an observational procedure. The engagement level, averaged across a 40 minute period, was 94 per cent. This represents time-on-task, or engaged learning time, and we know from a significant body of data the average engagement level in the average room is likely to be 65 to 70 per cent, and any figure over 80 per cent is considered excellent.
>
> (Yates & Higgs, 1998, p. 1)

Our own informal observations of classes from Years 8 and 9, taught using the method, had likewise indicated that time-on-task, that is, personal involvement in the learning process, was significantly higher than in conventional science classrooms.

These additional results might be attributed to a combination of factors, firstly, to the students' improved understanding of the collaborative nature of learning and secondly to the emphasis that the teachers placed on eliciting and then mediating between the students' and the scientific language used in a new topic (Wilkinson, 1999). Conceptual mediation is a language-based conceptual change procedure. It is now well understood that, for an individual, the meaning of any word develops

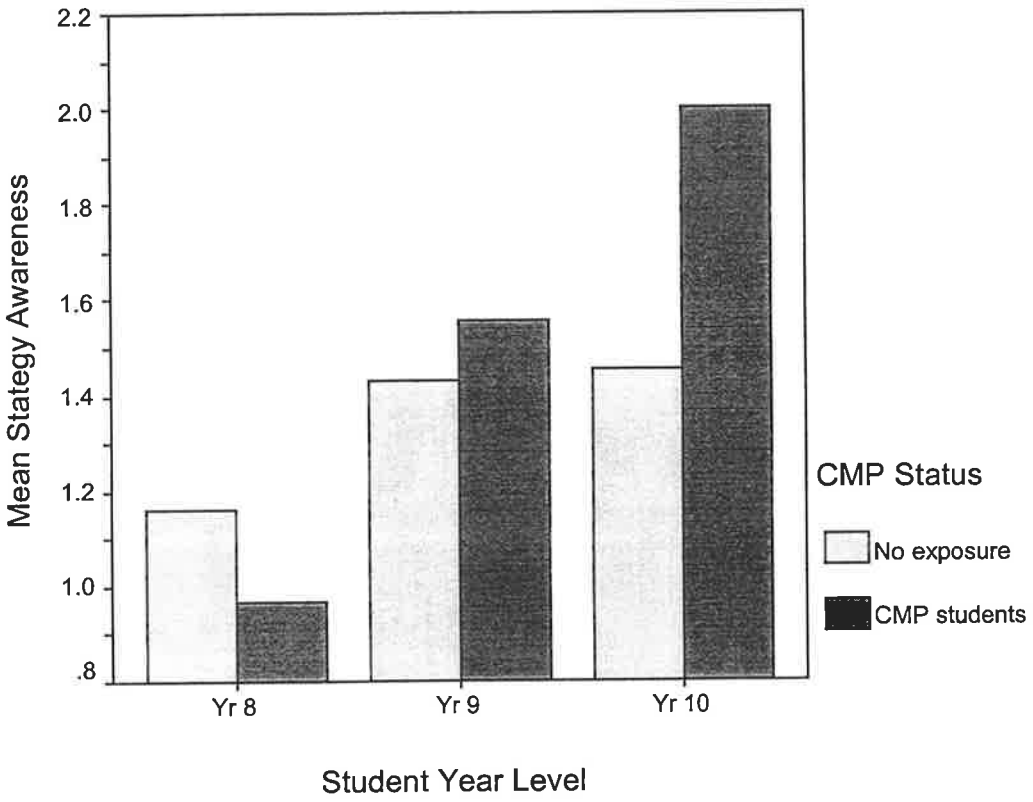
over time and is a significant variable in the process of conceptual development (Sutton, 1992; Vygotsky, 1987). Thirdly, and perhaps most importantly, the improvement in personal involvement during science lessons may be attributed to the understanding that students acquire about how to control the learning process when they are confronted by conceptual conflict.

The students in the Yates study were evaluated using two questionnaires: (i) Student Perception of Difficult Subjects Scale and (ii) Magill Personal Belief Questionnaire, which included one item that required students to provide a written response. A "probe" question was used to evaluate students' awareness of problem solving strategies:

> In our administration, the Magill Questionnaire also contained an item that requested that students write their own answers to the following probe: "*Suppose you have a very difficult problem to solve in mathematics or science. What sort of things could you do to help you work on this problem?*" Responses to this item were coded by two raters using the following scheme: 0 "no meaningful response", 1 "non-specific response", 2 "viable strategic response cited", and 3 "response suggests integrated or sequential strategies to a mature level". It may be noted that dependency on others (e.g., "*I would ask for help*") was rated as 1. Agreement amongst the two raters was 96% with disagreements reconciled through discussion.
>
> (Yates et al., 1999, p. 3)

Yates (1999) presented the results for this specific item in graphic form, shown in Figure 2 below.

Figure 2: Strategy awareness across year level and "CMP status"



Source: Yates et al. (1999), p. 7.

From this chart it can be seen that there is a progressive increase in the sophistication of approach to problem solving ability by students using conceptual mediation across the year levels, although this sophistication is statistically significant from that of the comparison group only at Year 10:

> The CMP status by year level interaction term was also significant ($F(2,174) = 3.44$, $p = .034$), due to the fact that at Year 10 the CMP students evidenced higher scores relative to the control students ($F(1,55) = 5.42$, $p = .024$).
>
> (Yates et al., 1999, p. 2)

It is of interest to note that there was no change in strategy awareness between Year 9 and Year 10 when the students had not used the conceptual mediation strategy.

Results also showed an improvement, over Years 8-10, in positive attitudes as a function of year level and "CMP status" (see Figure 3 below) a change which paralleled the changes shown for strategy awareness shown in Figure 2. There was also a significant decline in negative attitudes towards learning shown by these students, presented in Figure 4 below. It is of interest that here again there is no difference in mean negative learning indicator scores between the Year 9 and 10 students in the non-conceptual mediation group. More detailed statistical information is presented in Appendix 10.

Figure 3: Positive attitudes as a function of year level and "CMP status"

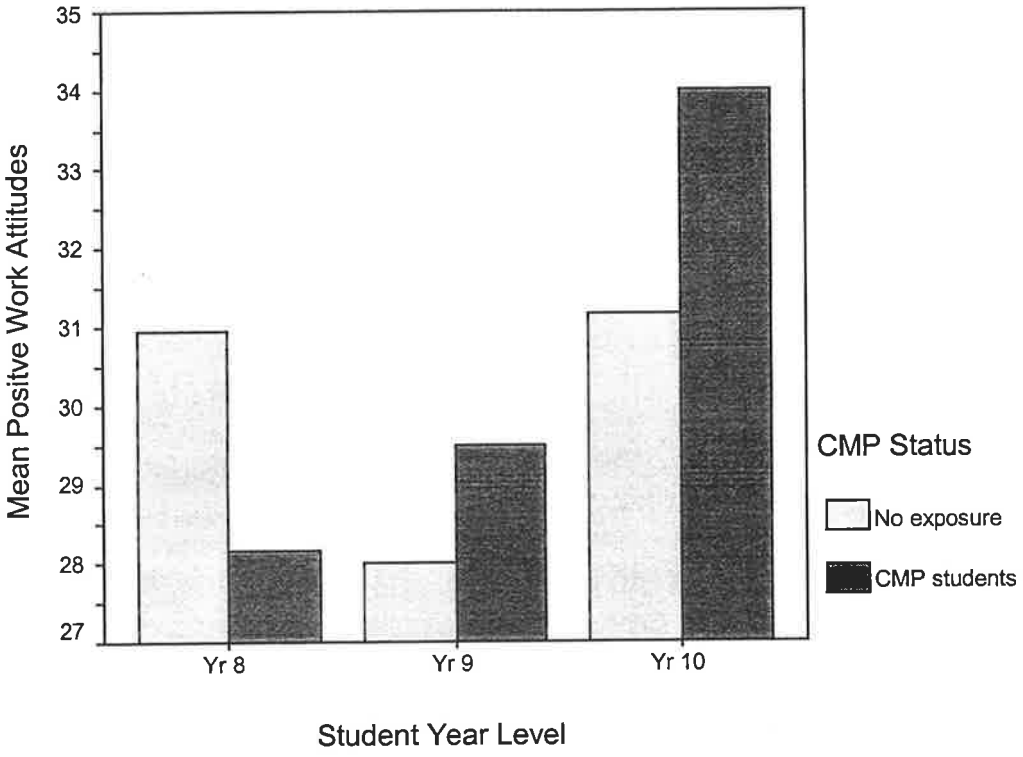
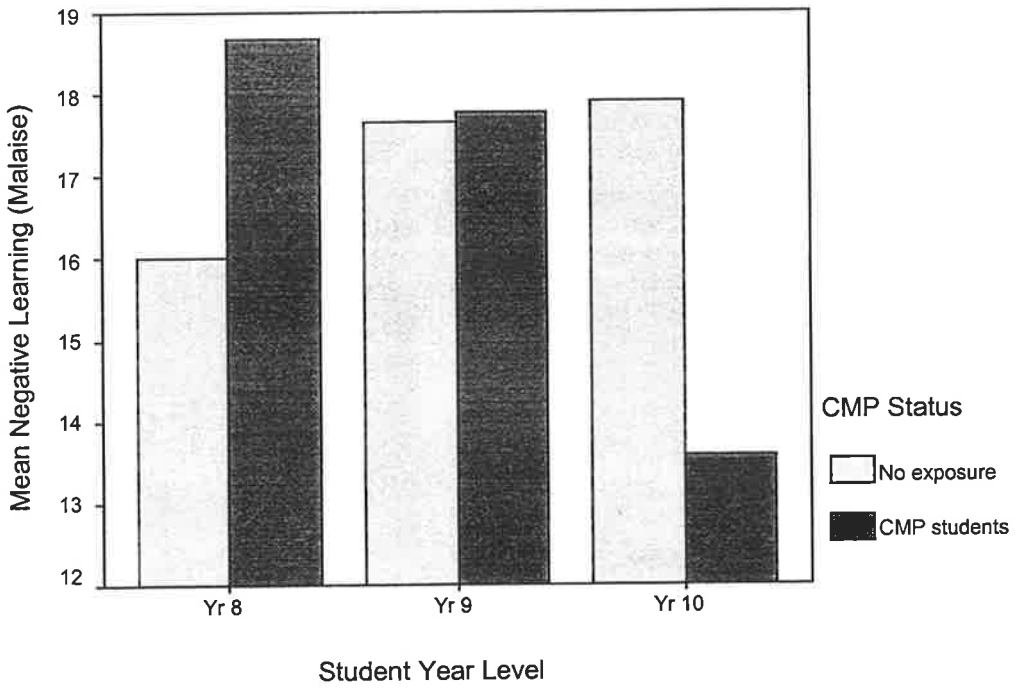
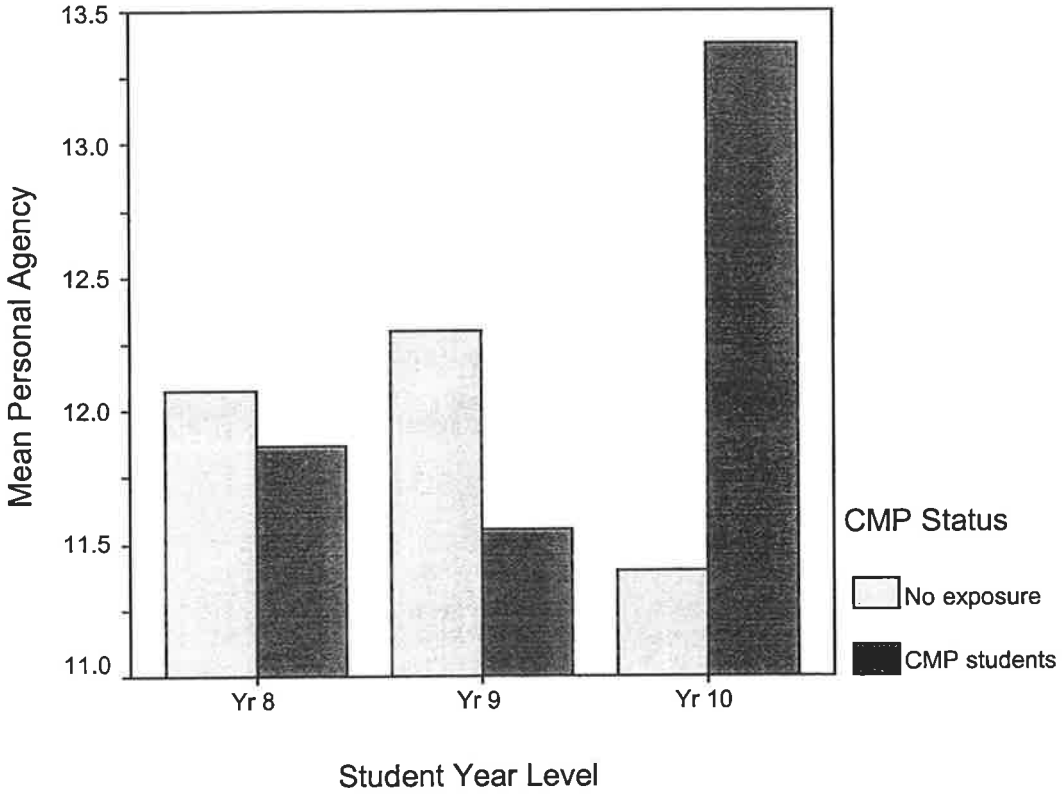


Figure 4: Negative learning indicators (malaise) as a function of year level and "CMP status"



Source: Yates et al. (1999), p. 6.

Figure 5: Personal agency as a function of year level and "CMP status"



Source: Yates et al. (1999), p. 5.

As Yates notes in his discussion of these results:

> One curious feature of the current data set is the almost linear increase in positive traits from Years 8 to 10 in the case of the CMP classes, as depicted in Figures 3, 4 and 5. Perhaps the students are "happier" via CMP by Year 9, and then begin to perceive real personal benefits by Year 10? These interpretations are well beyond the current data set, but they do suggest that the benefits of CMP are gradual and cumulative. The motivational impact of CMP may reside in that students are able to maintain high levels of *optimism and positivity* about their studies, and also about their ability to successfully negotiate the demands of an increasingly demanding curriculum.
>
> (Yates et al., 1999, p.8)

It is relevant however to contrast the results represented in Figure 3 with those represented in Figure 4 and in Figure 5, as shown above.

It would appear from Figure 3 that students in Year 8, who had been introduced to the mediational learning model feel less "personal agency", which can be understood as confidence or optimism (see Yates et al., 1999, presented as Appendix 10), and greater negativity or "malaise" than their peers who had not. This differential between the two groups of Year 8 students could be seen as a negative result for the project. However, the questions used by Yates in the "personal agency" section of the Magill Questionnaire do not permit a straightforward interpretation of the results. Questions like, " It takes a good deal of time and effort to acquire knowledge" and "When I see the problems we are expected to do I feel very incompetent" are particularly contextually bound. As Yates has pointed out:

> But what of the findings at Year 8 in which participation within CMP was associated with less desirable outcomes? We do not know how to interpret these data. But two explanations are (a) there is a cohort effect in that one of the CMP classes appeared to contain a number of dissatisfied students who do appear to be influencing their peers, and (b) it could be that learning CMP is initially an "awkward" method which may encounter some resistance from initially unwilling learners more accustomed to more traditional and passive "knowledge-soaking" arrangements. That is, the Year 8 students, in their transitional year, may be uncomfortable in learning via alternative methods.
>
> (Yates et al., 1999, p. 8)

As a consequence of having worked closely with these students, I interpret these apparently negative results as a reflection of a central goal of the project, that is, that students take personal responsibility for their learning. Students regularly complain to their teachers about the additional effort that is necessary when using the mediational learning strategies recommended to them. Although the majority of students complain, sometimes quite assertively, about the extra effort involved they also, almost begrudgingly, acknowledge that their academic results are considerably better than before the project commenced (see the following section for student interviews relating to this issue).

This confronts teachers with an interesting and challenging period during which both they and their students accommodate to the reality of a "least-effort principle" associated with learning to change what one already knows. It comes as no surprise that, when the least effort possible to achieve relearning of inappropriate habits,

skills or misconceptions is far greater than students may desire, a natural reluctance to undertake the activity is felt and expressed.

Taken together, the results of Yates' study gives a picture of a relatively long but academically beneficial transition from old beliefs and practices about learning to more effective and overall more efficient learning strategies. I believe that this picture is an accurate description of the situation at William Light R-12 School in 1999. We have learned much about the obstacles that confront us as science educators, and are actively seeking new ways of communicating these important new insights about learning for understanding to our students. Some students from conceptual mediation classes entering Year 11, both in 1998 and in 1999, have, due to their advanced level of understanding of scientific concepts, been invited by their teachers to study for Year 12 publicly examined subjects in science. This indicates that one of the project's aims, that of teaching for understanding, has been particularly successful for many of the students at William Light R-12 School.

8.3 Student Interviews and Student Evaluations of Old Way/New Way and Conceptual Mediation

The following two interviews, of students at William Light R-12 school, were conducted by a visiting senior teacher of science from Canberra High School. Of significant interest is that the comments made by these students mirror the results of the survey conducted by Yates et al. (1999), which we have just reviewed. This is particularly evident in the students' descriptions of their initial aversion to using mediational strategies, that is both Old Way/New Way and conceptual mediation, followed by descriptions of their experience of the academic benefits of the program and their eventual understanding that the program is of value to both them and their peers.

The interviews were an impromptu event and this is reflected in the nature of the questions put to the students. The selection of students was semi-random in nature, being influenced by the availability of students at that particular time.

This first interview is between Rosemary Koina (Senior Science Teacher, Canberra High School) and two Year 11 students Laura and Kate. Both students had been taught and had applied the recommended strategies of mediational learning in Years 8, 9 and 10. Although a Year 11 student Laura was one of a number of students who had, due to their advanced understanding of chemistry, accepted the offer to study the subject at a Year 12 (publicly examined) level.

Rosemary: Laura I wanted you to tell me about your experiences with conceptual mediation.

Laura: Well, I started conceptual mediation in Year 8 with Mr Wilkinson, and to start off with not very many people in the class, probably in fact most of the people in the class, really didn't like the idea of it because…they didn't like the idea of having their old ways shown to them. So, they didn't want to know that they were wrong. They thought their way was fine, but when we starting using the program, throughout the year, people accepted that it does eventually help you. You have to actually think and work out what's wrong and the differences between everything; but I guess the people still don't like the idea that its time-consuming. And, because I'm doing Year 12 chemistry now...we use it in every lesson, even if we don't know about it. He still...he writes notes on the board, and if someone says the wrong answer, he sort of does it quickly with them, and we sort of understand it; but it is very time-consuming for a Year 12 course because there is so much in the syllabus to learn, so it takes a while. And I had to do a formative test one day, and it was all on molecules and their structures and I'd got some of them wrong with the positives and the way like dissolves like and things like that, I got that wrong, so I had to sit there and go through my differences and I ended doing about 20 different...I had 20 things wrong or so and I had to do conceptual mediation 20 times. And I think the thing that I did, because it took me so long, was that I actually wrote too much, I didn't...compact it into small things to remember later on.

Rosemary: So are you finding that it is helping you to learn.

Laura: It is helping me to learn, because last year I didn't have Mr Wilkinson for maths, so we didn't do conceptual mediation at all, and all that we had was we did a sheet each lesson to learn the new way of working out triangles and the areas of squares and thing like that and...then we go straight on to a test

at the end of the week. But by the time we got the test, even though the test was open book, you had to think back. You took a while to remember where it actually was, and how to actually do it. I mean the formula might have been written out on the page, but then you had to remember where to substitute the numbers into the formula, so my grade actually went down last year because I wasn't using it.

Rosemary: Kate can you tell me about your experiences with conceptual mediation?

Kate: I did conceptual mediation when I was in Year 8 with Mr Wilkinson. I did it for maths and science, it helped me with a lot of things but...I didn't like having my wrong ideas brought out and put in front of me. I hate it when I'm wrong but it did help with some things and in Year 9 I didn't do it because I didn't have Mr Wilkinson but...my grade did go down a lot.

Rosemary: That's interesting isn't it?

Kate: In Year 10 I did (*conceptual mediation*) with Mr Wilkinson in Science and my grade went up…my understanding of what was going wrong.

Rosemary: And this year in Year 11 you don't have Mr Wilkinson do you?

Kate: No.

Rosemary: And, so you're not using it?

Kate: No.

Rosemary: But you don't use it yourself either. Why don't you use it yourself?

Kate: It's time consuming, it gobbles up time...with the work, like, that I am doing because I'm doing subjects outside of school hours, I don't have too much time in which to take something out and practise a lot.

Rosemary: OK and what about you Laura, when you didn't have Mr Wilkinson you didn't use it. What was your reason for not using it?

Laura: I guess the reason I didn't use it was because the teacher didn't. I mean we knew we were going wrong but we didn't, we weren't exactly shown the actual problem that we were getting wrong. We asked the teacher what was wrong but all he would do would turn the question around and say well how do you think? How do you do it, so we would show him then he would then scribble down on a piece of paper how to do it right and you just go back and do it and then after a couple of minutes, like, what did I do there? I might have got the answer right but through the procedure we got it wrong.

Rosemary: So you didn't understand where your error was and you couldn't work that out for yourself, and that's why you needed the teacher's help?

Laura: Yep!

Rosemary: Is that the same with you Kate?

Kate: Yeah...you kind of need the teacher's help just to say, look this is what you're doing wrong. If you want to get the right answer this is the procedure, and you go through step by step by step, and you practise those

steps and you can actually remember how to do it so even if you have a test a long way away you can still remember. I mean I had a problem remembering the formula for glucose.

Rosemary: Right?

Kate: So I practised that, and, but I didn't practise what the formula was for, so it came to this year and I still remembered that formula, but I had to find out what the name was!

Rosemary: Oh, so you knew your $C_6 H_{12} O_6$, but you didn't know that was glucose?

Kate: Yes.

Rosemary: OK, so you hadn't, sort of, tethered this to your understanding and you need your teacher to help you do that to find it.

Laura: Just to mainly point out where you're going wrong and start you off.

Rosemary: Right, OK, what's been most difficult to you, in using conceptual mediation Laura?

Laura: I think the main problem is time, and when we first started we saw the same difference every time. And as we get older, I think, we have to actually, see the, read between the lines, and see the other differences that are really there rather than just the physical ones.

Rosemary: Thank you very much, is there anything else Kate that you wanted to say about conceptual mediation?

Kate: Well, it's actually become clear to me that it is not a waste of time, and as you get older, with more work, you really have to find the time in which to do (it). Otherwise, you just forget, and you always just reinforce themselves, you never really learn anything!

Rosemary: What about you Laura, is there anything you would like to say?

Laura: I'd like to say that conceptual mediation is a good program; but I think people need to realize that although it may be boring in the start, and with growing up and going through school, you come to harder and more complicated concepts and you actually have to sit down and understand what they are to go onto the next thing, so I think you should use it.

Rosemary: So for you it works?

Laura: Yes it does.

Rosemary: That's your understanding?

Laura: Yes.

In this second interview, Rosemary is speaking to two Year 10 students, Tim and Luke, who had used mediational strategies in both Years 8 and 10 but not in Year 9.

Like Laura and Kate they too had had an opportunity to reflect on the differences in their personal academic achievement under differing teaching methodologies.

Rosemary: I noticed you doing some algebra in class with Mr. Wilkinson…is there anything in maths Tim that you find very hard?

Tim: …not really…at the start of the year it was a bit hard for me but it's pretty easy now. I'm getting good grades in my tests.

Rosemary: What do you think caused that change?

Tim: Just the way Mr (*distracted by Luke*) our approach to it, how he teaches.

Luke: I think it's how he teaches it, Old Way/New Way.

Tim: Conceptual mediation.

Luke: Yes.

Rosemary: How did you feel about it, when you first started doing it?

Tim: I didn't really like it that much.

Luke: Bit of a bore!

Rosemary: Bit of a drag eh?

Luke: It helps your education.

Tim: Looking back on it, I think it was worthwhile.

Rosemary: So, did you have anything specifically, that you could say, oh look this I really didn't understand and this is what we did with it?

Luke: Yeah, done that before.

Rosemary: Can you think of an example?

Luke: …well, no, I haven't personally, because I've, like, done all right this term like last term

Rosemary: (*Rosemary repeats the question for editing purposes.*) Luke can you think of any specific examples that you had really a lot of trouble with in maths?

Luke: Can't really think of it, just, …I've been doing pretty well in my tests and doing all right with school work.

Rosemary: Had you been using conceptual mediation before this year?

Luke: Ah, in Year 8 with science.

Rosemary: Did you have Mr Wilkinson?

Luke: Yeah with Mr Wilkinson, yeah, I didn't do too well in science though.

Rosemary: OK now, what about you Tim, you can't think of a specific example?

Tim: ...no.

Rosemary: But you're pretty convinced that it helps you?

Tim: Yeah

Rosemary: What convinced you?

Tim: ...just the extra study, learning it more.

Rosemary: And what made you realize that this was a better way to learn?

Tim: My grades where picking up, getting a lot better marks.

Rosemary: Were you finding the work easier to do?

Tim: Yeah a lot easier.

Rosemary: Now Luke, you said to me that there were some things that you found a bit, you know, it was a bit boring to start with. What exactly did you mean by that?

Luke: Yeah just like going over it over again, just learning it.

Rosemary: That's really interesting I've tried it with some of my Year 9 class and they say, "Oh ...5 times!", is that how you felt?

Luke: Yeah.

Rosemary: Would you, do you, do it yourself ever at home on anything your struggling with?

Luke: Most of the time we have to, if like, …we have a practice test just to see what we're in for, and then, we like, …if we get something wrong then we have to do corrections, and learn it 5 times, so we get it right in the test.

Rosemary: Would you voluntarily do that at home?

Luke: Yeah I probably would, just to get good marks, because like in our last test I got I think it was 23 out of 29 for our...practice test, and in the real test I got 29 out of 29.

Tim: And the old way to the new way.

Rosemary: So do you have trouble figuring that out sometimes?

Tim: …yep.

Rosemary: So what do you do when you're at home trying to figure it out?

Tim: …usually ask mum or dad.

Rosemary: So your parents understand about mediation too?

Tim: Yep.

Rosemary: That's great you can get that help isn't it?

Tim: Sometimes yep.

Rosemary: Do you use it or do the teachers use it?

Tim: Oh I use it, the (other) teachers don't use it, just Mr Wilkinson mainly.

Rosemary: What do you think about that?

Tim: I think it's not that good. I reckon that most of the other teachers should, because it helps the students learn a lot more.

Rosemary: OK Luke, what do you think the other kids think about mediation?

Luke: I think that they think its like a bit of a bore, but…its good because like you learn a lot more, because I've been getting Cs and Bs, and marks, I've gotten like an A, it helps a lot more!

Rosemary: Do you use it yourself in other classes?

Luke: Nah I haven't been, but, I reckon they should like introduce it to the other teachers.

Rosemary: Right, why do you think that?

Luke: Because it helps a lot.

A much earlier evaluation of the effectiveness of mediational learning was undertaken during 1993, by a class of junior-primary students from Hawthorndene Primary School. It is included here because of the unique nature of the student evaluation that occurred during a visit made to their class:

> An impromptu visit to Pam Sims' combined Year 1-2 class led to some rather unique feedback from her students on their attitudes to the use of the Old Way/New Way method. Pam, had for unrelated purposes, introduced her students to a dynamic rating scale strategy used for students' attitude measurement. Put simply the children would arrange themselves, across the front of the classroom, in a physical representation of their position on an imaginary attitude rating scale, ranging from zero to ten. A child who ranked the issue a zero would stand on the left-hand side of the room, while a child who ranked her attitude as a five, for example, would stand in the middle of the room, and so on. During an informal discussion with the class regarding their interest or otherwise in the Old Way/New Way method, one of the students suggested that we should apply the rating scale that they had recently used for rating their preferences on another topic. This idea was greeted with great enthusiasm by all the other students, and so Pam and I, swept along by the students' enthusiasm, found ourselves in the middle of an interesting feedback session on the use of Old Way/New Way.
>
> Pam was the first to ask them a question, and it had an affective quality to it: "Do you like using Old Way/New Way?" The room became a mass of little people racing around with obvious delight to their chosen spot in the room. Allegiances were formed and then just as suddenly broken. There was much discussion within groups although not necessarily about the topic! Then, all

was quiet, in stilled expectation, the students looked to us to ask them why they had chosen their particular place in the room.

The distribution of the students was as follows;

Six students chose the ten side of the room, four children the middle and eleven the zero end of the room. Being unfamiliar with this procedure I did not ask each individual student their chosen rank, that is the specific number they had allocated to their opinion, but did so for a second question asked later.

The opinions offered by the zero-liking for Old Way/New Way group (the ranking was announced by the students themselves) were as follows;

> "It's boring and you could be doing other things instead."
> (This opinion was held by at least half of this group.)
> "It's boring, you have to do it more than once!"
> (Interestingly, this statement was immediately responded to by one student from the ten group who said, "But you don't learn if you don't!")
> "It's a bit too boring because you keep doing it over and over again!"

The opinions of the middle group were as follows:

> "I'm a five and sometimes it's boring and sometimes it's not."
> "I'm a three, I think it's boring but it helps you a lot!"

"I'm a five, I like doing it a bit, it's sometimes really boring and sometimes it isn't."

"I can do it, the good thing is you don't have to do it 20 times."

"I'm a five, some words that you do take a long time."

From the ten group, the opinions presented were as follows:

"I'm a ten, I like it because you learn words. I have a tutor that comes to my home. I've got really good and now she will only come two more times!"

This was particularly important feedback as the student had been having significant learning difficulties and had already repeated a year of schooling. He was a delicate, introverted boy and his improvement in self-confidence, since the introduction of Old Way/New Way, was well illustrated by his heartfelt feedback.

"I'm a ten, I think it's quite easy to do the Old Way/New Way sheets, but it helps you a lot."

"I like it a lot, because my brothers don't like school I like to be smarter than them both!"

Due to the obvious value of this type of approach to attitude measurement another question was asked. This question was "Does using Old Way/New Way help you?" Again the children burst into activity. It was a delight to watch them find their place in the room on this new issue. The thoughtfulness

with which the children chose their place was very evident. The distribution was as follows:

Rank order:	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Frequency:	**10**	**3**	**0**	**1**	**1**	**1**	**2**	**0**	**0**	**1**	**3**

As can be seen from this distribution there was a strong belief that Old Way/New Way did help even though, as we saw from the first distribution, not everyone liked using it! The comments elicited from the students in response to this question were also very informative. Of the group that ranked the helpfulness of the method as zero or as a one we find that these are students who either didn't need to use the method or believed that they didn't.

"I know most of my numbers and words!"

"I know lots of my words and so I don't need to use it."

"I don't think it helps me because I know a lot of words. I don't need it!"

These opinions affirm the students belief that they do not need the method and so logically it was seen as of little or no help to them. Whether this was true or not for all of these students is another issue. Other comments were as follows:

"I'm a four. It sort of helps."

"I'm a five. It helps me a lot and it doesn't help me sometimes. The old way gets back into your head and so you keep getting muddled up."

"I'm a six. You forget it straight away." (I did not ask which she forgot straight away, I presumed it was the old way!)

> "I'm an eight. Sometimes it helps me and sometimes it doesn't. I'm always trying to be smarter than my brother."
>
> "I'm a nine. I think it helps you a bit, like when you have a test and then have done it Old Way/New Way and you probably have got it right the next time."
>
> "I'm a ten. Yes, it helps me a lot."

> This rather unique evaluation method was certainly greatly enjoyed by the students, by the class teacher, and by myself. It provided a valuable insight into their attitudes towards the use of the Old Way/New Way methodology and indicated that at a relatively young age students recognized that it was a valuable learning approach even though they didn't always enjoy using it.
>
> (Lyndon, 1993, p. 5ff)

These interviews represent only a small sample of the empirical data that has been collected over the five years of this action-research project. They were chosen for inclusion because they provide support for the results of the independent evaluation of the project undertaken by Yates (Yates, et al., 1999). They also well illustrate the wide range of students' initial and subsequent attitudes towards mediational learning.

9 CONCLUSIONS

In the preceding chapters I have presented a new theory and a new methodology for conceptual change. However, it is always necessary to ask the question: are the theory and the method really new, or do they merely represent a rediscovery of already existing, if perhaps forgotten or misunderstood, ideas and practices? It has become evident, from the reading of the broad range of philosophical and psychological theories, both historical and contemporary, that was necessary in order to develop a coherent theoretical view, albeit of a predominantly psychological nature, that there is perhaps little in the perspective that can be claimed to be completely novel. Certainly I would claim the re-interpretation of interference theory presented in this work as novel, and hopefully of long-term interest and value to future researchers in both psychology and in education. Another claim to novelty lies in the formalized practice of mediation itself as exemplified in Old Way/New Way and in the more complex process of conceptual mediation. The systematic Old Way/New Way procedure, found to be necessary for changing habits and skills, was developed empirically, that is, without reference to any specific theoretical perspective. The new interpretation of associative interference theory has not only provided strong theoretical support for this practical methodology but, as has been argued earlier, actually anticipated the existence of such a methodology. The final claim to novelty lies in the procedure for conceptual mediation and in its application in the classroom. This more complex methodology was developed in collaboration with a number of colleagues, namely, Rowell and Dawson from the University of Adelaide, and science teachers, Lloyd and Wilkinson, from the William Light R-12 School.

9.1 Historical Antecedents of Conceptual Mediation

However, despite these claims to novelty, there are certain historical antecedents of the conceptual mediation approach, which can be found in the Herbartian teaching method, in Plato's description of the Socratic method and in Dunlap's contribution to our understanding of learning and his recommendations for changing habits.

Fundamental to Herbart's pedagogy was the psychological process of apperception. Apperception was understood as a process by which new ideas were assimilated or eliminated by the influence of the individual's apperceptive mass associated with a particular idea, that is by the dynamic influence of an individual's prior knowledge:

> The task of the Herbartian teacher, then, was to discover how to progress from one concept to another and how to ensure the assimilation of new ideas to old. Herbart himself proposed that teaching method should proceed in four steps, but these were elaborated by later Herbartians to five: The first step, "Preparation", ensures a revision - a bringing back to consciousness - of old knowledge with which the new is to be related. "Presentation" the second step seems to indicate that the teacher will now tell the new facts, illustrate the new procedure, or demonstrate the new experiment. The third - "Association" - in a class lesson, corresponds to the stage where the teacher helps the class to analyse the new knowledge or experience and to compare and contrast it with the old. The teacher's role is to assure that psychological apperception is securely achieved - good teaching depends on efficiency at this stage. The fourth stage of the Herbartian system is "Systematisation" which, for the modern teacher, is mainly a matter of recapitulation or reviewing what has been learnt, and coming to some conclusions about it

> with reference to its wider significance. The consideration of further subsidiary evidence may be involved, particularly in science and the humanities. The final stage, "Application", is clearly the practising of the new skill, the use of the new knowledge in the other contexts, the use of the discovered rule to solve other problems.
>
> (Curtis & Boultwood, 1964, p. 361)

There is a clear and significant parallel between the prescriptions of the Herbartian teaching model and those of the practice of conceptual mediation. The first step, "preparation", is a process of elicitation of the old ideas or concepts. The second step, "presentation", is equivalent to the teaching of the "better theory". The third stage of the Herbartian model, that of "association", is where emphasis is placed on the role of the teacher to facilitate the process of apperception. It is also at this same stage in the conceptual mediation strategy that teacher and students would formally mediate between the conflicting concepts. This closely links the notion of mediation, and its goal of controlling the process of accelerated forgetting, to that of Herbart's psychological process of apperception. Herbart did not however directly propose the existence of an accelerated forgetting mechanism nor did he link the steps in his pedagogy to such a specific phenomenon. There is little doubt however that the two methodologies effectively deal, in a significant way, with the same phenomenon and in a similar manner. The conceptual mediation method places specific emphasis on the progressive nature of the mediational process and on the requirement for an optimum number of opportunities for conceptual differentiation. The remaining steps of the Herbartian method, that is, "Systematization" and "Application", are, from the description given above, self-explanatory. In the conceptual mediation strategy a process similar to "application" is undertaken immediately following mediation and

is referred to as generalization. In the Herbartian system, this activity is only undertaken following a review of the new learning and some attempt at evaluation of the concept's wider significance. The stage of "systematization" describes the integration of specific new knowledge into an individual's more general understanding of a topic, a necessary activity for any pedagogy. This important activity would normally be undertaken following the generalization phase of conceptual mediation. It represents a separate and necessary learning activity for students to undertake that may expose their need for further conceptual mediation. The significant parallels between conceptual mediation and Herbart's general pedagogical theory of apperception may well encourage some educators to revisit this once very influential but now largely forgotten pedagogy.

As proposed at the end of Chapter 2, which was devoted to the Socratic method interpreted here as a pedagogy for conceptual change, we find that Plato does not explicitly describe a formal mediational process designed to deal with the effects of conceptual conflict on retention. Socrates understood that newly elicited knowledge had a "dream-like quality" that was eliminated by the "correct" use of practice. He was also aware that such practice gave a newly acquired opinion the appearance of stability in memory. Stability in memory was, for Socrates, a significant defining characteristic of true knowledge.

Unfortunately, Socrates tells us, the true opinion, which comes about as the result of the correct practice of a newly acquired belief, retains a somewhat troublesome characteristic, that of "running away" from the mind. Thus, the true opinion is still subject to what is now described as a normal rate of forgetting. The normal rate of

forgetting is so gradual that an individual is often unaware of the loss of access to the knowledge, until it has "run away", that is, it is no longer independently retrievable.

In the present analysis of associative interference theory, we can find a contemporary description of the Socratic dream-like quality of new experience in the phenomenon of accelerated forgetting. However, we have also presented evidence that, when a new experience conflicts with prior learning, the normally beneficial effects of practice are unexpectedly transient. The dream-like quality of accelerated forgetting is, it appears, re-initiated moments after the cessation of practice.

The human mind has evolved a less-than-straightforward means for the control of this remarkable phenomenon. When conceptual conflict is created by new experience, the solution or control of the psychological impetus towards continuity is, I have argued, only attained through a conscious and effortful process, which I have called mediation. Conceptual mediation is necessary for the contiguous transformation of the retrieval status of an individual's conflicting concepts.

During mediation, the old concept re-acquires its dream-like quality as it is subject to a process of retrieval inhibition, that is, to accelerated forgetting. As the new concept is disinhibited, it gradually attains the status of what Socrates called a "true opinion". Thus, the newly disinhibited concept is now only subject to a natural rate of forgetting. It may appear, as Socrates warns Meno, to have developed the characteristic of stability of memory, however, the true stability in memory that is the defining characteristic of knowledge is yet to be attained.

The Socratic proposition that a truly stable form of memory exists which is achieved through "tethering" an opinion in the mind by reflecting on the reasons for holding it, is one that we have also come to in our analysis of learning for understanding in science. Any concept of understanding necessarily involves an individual moving beyond what is already known, beyond the limits of practice, and also beyond the natural constraints of conflicting experience.

Among the most significant intuitive obstacles to the use of Old Way/New Way and conceptual mediation, for both teachers and students, are the requirements to elicit and to re-elicit the student's prior knowledge. Dunlap's observation that the practice of an error leads to its elimination, and his subsequent challenge to the learning theories of his day, are of major significance for our understanding of the process of conceptual change. Negative practice was so named not because what was being practised was simply wrong, but because the effect of this practice upon retention is negative rather than positive as had been predicted by the learning theories of his era. It is, however, important to understand that it was not the negative practice alone that caused the change in retention, it was, instead, caused by the individual's conscious mental "set" to differentiate between an old habit and a desired new way:

> In negative practice the determining factors are the thoughts and desires involved in the practice...Obviously, learning or unlearning through negative practice are merely sticking examples under the general rule that the responses in practice are not the responses that are learned.
>
> (Dunlap, 1949, p. 96)

This necessary mental set, that is, to consciously differentiate between conflicting habits, represents the essential link between negative practice and the Old Way/New Way method from which the more complex cognitive procedure of conceptual mediation was developed.

9.2 Conceptual Mediation and Science Education

The main purpose of this treatise has been to provide the theoretical reasons for why the cognitive procedure of conceptual mediation is a necessary condition for the process of conceptual change:

> A major foundation for teaching for conceptual change is the assumption that effective teaching needs to be rooted in an understanding of how students learn. This assumption does not play out in a straightforward manner because the relationship between learning and teaching is not simple, not one-to-one, not unique and certainly not causal…A learning model does not prescribe a unique set of teaching sequences and strategies; and a particular teaching strategy does not determine the type of learning that will occur.
>
> (Hewson, Beeth & Thorley, 1998, p. 199)

Unlike the view of these researchers, my view is that the learning model of conceptual mediation, derived from both theoretical and practical analysis of conflict within learning, does prescribe practical teaching sequences and strategies that will, if followed, "determine the type of learning that will occur". The central claim is that, when attempting to change prior knowledge, special demands are placed on the

learner which require the learner to follow a specific learning strategy, namely, that of conceptual mediation.

In summary the theory proposes that when confronted with conflicting new experience the brain signals this through an experience of confusion and provides an immediate opportunity for mediation between pre-existing knowledge and the new information in the phenomenon known as associative interference. This is the automatic but transient presentation to the conscious mind of the original associations. If an individual reflects upon the confusion, he or she may become aware of a significant conflict between prior knowledge and new learning and this awareness may be accompanied by an even more significant emotional state that has been referred to earlier as perplexity. However, if the learner is now required to practise only the new information, the brain responds remarkably quickly to this demand by transiently unlearning the old association and by dissociating the old information from the new. This dissociation is enhanced by the transient retroactive inhibition of the old information in favour of the retrieval of the newly practised information. These related phenomena are but the prelude to the operation of a powerful and unconscious process of conceptual continuity, referred to as proactive inhibition, which has extremely detrimental effects on the long-term retention of new but conflicting learning.

It is proposed that the proactive inhibition of newly taught scientific concepts caused by the presence of unmediated conceptual conflict is the single most significant phenomenon confronting science educators and science teachers today. A cognitive procedure has been described that can redirect the effects of accelerated forgetting

and so facilitate the learning process. This new method is, I suggest, of considerable importance in determining how science may best be taught and to the design of future science curricula.

The method requires teachers and students to collaborate in an effortful process involving the elicitation of prior knowledge, the presentation of appropriate theory, reflection upon confusions and conflicts, comparison and differentiation of the competing or alternative frameworks, and most importantly the formal conceptual mediation between conflicting knowledge. The method requires the use of metacognitive strategies such as reflection, comparison and differentiation for the monitoring of learning outcomes and the use of effective cognitive procedures such as practice and conceptual mediation for the control of the process of learning itself:

> The critical relationship between metacognition and conceptual change also has been recognized by Australian scholars (Gunstone 1992, 1994; White 1993; White & Gunstone 1989) in work that has grown out of extensive studies of metacognition (e.g., Baird 1986, 1990; Baird & Mitchell 1986; Baird and Northfield 1992). As Gunstone (1994), has pointed out, a learner needs to be metacognitive in order to go through the conceptual change process. Gunstone and Northfield (1992) formulated this process as a learner recognising his or her existing ideas, evaluating them and deciding whether to reconstruct them on the basis of dissatisfaction with and/or fruitfulness of them.
>
> (Hewson, Beeth & Thorley, 1998, p. 205)

The general importance of metacognition as described by these authors is acknowledged. However, there is a necessary but missing psychological element in their models of conceptual change, one that the theory and practice of conceptual mediation provides. The phenomenon of accelerated forgetting as it relates to the learning of scientific concepts should be understood by all science educators and science teachers. The methodology of conceptual mediation is a vital missing piece of the science education jigsaw puzzle. It is a unique piece of the puzzle in that, when it is correctly placed, it transforms the picture before us.

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Appendix 6

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Appendix 7

Hot and Cold Procedures used in Rowell, J.A., Dawson, C.J., & Lyndon, E.H. (1990)

OLD WAY/NEW WAY "HOT PROCEDURE" FOR THE "EXPERT TEACHING" CLASS.

Introduction

Raport building, concepts introduced;
1) The brain is designed to forget.
2) How changing ides is difficult.
3) Attention and learning the relationship.

Reactivation

In this group situation reactivation had been undertaken via the "expert" teaching carried out on the previous day and specifically by reference to the topic to be undertaken. Less emphasis was made on the issue of students recalling their pretest performances. The main misconceptions however were identified as **WEIGHT, SHAPE,** and **AMOUNT.**

The misconceptions were labelled **OLD WAYS.** (see directions for using methodology).

Volume was presented as a measure of **SPACE.** This concept was then discussed and elaborated in a general way involving active participation from the students.

OLD WAY	**NEW WAY**
(1) Volume is related to **WEIGHT, SHAPE** and **AMOUNT** (as in number)	Volume is a measure of **SPACE** (x a number of students)
(2) Volume related to shape, **WEIGHT** and amount. **WEIGHT** demonstrated using three identical glass jars containing a different weight of material (1) 150g, (2) 250g, (3) 445g; **OLD WAY** prediction = different displacement.	Volume is a measure of **SPACE.** What is **SPACE**? (x a number of students)
(3) Volume and **SHAPE** using blocks LXBXD = 8CM3 AMOUNT = number	Volume is a measure of **SPACE** 1ML = 1CM3 (x a number of students)
(here some students verbalised recognition of the previous days expert lesson)	
(4) Volume and **SHAPE**	Volume is a measure of **SPACE**

(5) Volume and **SHAPE, WEIGHT** and **AMOUNT** reviewed as presented in previous demonstrations.	Volume is a measure of **SPACE** (x a number of students)

Generalization Phase

(1) A BOOK;
was selected at random and the class was asked how we would measure volume of this object, confirmed use of LxBxD. Object volume was calculated as 198cc.

(2) An ORANGE;
confirmed the need to submerge this object in order to determine it's volume. Confirmed the relationship of buoyancy and weight. (200g). Confirmed the need to measure displaced fluid. Object was weighed as well as volume determined.

(3) (4) PIECES OF PLASTICINE RANDOMLY SHAPED;
confirmed the need to equate object and displacement volume.

(5) SIX LARGE FLAT METAL RINGS;
Weight, 1200 grams, again contrary to appearances the metal rings had a lesser volume than the orange. This confirmed that **WEIGHT** was not the relevant variable.

(6) PIECES OF PLASTICINE RANDOM SHAPES;
contrary to appearances a sphere formed by combining the pieces of plasticine had a lesser volume that **SHAPE** was not the relevant variable.

OLD WAY/NEW WAY "COLD" PROCEDURES

Introduction

Rapport building, concepts introduced;
1) The brain is designed to forget, asked how many students had experienced this tendency.
2) How changing ideas is difficult. Examples used were spelling and changing ones mind about something you think you know.
3) That we would be looking at changing some ideas about volume.

Reactivation

In this group situation reactivation was attempted by reference to the results of the pretest describing what the class in general had anticipated would occur to the water level upon immersion of the playdo sphere and cylinder and then emphasising what had actually occurred. (See Q15 and 16 of the pretest).

The questions were presented and answers were accepted from the students if offered, however responses were seen to be effortful then the question was considered rhetorical and the answer was given.

The actual results were presented to the group in a general way which did not specify individuals although students were encouraged to recall which group they belonged to.

VOLUME 2 students; **WEIGHT** 8 students; **SHAPE** 10 students; **AMOUNT** 1 student.

These misconceptions were labelled the '**Old Way**' of explaining displacement volume.

Volume was presented as a measure of **space**. This concept was then discussed and elaborated in a general way involving active participation from the students.

OLDWAY	**NEWWAY**
(1 & 2) In the old way volume is a measure of space, weight, shape, amount. If weight was to be predictive of volume what would we expect if we submerged identical glass jars containing a different weight of material; (1) 30 grams; (2) 425 grams Immersed, measured displacement and confirmed that the rise was the same for both. Prediction that weight was relevant disconfirmed.	Volume is a measure of **SPACE** **DIFFERENCES** between OW/NW space not weight. How do we know? Well we have just measured the displacement caused by the jars of different weight.

This was generalised to the class by reference to five students who were asked to confirm the findings to the class.

(3) Volume is related to shape. Demonstration using cubes. Using LxBxD we show that there is not a change in volume.	Volume is a measure of **SPACE** not weight nor shape; ask 4 students to state the difference between the OW/NW.
(4) Three identical glass jars containing different weights of Iron fillings; 30g, 250g, 425g. OW prediction is that weight is related to Volume.	Volume is a measure of **SPACE**
(5) The OW is that weight, amount and shape are related to volume.	Volume is a measure of **SPACE**

Generalisations

1) Regular objects, LxBxD.

2) Metal chime bar, displacement used to determine volume.

3) Determining the volume of ones mouth. A novel suggestion, here using the equivalence of ml's and cc's.

4) Determining the volume of the room we were in; LxBxD.

5) Piano, consideration of internal and external volume. A glass jar was used as a model to illustrate the above issues.

6) Volume of a persons body.

Appendix 8

Lyndon, H., Lloyd, D., & Wilkinson, D. (1995). Changing student's conceptions: The conceptual mediation program.

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Appendix 9

The Mediational Learning Model: Teachers Handbook

Lyndon (1998)

MEDIATIONAL LEARNING WORKSHOP

CHANGING HABITS, SKILLS AND MISCONCEPTIONS

TEACHERS HANDBOOK

Harry Lyndon

1998

Introduction

This workshop will address the major issue of re-learning and how best to facilitate the process of change. What do we mean by "change" and how is it related to the concept of "learning"? Learning is defined as a measure of the changes that arise in individuals as a result of experience or practice. Change or learning then may occur simply as a result of experience and its casual repetition. This process results in the development of what are commonly referred to as habits. Habits are automated aspects of our behaviour that are, in general, context specific. Despite what common sense may suggest to us, habits are behaviours that do not transfer particularly well to new situations or contexts.

Changes may also arise as a result of a conscious choice to deliberately practise a particular activity. This usually results in the development of what we call a skill. Skills, like habits, are automated aspects of our behaviour but unlike habits they are normally free of contextual constraints. Thus a skill can be applied in a variety of settings and under a great range of physical conditions. Skills are highly transferable and reliable aspects of our behaviour.

When an individual seeks to change already acquired habits, skills, or concepts the approach to such change is by necessity a *mediational process* that places special demands on the learner.

When, despite the best of available support, someone has difficulty changing a habit or a skill or acquiring a new way of thinking, it is often said that they are experiencing learning difficulties. This workshop provides a new explanation of learning difficulties, a phenomenon regularly observed by teachers and industry-trainers in the course of their work.

Our perspective is new in that the experience of learning difficulties is seen to be a normal and universal characteristic of human cognitive development, rather than one arising from dysfunctional perceptual processes.

The natural tendency of the mind to conserve prior learning in the face of relevant new experience has been the subject of extensive psychological research since the turn of the century. This research provides firm support for the view that learning

difficulties arise as a natural outcome of powerful conserving processes that are initiated predominantly as a consequence of conceptual conflict.

Conventional help for individuals experiencing learning difficulties often fails to achieve sustainable improvements. The hard won improvements of one day are often gone the next. Although conventional intervention involving careful elaboration or reteaching of the desired skill and the encouragement of additional practice produces significant short-term improvements in performance, these are often not maintained in the long term. This age-old problem now has a new and a relatively simple solution.

There is a robust phenomenon associated with the experience of learning difficulties; it is referred to as proactive inhibition. This phenomenon is best understood as the effect of prior learning on new learning. The major characteristic of proactive inhibition is that despite the practice of a new habit, skill or idea, a conflicting prior habit, skill or idea has the power to intrude into individual performance and, over a short period of time, actually comes to dominate that performance.

This workshop will introduce the major phenomenon of *accelerated forgetting.* It is a fundamental, albeit remarkable, characteristic of human memory. It is initiated in the normal course of experience as an essential aspect of the perceptual process and permits the rapid acquisition of relevant new information. This capacity is an outstanding characteristic of human learning. Accelerated forgetting, however, is also activated whenever there is *conflict*, that is, a perceived difference, between what is already known and what is being taught. Accelerated forgetting is thus activated whenever an individual experiences proactive inhibition.

Proactive inhibition causes the accelerated forgetting of the new but conflicting habit, skill or idea. As a result, accelerated forgetting is one of the major phenomena associated with the experience of learning difficulties.

WORKSHOP ACTIVITY ONE: THE STROOP COLOUR CHARTS

This activity demonstrates the existence of the powerful conserving effect of prior knowledge i.e. proactive inhibition.

THE MEDIATIONAL LEARNING MODEL

The Mediational Learning Model explains accelerated forgetting and how individuals can take control of it through using the mediational learning methods of Old Way/New Way (to change habits and skills) and conceptual mediation (to change concepts and knowledge).

The model has had many years of successful application in schools and in the vocational education and training sector. Applications of the methods in industry have proved it to be an efficient and effective approach that addresses the learning needs of both industry-trainers and skilled employees.

Our natural interest in the personal experience of learning, memory and performance is a ready starting point for new experiences and ideas about becoming independent mediators of change. This approach builds on an individual's existing knowledge and skills, so that they may become successful and motivated learners.

By encouraging individuals to take an active role in sharing their personal experiences and understanding of learning, the model permits confirmation of significant pre-existing ideas, the introduction of relevant new concepts dealing with the nature of learning, and an opportunity to mediate between any conflicting views.

Issues discussed in this workshop will include:

- the nature of the learning experience;
- the relationship of attention and learning;
- the different role and functions of recognition and recall memory;
- the use of efficient learning strategies to improve recall memory;
- the nature of forgetting;
- the distinction between normal and accelerated rates of forgetting;
- the introduction and demonstration of the existence of proactive inhibition and its role as a knowledge protection mechanism;
- the use of conceptual mediation as an efficient strategy for controlling the effects of accelerated forgetting;
- the role of creativity in the learning process;
- the way to become an independent mediator of the natural process of conceptual change.

Individuals are empowered to take control of and accelerate the natural process of change through sharing a common language and learning framework.

THREE KINDS OF LEARNING

The model presents a simplified account of human learning. It addresses in a practical way the specific problems associated with changes in habits, skills and misconceptions that are caused by the existence of prior knowledge or experience.

To help explain the recommended methods of this model it is useful to classify the changes that occur in individuals in three distinct categories. These will be referred to as learning of the first, second and third kind.

Learning of the first kind

Personal change or learning may arise simply as a result of experience and its casual repetition. This process normally results in the development of what are commonly referred to as *habit* and *intuition*. Learning of the first kind is automated in the sense that no deliberate conscious effort is necessary for the development of habits and intuitions. Our experiences alone are the sufficient condition for such changes in our nature. Intuitions are an important part of our unconscious explanatory framework. They are in a sense our conceptual habits, derived from the repetition of experience. They inform us as to how things should or ought to be done rather than why things should be done that way.

Habits represent automated aspects of our behaviour or performance that are, in general, context specific. As mentioned earlier habits do not transfer particularly well to a new situation or context.

Learning of the second kind

Changes may also arise as a result of *a conscious choice to deliberately practise an activity*. This results in the development of what are called *skills*. Skills, like habits, are automated aspects of our behaviour. Unlike habits they are normally free of contextual constraints. This is because skills are initiated and developed as the result of a conceptual process, not simply an experiential one. Consequently, skills may be applied in a variety of settings and under a great range of physical conditions. Skills are highly transferable and reliable aspects of our behaviour.

Learning of the third kind

When an individual seeks to change already acquired habits, skills or misconceptions, i.e., to *relearn* something, the approach to such change is by necessity a *mediational learning process that places special demands on the learner.*

So, we learn or change in three different ways: we learn as a consequence of perceptual experience, through seeing, listening, feeling, and thinking; through deliberate practice; and importantly, through the conceptual process of mediational learning.

Sometimes the change or learning seems easy and sometimes it seems difficult. When we are involved in the process of relearning, we naturally find *attention,*

remembering, thinking and understanding difficult. This is when we need to learn by using mediational learning, *learning of the third kind.* The nature of the mediational process and how best to control this kind of learning will be explained later. First, it will be necessary to outline a number of basic characteristics of brain function.

THE IMPORTANCE OF VOLUNTARY ATTENTION

Given that learning may occur simply as a result of experience and its casual repetition it becomes increasingly important for individuals to control what is learned. It is important to understand that we *control* what is learned by choosing what we *pay attention to.*

When we are young we are easily *distracted.* New sights and sounds are always catching our attention. When something *distracts* us, like a loud noise or a bright light, we give attention to the source of the distraction even though we may not have wanted to. We call this necessary survival mechanism *involuntary attention.* As we get older we are more able to take more *control* of attention. We *choose* to give attention to things that interest us. We gradually learn how to deal with distractions by screening them out.

In our model of change the process of attention is taken to be a process of selective reactivation and inhibition of memory traces. This dual nature of the voluntary or selective-attention process is necessary due to the interplay of both perceptual and conceptual factors in human performance. It is perceptual in the sense that the physical context of any activity is important to performance, and conceptual in the sense that an individual's reaction to the physical context is based upon prior experience.

Giving voluntary attention to someone or something *is not always easy.* The mental effort given to control voluntary attention is called *concentration.* Learning to control attention is important because what we pay attention to we may learn even when we would prefer not to. This is particularly relevant to the area of skill development and the goal of initial error-free learning.

The learning that occurs at this level is automatic. It is an example of learning of the first kind, i.e., the measurable changes that occur as a result of experience or the casual unplanned repetition of experience.

YOUR MEMORY AND HOW TO "IMPROVE" IT

Perceptual processes in the brain are responsible for the organization of our experiences and the storing of them as memories. These are often referred to as memory traces or at other times simply as traces. The measures of these changes in our memory traces that arise as a result of the perceptual process are referred to as learning. So, learning as such is not seen as a process but rather as a product, a memory trace, and the product is often difficult to retrieve.

Our brain has two very different ways of retrieving or remembering our memory traces. These are referred to as *recognition* and *recall* memory. Knowing how these are different will help us to improve our *control* of memory.

Recognition memory

The essential difference between recognition and recall memory is that recognition is an externally cued and automatic reactivation of existing memory traces whereas recall is a self-initiated and thus a voluntary reactivation of memory.

Remembering that we have seen or heard something before and our ability to read words are examples of *recognition memory* at work. We just *know* that we have seen or heard something before.

When reading a book, if we don't recognize a word we may recognize the letters that make it up. Using these letters we recall the sounds they make and how best these go together. This process helps us to read words we do not immediately recognize.

Our recognition memory is automatic. We do not choose to remember things in this way; it just happens naturally and without conscious effort on our part.

Recall memory

When we remember things that are not present, for example what we did on the weekend or how to spell a word, we are using recall memory. For example when we spell a word easily, we say that we have *automatic recall* of how to spell that word. Sometimes it is not easy to remember how to spell a long or unfamiliar word and we call this *effortful recall.*

Recall memory is naturally effortful. Recall memory only becomes automatic and therefore effortless through practice.

TAKING CONTROL OF RECALL MEMORY THROUGH PRACTICE

We cannot *improve* our recognition memory through practice because it is an *automatic* process of memory trace reactivation. We can however increase the number of things that we recognize by learning about new things, people or places.

When we say we want to improve our memory we are really talking about improving our *recall memory, not our recognition memory.*

We have control over recall memory and we can improve our recall memory through the practice of what we have learned.

Recognition memory will only give us the feeling that we know something whenever we see or hear it again.

However, this will not help us in tests because in a test we have to rely on our recall memory.

Copying

People believe that copying a word by rewriting it five or ten times, will improve their *memory* for that particular word. They are often surprised and discouraged to find that this is not always so. Copying is an activity that uses mainly our recognition memory. This means that we are not practising the *recall* of the word. So, although copying a word will help us to read this word more easily the next time we encounter it, it will not help us to spell the word from memory.

Creativity

Most of the time we write words from memory rather than simply copying them. Here, spelling depends on the use of our effortful or automatic recall memory. If we have not practised the word then recall may be effortful.

Whenever we find a word too effortful to remember we stop trying to recall it and instead become *creative.* The usual thing we do next is to say the word to ourselves. Then, we try to invent the spelling of that word using the sounds and letters we recognize from saying the word to ourselves. Because most English words are not completely spelt the way they sound the chance of being correct using this approach is very low. We can avoid the problems of effortful recall and creative spelling by the use of a good recall strategy.

WORKSHOP VIDEO: APPLICATIONS OF THE OW/NW METHOD

WORKSHOP ACTIVITY TWO

Using the "look say cover write check" method to learn the spelling of a word.

This method is an interesting example of how practice influences recall memory.

(a) *Look* at a word and *say* it to yourself. Tell yourself what it is or what it means to you. Doing this will start the practice of your recall of this word.

(b) *Cover* the word over so that you cannot see any part of it. This will stop your recognition memory from working. This forces you to remember it using recall memory alone.

(c) *Write* the word down as best you can from recall memory. Sometimes it will be easy to write down all the letters in one attempt. Sometimes it will be effortful. The word might be too long for you to remember all the letters on the first attempt.

(d) *Check* the spelling of what you have written by uncovering the word. Check to see that you have written the word correctly. If it is incorrect pay attention to the differences. Tell yourself what they are or underline any missing letters. If you have added letters in your own spelling cross them out. When you check your spelling this way you are using recognition memory.

(e) Repeat this process with this same word fully another four times. Even if you have written the word correctly from memory the first time, do not stop there. Practising the recall of a new word once or twice is usually not enough to develop good recall. It will only help you to recognize this word more easily. Practising a new word three or four times will start to make the recall of the spelling of this word very easy. Practising the recall of a new word five times is usually sufficient to make the recall of this word effortless. It is a good idea to ensure that the spelling of new or difficult words become automatic. Practise the recall of a word using *Look Say Cover Write Check* until you have recalled it correctly *five times* in all.

(f) Sometimes words are too long or too hard to get right the first time. *Do not worry, this is natural.* Leaving letters out or adding a few of our own, only means that we need to practise recalling the word until we have done so correctly five times.

(This is a total of five correct spellings. There will not always be five correct spellings in a row.) This method is not intended to be used as spelling program. It should be used only when words are particularly difficult to recall.

Good spellers seem to be aware of the importance of practice of the recall of what they want to remember. In a study of good spellers learning new or unfamiliar words it was noted that they *avoided copying* any word they were learning to spell.

One good speller left a line between each repetition of the word as she practised its spelling. She began by looking at the model once and then wrote it from recall memory. When asked why she had left a line between each repetition she said, "That's so I can't see the word as I write it". She was successful because she used recall memory when she practised.

Another student wrote his word on the opposite side of the page, again *using recall and not recognition memory.*

THE BRAIN IS DESIGNED TO FORGET

There is no doubt that our brain does forget things. In fact it does this very well and it does so naturally. Many people talk about forgetting as if it were the same as losing. It is easy to see why people would think this way. Forgetting however is really a very complicated process involving the organization and storage of our experiences. It is important to realize that the brain is actually designed to forget and that forgetting is an adaptive and essential process without which we could not function as efficiently as we do.

The process we refer to as forgetting is actually a process of *retrieval inhibition*, a process that permits the rapid acquisition of new non-conflicting experience without the intrusion of irrelevant associations. Retrieval inhibition also ensures that incoming information is rapidly assimilated into the existing knowledge framework and then suppressed so that it does not interfere with the ongoing flow of experience. Retrieval inhibition is again involved in the relearning process whenever new experiences conflict with existing knowledge. Here, despite the deliberate practice of an activity, the inhibitory process causes significant difficulties for the recovery of newly established but conflicting memory traces.

Our brain also has two quite different *rates of forgetting*, i.e., rates of retrieval inhibition. There is a slow, normal rate of forgetting and a fast or accelerated rate of forgetting. Knowing the difference will help us take *control* of forgetting.

There are a number of common problems with memory that lead us to believe that we *lose* information. Sometimes we meet someone whose face we remember very well but we cannot remember his or her name no matter how hard we try. Now at times like this we say, "I have forgotten their name", but what we really mean to say is that even though we have *recognized* their face we cannot *recall* their name. It is natural to believe that because we *recognize* someone's face that we should just as easily be able to *recall* the person's name.

We now know that this is not really *losing* the memory. It is just that we have not practised recalling their name. To show that we have actually remembered is quite easy. Ask the person to tell us their name again and usually we *recognize* the name as well. In fact, if the person were to have deliberately given a false name, we would tend to disbelieve them. It is *natural* to have difficulty recalling someone's

name when we have not practised it or when we have not seen that person for a while. Practising someone's name using a recall memory strategy like LSCWC, or a mnemonic such as a rhyme will help us to remember, i.e., to recall that name.

Another common example that makes us mistakenly believe that we lose information from memory is forgetting to buy something that you went to the shop for. This is much the same as not remembering someone's name. We forget because there has not been enough practice of recall memory to help us remember all the items we wanted to buy. We will, however, recognize what we forgot to buy when we get home or look at a shopping list.

These events are common enough and are certainly frustrating to all of us but they do not provide evidence that we have somehow lost our memory.

Unpractised memories are only available to us through recognition memory. We know that recognition memory is long lasting and very stable. Most so-called "loss" in our ability to recognize something or someone is due to changes in how the memory is organized in the brain or is due to significant changes in the object or the person.

Memories that have been practised are available to us through *recall memory.*
We know that the more we practise something using a good recall strategy the easier it becomes to recall that memory.

We have made the point that practising something five times seems to be enough to develop an almost automatic recall of the memory. As mentioned there are two types of forgetting that affect memories that have been practised. *Notice, however, that this only applies to recall memory.* These two types of forgetting are *normal forgetting*, which happens slowly over time, and *accelerated forgetting* which, as its name suggests, happens much more quickly.

We measure these types of forgetting by the increase in the *effort* needed to recall something that we have practised.

Say that we have learnt a complex new skill such as playing a piece of music, how to solve a difficult puzzle or how to spell an unfamiliar word. If we now stop practising the new skill, normal forgetting starts to occur and slowly we find that it is harder and harder to recall the memory. Normal forgetting takes weeks to change an unpractised memory to one that can then only be remembered by recognition memory. We do not lose the memory it just gets harder to recall, until eventually we can only recognize it. A very important thing about this change in how effortful something is to recall is that if we begin to practise this skill again then the *relearning is much faster and easier than before.*

Even when something is now only recognized, relearning is easier than the first time. Something of what we originally learned, practised and then forgot has been *saved.* We have not lost this memory at all. It has changed in terms of its availability for recall, but it is still available through recognition memory and is accessed through re-experience.

We can take control of the normal rate forgetting by continuing to use and practise the things we want to remember!

Sometimes when we learn something new, or have to relearn, for example, how to spell a word a new way, we experience *accelerated forgetting*. This type of forgetting *only takes a few minutes or hours to work* instead of days or weeks as is the case with normal forgetting.

Just as with any memory that has been practised, it is not just lost. The memory is simply changed (subjected to *retrieval inhibition*) so that it can now only be recognized instead of being voluntarily recallable. This is a very interesting problem for us all.

The process of accelerated forgetting is activated when we are learning a new way of doing something which conflicts with our own way of doing something.

If someone spells the word 'said" in their own way, e.g., "sed", then that person's attempt to learn the correct way of spelling the word will lead to *confusion.* The brain initiates the accelerated forgetting of the correct way of spelling the word in order to stop this confusion. However, of course, this does not help the person if they actually want to remember the correct spelling. Accelerated forgetting is natural and it occurs when someone has their own way of doing something and they try to learn a new or better way. To take control of accelerated forgetting we need to use the Old Way/New Way method.

KEY ELEMENTS IN THE PERSPECTIVE

- A person's *errors* represent the presence of knowledge, not its absence. It is because of this prior knowledge that individuals experience difficulties with learning and maintaining new habits, skills and perspectives.

- An individual's prior habits, skills, knowledge and beliefs are protected from change. They are not subject to relearning as a consequence of re-experience or practice of a new way alone.

- The protective mechanism is known as *proactive inhibition.* This is simply the effect of prior knowledge on new but conflicting learning and the effect is to cause the *accelerated forgetting* of the new information.

- There is evidence of *considerable variation* within the population in the level of proactive inhibition that one inherits. The higher your level of proactive inhibition, the more resistant you will be to conventional correction methods.

- Proactive inhibition does not necessarily prevent learning from occurring; it does however cause confusion and perplexity which may make paying attention to the new information difficult. This factor significantly affects learning.

- Proactive inhibition prevents the association of ideas that are in conflict.

- Proactive inhibition will also inhibit the recall of an idea, which is in conflict with prior knowledge or belief.
- The powerful inhibitory effects of proactive inhibition may be reduced by the use of the Old Way/New Way and conceptual mediation methods

- Use of these methods will lead to the semi-permanent inhibition of the "old" habit, skill, or knowledge.

WORKSHOP ACTIVITY THREE:

Demonstration of the application of Old Way/New Way to overcome the persistent incorrect spelling of a word

This method starts by using the very habit, skill or idea you want to change. The method will be demonstrated through its application to the mediation of spelling problems.

When we spell a word our own way or talk about an idea or topic we "prime" our recall memory.

It becomes possible for us to remember additional things and because the idea is in our conscious memory we are able to have an influence on how this knowledge will be reorganized and stored away again when we stop thinking about it.

A reactivated "error" enters our short-term or conscious memory and *it is only at this point that the modification of memory is possible.* Change does not appear to be achievable without some form of reactivation of the error memory.

Using Old Way/New Way to change spelling habits

Prior to starting any trial, analyse the "error" and establish rapport with the person.

(i) Ask them to spell the word their own way. Then ask if you can call this the "old way" of spelling the word. It is important that the person acknowledges in some manner the labeling of their way as the old way. Strong resistance to labeling is rare and indicates that you may need to establish better rapport.

(ii) Ask the person if you can show them a "new way" of spelling the word. Consent is a signal that he/she is paying attention.

(iii) Demonstrate the new way and draw attention to the differences and similarities between the old way and the new way. When discriminating between the two, use the labels "old way" and "new way".

(iv) Ask the person to do it the old way again. It is important to repeat their *own way* of spelling a word before attempting the new way of spelling the word.

(v) Ask the person to write the word the *new way*. Then ask them to tell you the difference between the old and new ways of spelling the word. Not everyone will be able to easily articulate the differences and some help may be necessary. It has been observed that both adults and children require three facilitated discriminations before articulating the differences between the words becomes easier.

(vi) The procedure of asking the pupil to spell the old way, then the new way, followed by articulating the differences and, where relevant, the similarities, is repeated until five such discriminations have been completed. (N.B this is in addition to the original teaching phase). Our research has shown that the five discriminations are both necessary and also usually the optimum number of repetitions for this phase of the procedure. More discriminations may be done, but never less.

(vii) The new way must now be generalized or practised. Six generalizations have been found to be the optimum number. In very young children this may be achieved by simply writing the word the required six times. Novelty during this phase is readily achieved through the use of different writing mediums or by introducing the notion of different letter sizes in writing the word. *A particularly popular strategy with very young children is to ask them to write the word progressively smaller until only they can see it.* For older children and adults simply ask them to write six simple sentences using the new way spelling of the word.

It is preferable for the person to construct their own sentences. However, it is acceptable to facilitate generalization by suggesting sentences. This is a matter of judgement.

The last three sentences are the most difficult for learners to construct but also the most valuable in terms of fostering generalization and transfer.

Don't panic if...

(i) You ask the person to write a word their own way and instead they spell it correctly, look you straight in the eye, and insist that they have always spelt the word that way.

Action: Tell them that it is the new way of spelling the word. Ask if they know another way of writing the word. This will usually elicit the required old way. Occasionally the person is unable to readily recall the old way. In this situation write the old way for them and suggest that *sometimes* when they writes this word they spell it that way. Ask them to write the word as shown, then call it the old way and proceed.

(ii) The person writes the word an old way when a new way is required or vice versa (This may occur at any point during the trial).

Action: Simply point out what has occurred and what is required and then continue.

Post-trial guidelines

(i) It has been established empirically that after one trial, the individual has an 80 per cent probability of recalling the new way, a 20 per cent probability of recalling the old way and a 90 per cent probability of self-correcting an old way when it occurs. This latter probability is to a certain extent cue-dependent as is also the case under conventional correction methods. Although it has not been examined specifically it is plausible to suggest that as a result of the improved transfer with Old Way/New Way the degree of cue dependency is much less. There is supportive evidence for this claim in that the person's ability to discriminate between the old and new way is strongly maintained for considerable periods of time after the trials.

(ii) One trial is usually insufficient for full inhibition of the old way, particularly in children. This is due to the phenomenon of spontaneous recovery. (Underwood, 1966). As the name implies, what is spontaneously recovered is the old way. We have observed that the effect becomes apparent two to three weeks after trials with a particular concept. Consequently, we advise an additional trial with the same concept after two weeks.

There is no improvement in transfer to be gained from more frequent trials. This makes Old Way/New Way a most efficient method in respect of the time taken to learn a new concept.

If more than three trials appear necessary, then one should re-evaluate both the analysis of what is considered the old way and the procedures being followed.

(iii) As one would expect, new ways benefit from being practised. Although additional trials are unnecessary for approximately two weeks, incidental or deliberate use of the new way is most beneficial. This is particularly so when dealing with complex skills.

(iv) Between trials, where an old way occurs and self-correction does not follow, the facilitator or trainer may need to intervene. The simplest and best approach is to bring the person's attention to their old way, ask them to produce the new way and to tell you the difference between the two. This has been found to be sufficient in reactivating the new way. If the old way still persists then this indicates that a further re-trial is necessary. Do not, however, be tempted to re-trial before the appropriate time, that is, before two weeks have passed.

(v) Selecting old ways from the person's current written work is a good method for ensuring the meaningfulness of the trials. Words are often selected that, while they may be interesting, have a low frequency of use in their work. This may lead to the need for more trials. Spontaneous recovery is a powerful natural phenomenon.

(vi) During trials, focus is maintained on the discrimination between the old and new ways. Do not bring the person's attention to any *other* errors that may be made.

(vii) It is helpful if the work is neatly set out. This can be achieved by following the format outlined in Figure 1 (a copy of an Old Way/New Way poster made available to teachers trained in the technique).

WORKSHOP ACTIVITY FOUR:

Demonstration of the application of OW/NW on a whole group basis.

The activity known as "Faces" is a very clear example of early learning commonly influencing the performance of people of all ages involved in the task of drawing a human face.

WORKSHOP ACTIVITY FIVE:

The importance of homework: an example of the importance of effective recall strategies in skilled performance

We cannot fully understand the phenomenon of learning until we understand the phenomenon of forgetting. Learning is understood to be the changes arising in an individual as a result of practice, through the mediation of prior learning or simply through experience.

The brain however is also designed to forget. Forgetting is not simply a process of loss or decay of a memory trace but rather it is a process of *retrieval inhibition.* By this is meant that a memory becomes harder and harder to consciously remember. What was a fresh and interesting experience minutes, hours or days before, becomes what we loosely term a faded memory.

Thus the *measurable changes in our learning* due to changes in our ability to *consciously access* what we have learned, are what we mean by *forgetting*.

We observe two rates of forgetting: a slow rate, affecting the recall of well-practised items usually taking weeks to be noticed and an accelerated rate of forgetting of ideas which are in conflict or of experiences that are not practised, usually being noticeable in less than an hour.

We must carefully distinguish between the learning that occurs due to experience alone, learning which is subject to accelerated rates of forgetting, and the learning that occurs due to the deliberate practice of an item.

When we deliberately and progressively practise the recall of an item we gradually change the status of that memory; it becomes easier to *recall.* It becomes easier to access that memory consciously, i.e., voluntarily.

Students are often misled by their natural capacity to recall items after re-experiencing a situation. It is also their experience that such recall is generally *transient* but this fact they all too quickly forget when it comes to studying for an examination.

The cyclic nature of learning and forgetting creates many problems for both student and teacher.

Many students complain that they do not get any benefit from their homework and to some of them it appears as just "busy work", something imposed on them by their teachers or parents, something which just takes up their valuable free time.

Other students complain that despite doing their homework they do not improve their test results and are thus confused as to the value of the work that they are required to do.

A common experience of students is that their mind "goes blank" during an examination. They experience an inability to remember information that they have practised the night before. They do not understand why it is that work, which the night before was readily remembered, should now be a faint or unattainable memory.

The above examples are in fact due to the normal functioning of the human memory in response to the type of learning strategy that students use in their attempts to be successful.

The Mediational Learning Model makes explicit the memory and learning traps for students and offers a model of how to control learning and remembering more easily.

Trap 1. The limitations of recognition memory

"But I already *know* that. It's *boring!* Why should I have to *practise?"*

Recognition memory is an automatic capacity of the brain. It can arise simply from the learning that occurs from any experience we may have. For recognition memory to function it is necessary that we have a re-experience. We are presented with a sense of *knowing* that we have had that experience before.

When students re-read a passage in a book they experience recognition memory at work. They also experience a *recall memory priming effect* in that any readily associated ideas are automatically presented to them. This again gives them a *false* sense of "knowing" which leads them to mistakenly believe that: *no further practice of their "knowledge" is necessary.* This they later find is not necessarily true and usually this is discovered during a test. *What then should students do?*

- They should: *not* rely on *recognition* memory. A memory stored at this level requires the re-experience of the original or similar situation to permit us to remember that event.

- Be aware that during a lesson teachers are often only able to teach to a level of recognition memory. While students may be taught to a level of recognition memory they will actually be tested for their ability to *recall* what they have learned.

- They should understand that *practice and mediation* will be essential and it will need to be done as *homework.* Only practice and mediation will prevent them from experiencing "memory blackouts" during tests.

Trap 2. Reading and copying as a learning strategy

Reading through the required text for homework and taking notes as you go may seem like a useful strategy for learning and indeed it is a very good starting point.

However, reading as a skill and the copying of notes from a text all involve recognition memory and as such do not permit the stimulation of the essential recall memory process.

Taking control of the recall memory process will guarantee good test performances.

Finding a better way to study is a necessity for all students and understanding *why* it is a better way is fundamental.

We can apply the ideas discussed under the Look Say Cover Write Check approach.

- Read the passage as carefully and as quickly as you can and make a note of any important point. Make only brief notes and avoid simply copying the notes you make. Instead, try to put things in your own words. Then,

- *Cover* , i.e., hide from view, the passage just read and the notes you have taken and *recall* as much of the *meaning* of the passage as you can and write down as many ideas from your notes as you can recall. You will find that after the first reading and note taking that your *recall* will be very limited. This is *natural.* Then,

- *Repeat this whole process at least another two times!* You will discover that your reading speed increases on each repetition. Your *understanding* of what is being read and what is important will also *change,* significantly. When you attempt to recall the important points these will be readily recalled. You can then go to sleep knowing you have practised your recall memory and that you will *not* experience a mental blank next day during a test.

Trap 3. Accelerated forgetting

This is the rate of forgetting associated with recognition level storage and also with the effects of conceptual conflict. Refer to the section on the Old Way / New Way method.

Trap 4. Rote learning means learning without understanding

Rote learning simply means practising without regard to the meaning of what is being learned. An example is the learning of tables by young students or the learning by heart of passages of poetry or music. Rote learning is limited and is subject to both accelerated and normal rates of forgetting.

The forgetting of habits depends upon changed stimulus conditions whereas the forgetting of skills is conditional on the continued use of the skill. However, what we *understand* is not subject to forgetting. *These differences are very significant.*

CONCLUDING REMARKS

Remediation is usually considered to be an interpersonal teacher-directed activity. It generally involves evaluating a person's performance, determining needs, presenting additional information and/or correcting performance. Consolidation of this new information is then attempted through practice that is sometimes extensive. The effectiveness of this widely used approach, based as it is on teaching and re-teaching techniques, has been seriously questioned since the early sixties.

Where there is no conflict between what someone knows and what is being taught then the use of effective initial teaching strategies will usually be successful.

Often, however, a perceived difference or conflict, either conscious or unconscious, exists between what the learner already knows and what is being taught. Under these conditions even the use of effective teaching strategies can lead to significant learning difficulties being experienced by the learner. The major symptoms of such conflict and the resulting learning difficulties are confusion, frustration, avoidance of the task and/or slow rates of acquisition followed then by the difficulty individuals have with independently recalling the newly taught procedures and ideas.

The Mediation Learning model offers the learner practical procedures which permit direct personal control and facilitation of the natural process of change. With this new approach change is achievable through individuals recognising and understanding the need for change and confidently knowing how to achieve it.

Both Old Way/New Way and conceptual mediation require the individual to consciously acknowledge that there is a conflict; to learn the difference between the old and the new ways; to perform both the old and the new way and to practise the difference between them. This results in the redirection of the accelerated forgetting effect so that the old way is forgotten instead of the new.

In this innovative model of learning *accelerated forgetting* is seen as both the *default rate* of forgetting associated with learning from experience and it is also initiated whenever there is a conflict between what is already known and what is being taught, that is as a result of *proactive inhibition.* This accelerated rate of forgetting is in contrast to what is referred to as the normal rate of forgetting which is associated with learning through practice of new concepts or skills which are not in conflict with prior experience.

Accelerated forgetting caused by proactive inhibition is seen as the major phenomenon associated with the experience of learning difficulties whether this is in the field of training or of education in general.

NB: This has been a brief introduction to the methodology. There remain many issues that would involve extensive elaboration.

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Appendix 10

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