A constructivist theory of learning: implications for teaching

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A CONSTRUCTIVIST THEORY OF LEARNING:
IMPLICATIONS FOR TEACHING

A thesis submitted in fulfilment of the requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

THE UNIVERSITY OF WOLLONGONG

by

GRAHAM DALE HENDRY, BA(HONS)

FACULTY OF EDUCATION

1992
DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except that which is acknowledged.

Signed

Graham D. Hendry
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Mankind's plague is the conceit of knowing.

Montaigne, 1575-76.¹

CHAPTER 1

1.1 Introduction

In everyday use, the word ‘learning’ typically means “the action of acquiring knowledge” (Oxford English Dictionary, OED). Given this common definition, how learning occurs is the main problem upon which this thesis focuses. If within an educational system we adopt a goal of helping young people to learn, and assume a legal and moral responsibility to achieve this goal, then the question of how learning occurs is crucial, because it is from a logical theory that we can derive pedagogical practices which will (according to a theory) promote learning in young people, rather than hinder it, or render it inefficient.

However, within education - in educational psychology and in particular, in pedagogic institutions - use of the word ‘theory’ is itself problematical. Used in the literature, ‘theory’ generally means a systematic explanation of a ‘phenomenon’ (e.g., a theory of reading), but in a more limited sense, it can also refer to an ideology, or a view (about, e.g., learning), which is more descriptive, rather than explanatory. (For a thorough analysis of the formal meaning of ‘theory’ in psychology, see Marx, 1976).

By contrast, in the teaching profession, the term ‘theory’ (or theoretical) is often used, even in a derisive way, to denote a collection of alternative practices. These alternative practices are, in turn, derived from, or ‘reflect’, an alternative view (properly called a ‘theory’ in one sense). The word ‘practice’, conversely, only refers to established instructional methods (Munro, 1984). Thus for Munro, the so called ‘debate’ in education about theory and practice resolves into an “invective about ‘airey fairey’, ‘trendy’, ‘theoretical’ teachers ... and stolid comment on ‘sound’, ‘practical’, ‘well-trained and safe’ methods” (p. 90). That is, a forum that should be based, at least in part, upon (i) logical analysis of different ‘theories’, or views, of learning, and (ii) findings of
systematic research, revolves instead around misuse and misinterpretation of terminology, and therefore confounds attempts at serious evaluation of different theories and practices.

If idiomatic usage of the word 'theory' within the profession is put to one side, then theories of learning can be more readily classified. There are two major types: (i) explanations of how learning occurs held by theorists and published in scholarly journals and books, and (ii) teachers' own so-called 'theories', or views about learning.¹

The claim that teachers do hold 'theories' about learning is made by several authors (Coles, 1984; Baird, 1988; Osborne, 1984; Parker, 1988; Reid, Forrestal & Cook, 1989; Shapiro, 1988), and is supported by a number of research studies (Barnes & Shemilt, 1974; Fox 1983; Munby, 1984; Parsons, Graham & Honess, 1983; Perrott, 1983). Preliminary studies indicate that such views have little direct correspondence with published learning theories (Munby, 1984; Whitaker & Moses, 1988), and may mainly consist of general, pragmatic ideas, for example, 'a teacher should make learning fun' (Munby, 1984).

Within the literature, teachers’ ‘theories’ are said to guide, influence or inform their pedagogical practices (Coles, 1984; Driver, 1988; Osborne, 1984; Parker, 1988). For example, Coles (1984) states that teacher’s “theories are constructed and used in their own teaching context and guide their practice” (p. 99). For Osborne (1984) “these theories about the way children learn influence teaching plans and permeate teaching actions” (p. 7), while for Parker (1988), teacher’s views of teaching and learning “clearly inform, or give rise to teachers’ classroom practices” (p. 23).

¹ For Shapiro (1988), curriculum developers also hold ideas "about the nature of students and how they learn" (p. 97). Presumably, parents and educational policy-makers and administrators must also form views about children's learning processes.
However, research which supports these claims is lacking, and it is not at all clear how teachers’ views guide their practices. Nevertheless, it does seem reasonable to assume that if a teacher has specific ideas about learning, and holds as a goal the promotion of learning, then he/she will most likely act according to these beliefs, rather than contrariwise.

Having established that the main question, ‘how does learning occur?’ is crucial in education and that formulating a theory to answer it is worthwhile, I need also to establish briefly how we can determine the validity of such a theory, and thereby how we could (in part) justify practices derived from it. Of course, the epistemological element in this problem is much more aptly addressed by authors in the discipline of the history and philosophy of science, and I will not deal with it at any length here.

Suffice to say that, traditionally, the validity of a theory is determined by deriving hypotheses and testing the latter through observation and measurement. There is however, at least one other way the validity of a theory can be determined: it must be logically coherent or consistent.

Thus if a theory of learning, be it either a theorist’s formulation or a teacher’s view, is logically flawed, then teaching practices which are derived from the former must be questioned. In the absence of a systematic explanation or a coherent view, practices which are derived from other sources, such as ‘common sense’ or “an admixture of psychological dictum” (Watts & Bentley, 1986, p. 167) and ‘what seems to have worked in the past’, might or might not be in the interests of all students.

It is therefore important to analyse current public theories of learning, and the views of teaching and learning which teachers hold.

---

2 For Kamii (1985) a ‘common sense’ view of teaching and learning is that the former “consists of telling or presenting knowledge, and (the latter) takes place by the internalisation of what is taught” (p. 4). This ‘common sense’ view will be criticised in Chapter Six.
In Chapters Two and Three, I will review and examine several contemporary theories of knowledge and learning: network models of memory, Ausubel’s and Novak’s cognitive structure theories, schema theories, Wittrock’s generative model of learning and Piaget’s theory of genetic epistemology. It will be shown that all but one of these theories (Piaget’s theory of genetic epistemology), contain logical flaws, and that all fail to explain exactly how learning takes place. This is, in part, why I have posed, or re-posed, the problem, ‘how does learning occur?’

These theories were chosen for three main reasons. First, consistent with the definition with which I began above, in each theory, learning is implicitly defined as the action of acquiring knowledge. I will not review behaviourist theories which focus upon the acquisition of stimulus-response associations, ‘behaviours’ or physical skills, for example, the theories of Watson, Pavlov, Thorndike, Guthrie, Hull, Tolman, Skinner or Mowrer (Heinen, Sherman & Stafford, 1990), or Bandura’s social learning theory - though methodological behaviourism will be reviewed in Section 1.2 below as part of a selective historical review. Nor will I review theories of ‘learning’, which are mainly characterised by description, rather than explanation, and are more properly classified as theories, or models, of instruction, for example, the works of Bruner and Gagne (Heinen, et al. 1990).³

A second reason for choosing the theories above is that, with the exception of the theory of genetic epistemology, the former seem to be founded upon a more general, mostly implicit, approach, not unlike the mechanical view in physics and David Hume’s (1739) work, which I have likewise called the mechanical view (in education). It is this approach which I will reject in favour of an alternative assumption about learning in Chapter Three.

³ Neither will I review artificial intelligence (AI) approaches to learning, or ACT theory (Anderson, 1981, 1983). See Dreyfus and Dreyfus (1986) for a criticism of the AI approach, and Shuell (1986) for a review of ACT theory.
Thirdly, again with the exception of Piaget's theory, these theories are consistent with a general view of teaching and learning in the teaching profession, known as the transmission view, which will be critically examined in Chapter Six.

The alternative assumption about learning put forward in Chapter Three is that new knowledge is created or made out of what we already know. This assumption is called constructivism. But it only recasts the question, 'how does learning occur?' into 'how do we construct (make) knowledge?'.

In my attempt to answer this question, I begin with a fundamental postulate upon which a theory put forward in Chapters Four and Five stands or falls. This postulate states that what we call knowledge, an idea, a thought, is a continuous spatio-temporal pattern of nerve impulses in our cerebral cortex (cf. Iran-Nejad & Ortony, 1984). Though this might seem implausible, let me briefly relate a credible basis for it.

First, there is a long and rich tradition in psychology, at least since Hume (1739), of attempts to explain thought and feeling, knowledge, ideas, perception and learning in terms of neurophysiological structures and processes.

For example, early in this century, Wolfgang Kohler postulated that "when we see an object, an electric current flows through and around the corresponding part of the visual cortex" (Kohler, 1965, p. 278). For Kohler, it is the operation of field forces in an electromagnetic field in our cortex, generated by this electrical current, which accounts for how we perceive 'whole' extended bodies (Bourassa, 1986; Gordon, 1989).

In the nineteen forties, the Canadian psychologist, Donald Hebb, rejected Kohler's postulate, proposing instead that nervous activity (i.e., primarily, nerve impulses) in a
group of neurons arranged in a system of closed pathways, called a *cell-assembly*, accounts for ‘whole object’ perception (Hebb, 1949).

At about the same time, the Russian neuropsychologist, Aleksandr Luria, was studying and conducting an extensive review of research on how lesions in, and invasive injuries to, the brain affect perception, problem-solving, language and memory. His reports provide compelling evidence that lesions in specific regions of the brain and, in particular, areas of the cerebral cortex, result in specific, well-defined deficiencies in a person’s knowledge. For example (one of very many), a “patient with a lesion of the secondary visual (cortex) is not blind; he can still see the individual features and, sometimes, the individual parts of objects. His defect is that he cannot combine these individual features into complete forms” (Luria, 1973, p. 116).

Following Head (1920) and Bartlett (1932) during the nineteen sixties and seventies, several authors began to equate knowledge, or units of knowledge called *schemata*, with a dynamic organisation or pattern of neuronal processes, culminating in Iran-Nejad’s (1989a, b, c; Iran-Nejad & Ortony, 1984; Iran-Nejad, Clore & Vondruska, 1984) unique ‘biofunctional’ (i.e., semi-neurophysiological) ‘schema’ theory of knowledge. This is why I spend some time in Chapter Two reviewing usage of the word ‘schema’, before examining the characteristic use of the term in schema theories and explanations of how schemata are acquired.

Secondly, in the field of neurophysiology itself, one of the most robust findings in recent years has been how intrinsically ‘plastic’, or changeable, nervous tissue actually is. Brain tissue can grow and expand; parts of nerve cells can simply ‘sprout’, like new leaves and branches on a tree.

Starting with basic neurophysiological theory, which today is relatively far more enriched by experimental evidence that it was in Hebb’s time, it is possible to derive principles of
the generation of a continuous spatio-temporal pattern of impulses in our cerebral cortex, and deduce from these principles, in turn, three ways in which a new pattern is formed. Thus a certain amount of description and explanation of histological structures, neurophysiological processes and anatomical structures of the brain is dealt with in Chapters Four and Five.

But the derivation of the ways in which a new pattern is formed does not constitute an explanation of how, for example, we learn by reading. In order to expand the theory to the realism of learning in a classroom, two postulates about the meaning of words and intrinsic motivation are logically linked to it in Chapter Six. This expanded theory is tested in a clinical study reported in Chapter Seven. The result of this study is negative: the hypothesis was not confirmed for all participants. Logically, this result does not necessarily invalidate the specific theory of construction, but it does require that the expanded theory be developed in one direction, rather than another.

As I will claim, to test more directly logical implications of the specific theory I would have to make measurements, for example, of a person's event-related potentials, which I am not qualified to do. In Chapter Eight, however, I will lay out a plan of future research, both psychological and physiological, which could be conducted, in the case of the former, to inform the development of the theory, and in the case of the latter, to test it more directly.

In the final Chapter, I will derive from the theory and research reported in Chapter Seven implications for teaching and then infer several general strategies, or practices, which a teacher could use to help young people to learn.

Let me now begin the task of solving the problem, 'how does learning occur?' by undertaking a selective historical review of ideas about knowledge and learning.
1.2 A selective historical review of ideas about knowledge and learning

At least since the time of the Greek philosophers, thinkers have puzzled over the problem of how we acquire knowledge (Kandel, 1980; Vosniadou & Brewer, 1987). Three major assumptions which underlie attempts to solve this problem can be identified. These are (i) empiricism, (ii) preformism, or rationalism (Kandel, 1989) and (iii) constructivism.

Empiricism is the assumption that all knowledge is acquired through experience. Preformism is the idea that we are born with all, or some, of our knowledge fully formed. Constructivism is the assumption that all knowledge is actively created by a person from within.

In this century, two distinctive, major views of learning can also be recognised. These views, methodological behaviourism and the information-processing approach, will be reviewed in more detail below.

I shall next examine three theories which are built upon one or other of the three major assumptions above, and which best represent an extension of each of these assumptions. The first of these theories is Hume’s (1739) associationism. Hume classified the ‘perceptions of the mind’, or our thoughts, into impressions and ideas, and both of these into the simple and complex.

Simple ideas are exact though faint copies of vivid, ‘forceful’ impressions (immediate sensations, or what are currently called ‘sense data’, Oldroyd, 1986; Wilkerson, 1976). For example, Hume states that “of (an) impression there is a copy taken by the mind, which remains after the impression ceases; and this we call (a simple) idea” (Hume, 1739, p. 8). Simple ideas combine through association or attraction to form complex ideas.
In sum, for Hume, all knowledge is acquired through experience, or by being in ‘contact’ with a world and having impressions. Learning occurs as a person forms simple ideas, or faint ‘tracings’ of impressions, and combines these ideas into complex groups through association (which is like an attractive force or ‘pull’. As you will see, Hume, like Kant, was influenced by Isaac Newton).

By contrast, however, Kant (1987) states that “though all our knowledge begins with experience, it does not follow that it all arises out of experience” (p. 41). Kant assumes that we possess forms of a priori knowledge, or knowledge which is held prior to experience (thus a priori). The latter consists of pre-existing forms of thought, ‘mental frames’ (Oldroyd, 1986) or an ‘inborn mental framework’ (Berkson & Wettersten, 1984). Knowledge acquired through experience is called empirical knowledge.

The forms of a priori knowledge are the pure intuitions (immediate awarenesses) of space and time of the sensibility (in fact, Newton’s ideas of absolute space and time), and the categories (primary or pure concepts) of the understanding (Kant, 1787).

Kant assumes that a person organises, ‘shapes’ (Oldroyd, 1986), ‘structures’ (Fabricius, 1983; Rotman, 1977) or ‘syntheses’ (Beyer, 1986), his/her multiple sense impressions, or intuitions, through the forms of a priori knowledge. Thus we acquire empirical knowledge, or ideas, by being in ‘contact’ with a world and synthesising our intuitions through a priori forms.

In this century, it is Piaget who has been one of the most systematic critics of both the British empiricists (e.g., Hume) and Kant’s ‘a priorism’. For Piaget, logico-mathematical knowledge or structures of reasoning (Kant’s categories of understanding) are not copies of impressions, nor do these structures exist preformed, but rather, they are progressively constructed from within by a child through his/her continuous action
upon a world (Kitchener, 1986; Piaget, 1970a, b) (Piaget’s theory will be examined further in Chapter Three).

Piaget’s constructivist theory of genetic epistemology was, in turn, developed alongside stimulus-response theory (Berkson & Wettersten, 1984) or methodological behaviourism (Miller, 1988).

Methodological behaviourism is based upon the assumption that only ‘observable events’, or ‘observable’ parts of a world, can be incorporated in an explanation of how learning occurs. For behaviourists, so-called ‘mental states’ are not observable, and are thus “not legitimate subjects of study or causes of behaviour” (Miller, 1988, p. 4). That is, behaviourists (at least in doing their experiments) reject the ideas of thought and feeling, ‘mentalistic concepts’ (Michell, 1988), or ‘mentalism’ (Bourassa, 1986; Mandler, 1985).

Events which are observable are called stimuli and responses (bodily movements). Learning occurs when an association, or bond, is formed between a stimulus (S) and a response (R) (Bower & Hilgard, 1981; Chodorow & Manning, 1983).

For Watson (1919) thoughts do not differ toto caelo (by an immense amount) from ‘acquired habits’, or associated stimuli and responses (see p. 355). Feelings are viewed in the same way (i.e., as S-R associations). That is, thoughts and feelings are defined in terms of observable events.

Thus for Wittrock (1978a) “behaviourists could no longer say ‘how are you?’ when they met each other. To answer that question they would have to express feelings ... To solve this social problem, when meeting each other it was suggested that the first behaviourist say to the other behaviourist, ‘I see that you are fine, how am I?’” (p. 17). To the extent that behaviourism focuses upon observable stimuli and behaviour (be it bodily
movements, or so-called 'verbal behaviour'), rather than knowledge, or ideas, it is irrelevant to the problem of how a person acquires the latter.

In education, however, a modified version of behaviourism, Skinner's theory of operant conditioning, led to the adoption of several pedagogical practices some of which still persist in classrooms today. For Skinner, learning occurs when a child emits a particular behaviour or response, and this response is reinforced, or strengthened, by the consequences or stimuli which follow it (Bower & Hilgard, 1981; Milholland & Forisha, 1972; Wittrock, 1981a). In a classroom, a teacher arranges reinforcers for children contingent upon certain types of emitted behaviour (Wittrock, 1981a). A child is viewed as passive, rather than active, during this process of 'environmental manipulation' (Seaver & Cartwright, 1977).

By contrast, in a constructivist theory a student is by definition assumed to be active in learning. If 'environmental' manipulation does occur in contemporary classrooms, then it must operate both ways - students cleverly manipulate their teacher and (though not always so cleverly) vice versa.

An underlying view of a child as passive also pervades an approach known as information-processing theory (or the 'computer analogy'). In this view, the mind is likened to a computer, or an electronic machine, and thinking is defined as the processing or transformation of information (Andre & Phye, 1986).

In common use, the word 'information' means "knowledge communicated concerning some particular fact, subject or event" (OED). But within the literature, it is often unclear what is meant by the word 'information'. On one hand, it is as if 'information' is used to mean communicated or transmitted knowledge\(^4\) while, on the other, it often refers to

\(^4\) For example, Reber (1985) states that 'cognitive scientists' typically use the term 'information' to mean "any knowledge that is received, processed and understood" (p. 355).
'inputs', or nerve impulses which propagate from sensory receptors toward the central nervous system (Gibson, 1985).

Alternatively, for Kurtzman (1983) information is "a pattern of differences among the elements of a medium" (p. 10) (though how 'differences' can exist in themselves is unclear). In people, "the medium is comprised of neurons in the brain" (p. 10). Presumably, the term 'medium' can also refer to an external world.

Perhaps the most widely held idea of information is that it is a 'ready-made' (Richards & von Glasersfeld, 1979), 'atomistic something' which "resides ... in the world" (Bussis, Chittenden, Amarel & Klausner, 1985, p. 65) and somehow denotes "just about everything that exists or happens in (the latter)" (Bussis, et al. p. 65).

Learning occurs when this ready made 'something' is received by our sensory receptors, 'taken in' and transformed into information or knowledge in our brains, or minds, and 'stored' or held in the latter (e.g., "learning involves the acquisition and storage of information", Phillips & Baddeley, 1989, p. 62). In this sense, information is like impressions or intuitions, and the processes which operate on the former are like Kant's forms of a priori knowledge.

It is from information-processing theory that several theories, collectively called schema theory (Anderson & Pearson, 1985; Pearson & Spiro, 1980; Schallert, 1982), have developed (Anderson & Pearson, 1984). In schema theory, however, information taken in is not assumed to be processed in the sense of being operated upon or changed, but is only channelled, or guided, to various locations.

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5 For Pearson and Spiro (1980) "schema theory is first and foremost a theory of information-processing" (p. 72).
In sum, two major assumptions upon which the information-processing approach is based are that a transmittable 'something' exists, which represents what is 'real', and the processing, arranging, or channelling of this incoming, existential 'something' by the brain or mind is knowing.

**1.3 Summary**

It might be (following Kant) that all knowledge begins with experience; that is, being in 'contact' with a world through specialised neurons called sensory receptors. It does not arise, however, *only* out of this 'contact'; rather, knowledge or a spatio-temporal pattern of nerve impulses is constructed out of itself by the functioning of the nervous system in interaction with a world.

Perhaps the most important implication of this view of learning is that a term like 'information' and the theory built up around it become superfluous, rendering the transmission-of-knowledge-approach to teaching and accompanying methods of assessment questionable.

The theories reviewed in the next two Chapters were chosen not only because they purport to be explanations of how knowledge is organised and acquired, are consistent with a 'professionally' favoured transmission view, and are taught, for example, in teacher education courses (and reviewed in educational psychology textbooks, e.g., Langford 1989), but also because they seem (with the exception of the theory of genetic epistemology) to be founded upon a more general, mostly implicit view of knowledge and learning in education which I will call the *mechanical view*. 
CHAPTER 2

2.1 Introduction

In this Chapter, several current theories of knowledge and learning will be reviewed and analysed. These theories include (i) network models of memory, (ii) the cognitive structure theories of Ausubel and Novak, and (iii) schema theories.

All these theories seemed to be based upon an underlying view which is similar to an approach in physics, called the mechanical view (Einstein & Infeld, 1938). This latter view is also evident in the philosophy of Hume.

2.2 The mechanical view in physics and the philosophy of Hume

In physics, the mechanical view is a belief about natural phenomena based upon Newton's mechanics. The latter is, in turn, founded upon several fundamental ideas. These may be listed as follows:

(i) absolute space and time.
(ii) the material point, which is a body that may be described with sufficient accuracy as a point with the coordinates $x^1, x^2, x^3$.
(iii) the law of inertia, which may be stated thus: a material point will continue in a state of rest or a state of uniform motion in a straight line unless otherwise acted upon by a force.
(iv) the law of motion, which is force equals mass times acceleration.
(v) laws of force, or relationships between material points (Einstein, 1936).

In mechanics, two discrete particles (i.e., material points), may either attract or repel each other through a force which acts between them. The force of attraction or repulsion acts
along a straight line connecting the particles, and the strength of the force varies with the
distance between the latter (Einstein & Infeld, 1938).

The practical success of mechanics "contributed to the belief that it is possible to describe
all natural phenomena in terms of simple forces between (discrete particles)" (p. 54). This belief is the "so-called mechanical view" (p. 55).

In philosophy, the mechanical view was adopted by Hume (1739) in his associationist
type of thought. For Hume, thoughts are divided into ideas and impressions, and both
are divided into the simple and the complex. Simple ideas "exactly represent" (p. 4)
simple impressions, and differ from the latter only in the degree "of force and liveliness
with which they strike upon the mind" (p. 1). Both "are such as admit of no distinction
or separation" (p. 2). That is, simple ideas and impressions are irreducible elements of
thought.

Simple ideas combine to form a complex idea by association, which "is a gentle force,
which commonly prevails" (p. 10). Association is "a kind of attraction" (p. 12). It is
like an attractive force in absolute space. In this way, upon the appearance of one idea in
thought, another is naturally introduced.

Hume proposes three principles of association, which may be stated thus: (i) ideas which
are similar attract, (ii) ideas which repeatedly occur together in time or place attract, and
(iii) the ideas of a particular cause and its effect attract (the last principles, as Hume has
shown, being reducible to the second).

Hume states that "twould have been easy to have made an imaginary dissection of the
brain, and have shewn, why upon our conception of any idea, the animal spirits run into
all the contiguous traces, and rouse up other ideas, that are related to it ... I shall therefore
observe, that as the mind is endow'd with a power of exciting any idea it pleases;
whenever it dispatches the spirits into that region of the brain, in which the idea is plac'd; these spirits always excite the idea, when they run precisely into the proper traces, and rummage that cell, which belongs to the idea” (p. 60-61).

That is, a cell, which ‘belongs’ to an idea, is joined or connected with other cells in the brain by ‘contiguous traces’, which are like pathways or channels along which ‘animal spirits’ may flow. Presumably, ideas come into thought when the ‘spirits’ excite a cell, and fall out when the ‘spirits’ pass on. Thus Hume’s idea of association as a gentle attractive force, is reduced, in his neurophysiological theory of association, to the flow of ‘spirits’.

To summarise, in the same way that, in physics, a world is divided into discrete particles, in Hume’s theory, thought is separated into irreducible simple ideas. Like particles, these ideas may attract each other. But, whereas, in physics, a force of attraction acts along a straight line in absolute space, in Hume’s theory, attraction, or association, is the flow of ‘spirits’ in the ‘contiguous traces’ of the brain.

2.3 The mechanical view in education

In education, an approach can be identified which is similar in a number of ways to the mechanical view in physics and the philosophy of Hume. This approach is based on a fundamental, mostly implicit, assumption that the mind is like a (an absolute) space (Roediger, 1979, 1980).

In the same way that, in physics, natural phenomena are divided into discrete particles, in the mechanical view in education, knowledge is reduced to separate elements. Like particles, these elements exist in an absolute void (the space of the mind). But unlike the mechanical view in physics, the elements are not free to move, but are ‘located’ in
specific 'places' (Belli, 1986). They are joined by fixed pathways which are similar to Hume's 'contiguous traces'.

In this view, knowledge is acquired when information passes from an external world through the 'sense organs' and into the space of the mind. For example, Gibson and Gibson (1955) raise the question, “does all knowledge (information is the contemporary term) come through the sense organs or is some contributed by the mind itself?” (p. 32). For Berlyne (1971) information is “transmitted through (the) sense organs from (an) outside world” (p. 189). Rumelhart (1980) states that “information comes in from our sense organs” (p. 46).

The mechanical view in education is developed in more detail in several 'quasi-neurological' (Iran-Nejad, 1987) theories of knowledge and learning which are collectively called 'network models' of memory, or semantic memory (Cohen, 1983; Matlin, 1983), or 'associative network' models or theories (Hayes-Roth, 1977; Morton & Bekerian, 1986).

2.4 Network models of memory

In most network models of memory, the elements of knowledge are referred to as concepts (Balota & Lorch, 1986; Chi & Rees, 1983; Cohen, 1983; Hayes-Roth, 1977; Matlin, 1983; Ratcliff & McKoon, 1981).1

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1 In some network models of memory, elements or units of knowledge, or 'mental data' (Anderson, 1981) are called propositions. A proposition is made up of two arguments related by a relation, or predicate, for example, in the proposition ‘Dick likes Jane’, Dick and Jane are the arguments, and ‘likes’ is the predicate (Stillings, Feinstein, Garfield, Rissland, Rosenbaum, Weisler & Baker-Ward, 1987). A proposition is a 'unit' in that it can be either true or false (Anderson, 1981; Stillings et al. 1987). For a detailed discussion of propositional networks, see Stillings, et al. (1987).
A concept is said to be represented\(^2\) by a \textit{node} (Balota & Lorch, 1986; Chi & Rees, 1983; Cohen, 1983; Matlin, 1983; Ratcliff & McKoon, 1981; Samuels & Eisenberg, 1981). Relations between concepts are said to be represented by ‘associative pathways’ (Balota & Lorch, 1987), associations (Matlin, 1983) or links (Chi & Rees, 1983; Cohen, 1983; Matlin, 1983; Ratcliff & McKoon, 1981), that is, by fixed pathways. Nodes are joined by these pathways in the space of the mind, named memory, to form a ‘memory’, ‘semantic’ or ‘associative’ network (Balota & Lorch, 1986; Matlin, 1983; Morton & Bekerian, 1986).

Presumably, in network models of memory, the word ‘node’, means some sort of junction, swelling, or knot. In general terms, a ‘node’ is “a knot or complication; an entanglement” (OED). In this sense, a node is like a material point in physics, that is, it can be described with sufficient accuracy as a point in absolute space. Thus for Moreira and Santos (1981) concepts “are represented by points” (p. 526).

A fixed pathway is often called an association, whereas, for Hume, the word ‘association’ refers to a gentle attractive force (rather than a ‘contiguous trace’). But like Hume’s ‘animal spirits’, some sort of activity, which is called \textit{activation}, can flow from a node along a pathway and activate other nodes (Anderson, 1984; Balota & Lorch, 1986; Matlin, 1983).

For Balota and Lorch (1986) the ‘spread’ of activation in a network of nodes is governed by several principles which may be listed as follows:

(i) the ‘strength’ of a fixed pathway or association is a function of its length.

\(^2\) Used in the literature in this way, the word ‘represent’ presumably means “to symbolise, to serve as a visual or concrete embodiment of” (OED).
(ii) the amount of activation which spreads along a fixed pathway is a function of the strength of the latter relative to the sum of the strengths of all pathways which extend from a node.

(iii) the level of activation of a node is determined by the amount of activation it receives.

Anderson (1984) claims that "more active nodes are processed 'better'" (p. 61). He also states that the latter sentence "contains the assertion that more active information is processed better" (p. 62). Thus nodes are information. For Samuels and Eisenberg (1981) nodes "represent pieces or chunks of information" (P. 58).

But Anderson also claims that a network of nodes 'can be thought of' as a group of neurons (cells of the nervous system), and a level of activation 'can be thought of' as a neuron's rate of 'firing' (frequency of nerve impulses). Though it follows from Anderson's first definition of nodes that neurons are information, this implication is contradicted by the statement that "it is believed that neurons encode information by changes in their rate of firing" (p. 64). Presumably, in this statement, Anderson uses 'information' to refer to something which exists ready-made in an external world. The former is converted by neurons into changes in the frequency of nerve impulses.

In sum, for Anderson, the term 'information' can have two mutually exclusive meanings. It can either mean elements of knowledge (nodes), or an external something which is transformed into changes in impulse frequency.

2.4.1 Learning

In general, learning in network models of memory is assumed to occur when elements of knowledge or information, or 'nodes' (Chi & Rees, 1983), pass into memory and are
linked with appropriate existing nodes. For example, Chi and Rees state that “learning is the insertion of new nodes into their proper places (in memory)” (p. 86).

However, it is not explained how new nodes are linked with appropriate or proper existing nodes, nor is it clear how new nodes can be ‘inserted’ into memory. Again, there appears to be a confusion between information in a world, and information in memory. Regardless, this problem is not solved by assuming that we ‘know’ where to place and ‘link up’ a new node, because the latter is, by definition, new or novel, and the possible relations it has to a person’s existing knowledge are initially unknowable.

Learning is also assumed to occur when (i) new links are formed between existing nodes (Chi & Rees, 1983; Morton & Bekerian, 1986) or (ii) existing links are ‘strengthened’ (Chi & Rees, 1983). The result of this latter process is that “activation (can) flow more readily” (p. 90). It is not clarified, however, exactly how these two types of learning take place.

In the next section, the theories of knowledge and learning of Ausubel and Novak will be reviewed. Both theorists refer to the organisation of elements of knowledge in our minds as ‘cognitive structure’.

### 2.5 The cognitive structure theories of Ausubel and Novak

The word ‘structure’ is an adaptation of the Latin word *structura* which means “to build” (OED). A ‘structure’ is generally defined as “an organised body or combination of mutually connected parts of elements” (OED).

For Ausubel, ‘cognitive structure’ is broadly defined as the ‘stability’ (Ausubel, 1963), or ‘quantity’ (Ausubel & Robinson, 1969) ‘clarity and organisation’ of a child’s ‘present knowledge’ (Ausubel & Robinson, 1969) or ‘subject-matter knowledge in a given
discipline' (Ausubel, 1963). That is, 'cognitive structure' refers both to qualities (stability and clarity) of our knowledge, and its organisation.

This organisation, in our 'own minds', of 'subject-matter knowledge' is further delineated as a *hierarchical structure* in which "inclusive concepts occupy a position at the apex of the structure and subsume progressively less inclusive and more highly differentiated subconcepts and factual data" (Ausubel, 1963, p. 79).

Though it is possible to interpret 'hierarchical structure' to mean a hierarchical network of elements in the space of memory (or the mind), Ausubel (1962) assumes that concepts, sub-concepts and factual data, or 'specific informational data', are 'traces' or "representation(s) of past experience in the nervous system" (p. 216). However, the exact form of such traces is not discussed, nor is this assumption linked in any systematic way with his theory of learning (examined below).

Novak (1977a) defines 'cognitive structure' (after Ausubel) as "a framework of hierarchically organised concepts" (p. 25). For Novak (1979a, 1985) 'cognitive structure' is an organised framework or network of knowledge within our minds.

### 2.5.1 Learning

Ausubel and associates (Ausubel, 1962, 1963, 1967; Ausubel & Robinson, 1969; Ausubel, Stager & Gaite, 1968) divide learning into two types, which are called *rote* and *meaningful* learning.

In rote learning, we acquire 'material' which is not "anchored to existing ideational systems" (Ausubel, 1963, p. 24). That is, material is not linked with existing concepts or ideas in cognitive structure, and forms "discrete and isolated traces" (Ausubel, 1962, p. 217).
Meaningful learning occurs when new material, concepts, information, or situations are related or ‘anchored’ to, or subsumed by, relevant ‘components’, ‘stable elements’, a ‘more inclusive conceptual system’ or existing ideas in cognitive structure (Ausubel, 1962, 1963, 1967; Ausubel, Stager & Gaite, 1968).

However, it is not explained exactly how new material is related to, or subsumed by, relevant ideas, nor is it clear what is meant by terms such as ‘material’ or ‘concepts’. Ausubel (1963) states that “an implicit judgement of relevance is usually required in deciding under which proposition to catalogue new knowledge” (p. 20). But this statement begs the question. We cannot make a judgement, implicit or otherwise, about the relevance of new knowledge because, by definition, we cannot initially ‘know’ this knowledge.

Novak and associates (Novak, 1977a, b, 1979a, b, 1980, 1985; Novak, Gowin & Johansen, 1983) also discuss two types of learning, called rote and meaningful (after Ausubel). In rote learning we acquire (in place of new ‘material’) new information which is not joined with existing concepts. The information is said to be arbitrarily incorporated into cognitive structure (Novak, 1977b, 1979a, b; Novak, 1980; Novak, et al., 1983). By contrast, “meaningful learning occurs when new information is linked with existing concepts” (Novak, 1977a, p. 25-26). The process by which new input is linked with existing concepts is called assimilation (Novak, 1977a). However, again, it is not explained how this process of linkage takes place, that is, how new information makes contact with the proper concepts.

As well as the formation of concepts through meaningful learning, Novak states that new concepts can also be formed in a kind of ‘discovery’ learning, which consists of “hypothesis generation and testing as well as generalisation from specific instances” (Novak, 1977a, p. 77) (after Ausubel). But the process by which a hypothesis is
generated and tested is not explained. Supposedly, we can confirm a hypothesis because we are able, by some process, to ‘match’ information to existing concepts. But how we know that a hypothesis is falsified, or how we acquire a new concept during hypothesis testing is unclear.

In generalisation from specific instances, Novak claims that through repeated encounters with examples of concepts a person “gradually discovers the criterial attributes that characterise (the latter)” (p. 77). That is, ‘criterial attributes’ must somehow gradually ‘sink in’.

To summarise, like network models of memory, the cognitive structure theories of Ausubel and Novak overlook the problem of how new material or information is linked with the appropriate existing elements of knowledge in our minds. I will call this problem the link paradox. In later sections, several theories of knowledge and learning, called schema theories, will be reviewed. Schema theories, like network models of memory, are detailed developments of the mechanical view in education (Section 2.3).

First, in the next section, other definitions in the literature of the word ‘schema’ will be reviewed, in part, in order to highlight (i) a historical trend of equating knowledge with neuronal structures and processes, and (ii) the dichotomy between ‘dynamic, organismic’ (Iran-Nejad, 1989c) and static, ‘mechanical’ views of knowledge. For a complete review of the meaning of ‘schema’ prior to 1967, see Paul (1967).

2.6 Schema

The word ‘schema’ (or ‘scheme’) comes from the Greek word schema, meaning “form, figure” (OED). In general use, ‘schema’ means “a diagrammatic representation” (OED). A ‘representation’ is “an image, likeness, or reproduction in some manner of a thing” (OED).
For Kant (1787) the word 'schema' has a different meaning. In the following quotations, he uses the word 'image' to refer to both the immediate perception of a thing, or an image *in concreto*, and what we now call a mental image. For clarity, I will use the terminology 'percept' and 'mental image'.

Kant defines a 'schema' as a “representation of a universal procedure of imagination (which 'provides') an image for a concept” (p. 186). A mental image must be ‘provided’ for a concept because “no image could ever be adequate to (for example) the concept of (a) triangle in general. It would never attain that universality of the concept which renders it valid of all triangles, whether right-angled , obtuse-angled, or acute-angled” (p. 182). That is, a percept of a single instance of a triangle cannot stand for all triangles, rather, it is a schema which determines the mental image which we have of ‘triangle’. A schema “can exist nowhere but in thought. It is a rule of synthesis of the imagination” (Kant, 1787, p. 182).

However, the difference between a mental image and a concept is not clear. For instance, Kant states that “the concept ‘dog’ signifies a rule according to which my imagination can delineate the figure of a four-footed animal in a general manner” (p. 182-3). That is, a concept is a signification of a rule of synthesis, or schema, though how this signification differs from a ‘figure’, or mental image, which the schema provides, is not stated. It may be that by ‘concept’, Kant means ‘word’. Thus a word may signify, or symbolise, a schema, and the image it generates.

Kant’s derivation of the mutual exclusiveness of ‘percepts’ and ‘images’ is an important clarification, and it should be noted that schema theory, reviewed below, is, in part, a consistent and systematic attempt to account for Kant’s distinction.
For Piaget (1970a) a ‘schema’ is a general mental image. Piaget defines a \textit{scheme} as an underlying form common to several actions; for example, it is the form common to actions of ‘pushing’ an object with a stick or other instrument (Piaget, 1970a). Mental images “can be schematised, but in an entirely different sense, for images in themselves, however schematic, are not schemes. We shall therefore use the term schemata to designate them” (p. 719). That is, whereas, for Kant, a schema is a rule of synthesis which ‘provides’ an image for a concept, for Piaget, it is the image itself.

By contrast, Bartlett (1932) stipulates that a schema is “an active organisation of past reactions, or of past experiences, which must always be supposed to be operating in an well-adapted organic response” (p. 201). It is unclear, however, what is meant by the terms ‘reactions’ and ‘experiences’. In defining schema Bartlett states that “it would probably be best to speak of ‘active developing patterns’; but the word ‘pattern’, too, being now very widely and variously employed, has its own difficulties; and it, like ‘schema’, suggests a greater articulation of detail than is normally found. I think probably the term ‘organised setting’ approximates more closely and clearly to the notion required” (p. 201).

An organised setting (schema) is ‘built up’ from incoming nerve impulses. Each “incoming change contributes its part to the total ‘schema’ of the moment in the order to which it occurs” (p. 203). A schema is not a \textit{fixed} ‘framework’ or ‘trace’, “stored up somewhere, and then re-excited at some much later moment” (p. 212).

In sum, for Bartlett, an organised setting (schema) is some sort of overall dynamic pattern of neuronal processes.

\footnote{Vuyk (1981) states that to refer to a ‘scheme’, “originally, Piaget used the (French) term \textit{schema}, translated as ‘schema’ ... As early as 1936 he switched to (the French word) \textit{scheme}. This should be translated as ‘scheme’ as Piaget now uses the word \textit{schema} in a different sense” (p. 63).}
In sum, for Neisser (1976, 1978) a schema accepts information, and produces movement of the body which allow us to pick up more information. A “schema is just one phase of an ongoing activity which relates (a) perceiver to (an) environment” (Neisser, 1976, p. 23).

In a unique, wide-ranging extension of the ideas of Bartlett, Kagan and Neisser, Iran-Nejad (Iran-Nejad, 1989a, b, c; Iran-Nejad & Ortony, 1984) has taken the explicit step of assuming that knowledge is itself a pattern of neuronal processes or activity (an assumption also independently made by the author, Hendry, 1985). For Iran-Nejad, knowledge, ideas, concepts, schemas, mental or knowledge schemas, or mental, cognitive or knowledge structures, are transient, dynamic, or biofunctional, patterns; patterns of energy or ongoing patterns of activity of various complexity which are ‘created and upheld by constellations of brain microsystems’ (Iran-Nejad, 1989a, b, c; Iran-Nejad & Ortony, 1984). A ‘brain microsystem’ or ‘neuronal element’ is a nerve cell, or neuron (Iran-Nejad & Ortony, 1984). Microsystems can create “two qualitatively different types of activity and thereby create two qualitatively different types of knowledge ... called thematic (and) ... categorical knowledge” (Iran-Nejad, 1989b, p. 431) or ‘tacit’ and ‘live’ knowledge (TALK) (Iran-Nejad, 1989c). Iran-Nejad’s biofunctional schema theory is extensive in its explanation of various psychological concepts (e.g., similarity, metaphor and incompatibility), as well as affect or emotion (Iran-Nejad, Clore & Vondruska, 1984).

Parts of the theory presented in Chapters Four and Six can be directly linked to Iran-Nejad’s theory, which is stated at a slightly ‘higher’ ideational level. Iran-Nejad does not go as deeply into neurophysiological theory as I, but instead ‘hopes’ that his “model of the mind ... is compatible with what is known about the brain and the nervous system” (Iran-Nejad & Ortony, 1984, p. 206). The task of clarifying all possible links will not be
undertaken here, nor will a detailed review of the Iran-Nejad’s work be conducted, except of course, at relevant points in the chapters mentioned.

To summarise, in general, Bartlett (1932), Kagan (1970, 1971, 1972), Neisser (1976) and Iran-Nejad (Iran-Nejad, 1980; 1989a, b, c; Iran-Nejad & Ortony, 1984), all define a schema as some sort of *dynamic* organisation or pattern of neuronal processes.

By contrast, in schema theories, the word ‘schema’ generally refers to a *static*, or fixed, organisation of elements, or structure (Weaver, 1985), ‘long-term’ structure (Iran-Nejad & Ortony, 1984) or ‘mechanical frame’ (Iran-Nejad, 1990), in the space of memory, which exists “independently of (a) dynamic component” (Iran-Nejad & Ortony, 1984, p. 176).

In the following sections, though the currency of schema theories has diminished somewhat in psychology (see Iran-Nejad, 1989a), these theories are reviewed and examined at some length, in part, because (i) they represent the most highly developed extensions of the more general mechanical view (which is rejected below and in Chapter Three) and (ii) within education, have been adopted (e.g., Just and Carpenter, 1987) and widely accepted as useful theories of *reading* comprehension (upon which a study reported in Chapter Seven bears), and are collectively known as the schema, or ‘schema-interactive’, theory of reading (Garner, 1987; Singer & Donlan, 1989).

### 2.7 Schema theories

In schema theories, the word ‘schema’ is variously defined as follows:


(ii) an abstract structure of information (Anderson, R. C., 1984a)
(iii) an abstract description of a thing or event (Anderson, Pichert, Goetz, Schallert, Stevens, & Trollip, 1976; Pichert & Anderson, 1977).

(iv) a schematic representation or mental structure (Anderson, Spiro & Anderson, 1978; Andre & Phye, 1986).

(v) a hypothetical structure (Blachowicz, 1984; Pearson & Spiro, 1980).


(vii) a data structure (Rumelhart & Ortony, 1977).

(viii) an abstract cognitive structure or ‘cognitive template’ (Hacker, 1980).

(ix) a cognitive structure or organised representation of knowledge (G. Mandler, 1985; J.M. Mandler, 1979).

(x) an organisational structure (Merrill, Keley & Wilson, 1981).

(xi) an organised unit or structure of memory (Chi & Rees, 1983).

(xii) a framework (Just & Carpenter, 1987; Richgels, 1982, 1984).

(xiii) an organised group of concepts (Samuels, 1982, 1983; Samuels & Eisenberg, 1981).

(xiv) a cluster of knowledge (a set of concepts and associations among the concepts) (Thorndyke & Hayes-Roth, 1979).

(xv) a structured cluster of knowledge (Thorndyke & Yekovich, 1980)

(xvi) a cluster of knowledge, ‘a skeleton structure’ or an organised collection of facts and relations (Thorndyke, 1984).

(xvii) a ‘natural bunch of knowledge’ (Mavrogenes, 1983) or ‘packet of information’ (Baddeley, 1990).

(xviii) a ‘cognitive filter’ (Sheridan, 1981).

Chi and Rees (1983) also claim that a schema can be viewed as (xx) “a set of nodes in a network that are very tightly interrelated via multiple links” or (xxi) “a group of (related) production rules” (p. 90).

A production rule (or production) is like a stimulus-response connection. It consists of a condition and an action, and is commonly symbolised by an ‘if-then’ statement. The condition can contain variables which can be filled by incoming information. If information matches the condition, then the action occurs (Anderson, 1983; Chi & Rees, 1983).

For Brewer and Nakamura (1984) schemata “are the unconscious cognitive structures and processes that underlie human knowledge and skills” (p. 136) (though it is not clear how a schema can be both a fixed structure and a process). Two functions of a schema are to determine “the amount of attention allocated to (particular) information” (p. 143) and to ‘guide’ the retrieval of the latter in recall (Brewer & Nakamura, 1984). But exactly how these functions are performed is not explained.

Rumelhart (1980) states that schemata are “active computational devices capable of evaluating the quality of their own fit to the available data” (p. 39). Each part of a schema “carries out its assigned task of evaluating its goodness of fit whenever activated” (p. 39). How this process of evaluation is said to occur will be examined below.

In summary, among and even within individual schema theories, there are several varied definitions of ‘schema’. For example, Alba and Hasher (1983) state that “the term schema has no fixed definition” (p. 203). For Gagne (1985) it is “difficult to find an agreed-on definition for schema” (p. 56). Brown (1979) claims that “the use of the term ‘schema’ is widespread, vague, and not always overladen with meaning” (p. 231).

But they are also often referred to as concepts themselves (Anderson & Pearson, 1984; Ortony, 1978; Pearson & Spiro, 1980), groups or clusters of concepts (Samuels, 1982, 1983; Samuels & Eisenberg, 1981; Thorndyke & Hayes-Roth, 1979), clusters or bunches of knowledge (Horton & Mills, 1984; Johnson & Hasher, 1987; Mavroggenes, 1983; Thorndyke, 1984; Thorndyke & Yekovich, 1980), organised knowledge (Anderson, R.C., 1984b; Norman, 1982) or knowledge (Anderson & Pearson, 1984; Rumelhart, 1980).


A variable or slot is something which can take on, or be filled or replaced by, different values (Blachowicz, 1984; Hacker, 1980; Pearson & Spiro, 1980; Rumelhart & Norman 1978; Rumelhart & Ortony, 1977), or accept, contain or be filled by specific information (Brewer & Nakamura, 1984), incoming information (Thorndyke, 1984), information (Just & Carpenter, 1987) or stimuli (Howard, 1987, 1988). However, the form of a variable or slot is not clarified (for Howard, 1988, p. 30, a slot “is a kind of blank
space"), nor is it explained how a variable can be given values (‘value’ is itself a vague term) or be filled by incoming information.

A single variable “can take on any of a range of possible values, but some values are more typical than others” (Rumelhart & Ortony, 1977, p. 105). It is unclear, however, how a particular value is determined to be ‘more typical’. The range of possible values which can be taken on (or type of information which can fill a variable) is specified by things called constraints, that are ‘associated’ (Rumelhart & Ortony, 1977) with the variable in question (Blachowicz, 1984; Pearson & Spiro, 1980; Rumelhart & Ortony, 1977).

In comprehension (which will be discussed below), if a variable cannot be filled by incoming information, then it can be filled from within a schema by a ‘typical filler’ (Just & Carpenter, 1987) or default value, which is also somehow ‘associated with’ the variable (Rumelhart & Norman, 1978). A default value is the most typical value for the variable in question (Blachowicz, 1984; Just & Carpenter, 1987; Rumelhart & Norman, 1978; Rumelhart & Ortony, 1977; Schallert, 1982) or the value which ‘normally applies’ (Rumelhart & Norman, 1978).

The variables of a schema are said to be joined or linked by general or typical relations (Anderson, 1978; Anderson & Pearson, 1984; Anderson, et al. 1976; Pichert & Anderson, 1977; Rumelhart & Ortony, 1977), ‘fixed structural’ relations (Brewer & Nakamura, 1984), a network of interrelations (Rumelhart & Norman, 1978) or ‘part-whole’ or ‘subordinate-superordinate’ relations (Just & Carpenter, 1987).

The elements of a schema can also be other schemata. The latter are called subschemata, and are “represented ... by names or labels, not by their entire structures” (Rumelhart &

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4 For Adams and Collins (1979) several default values can be associated with the same variable or slot. It is unclear, however, how a particular default value is determined to be the most appropriate.

In the work of Rumelhart (1980) and Rumelhart and Ortony (1977) some subschemata are elementary, or 'atomic'; that is, they cannot be reduced to other structures. Adams and Collins (1979) state that these schemata “apply to unique perceptual events” (p. 3). During comprehension (see below), schemata organise or 'channel' incoming information (Merrill, Kelety & Wilson, 1981; Thorndyke, 1984). For example, a schema is said to organise or 'chunk' the information in a text during reading (Just & Carpenter, 1987; Mavrogenes, 1983; Samuels, 1982, 1983; Samuels & Eisenberg, 1981). Kintsch and Kintsch (1978) specifically define a schema as a person's knowledge “of the general organisational principles underlying a particular type of text” (p. 18). During reading, a schema guides the formation of the specific macrostructure or 'gist' of a text.

To summarise, a schema is commonly defined as a structure or set of 'empty' elements or forms, called variables, which are joined by typical relations to form a hierarchical network in the space of memory. A schema is 'skeletal' (Paul, 1967; Thorndyke, 1984) in the sense that it is an 'empty' framework, rather than "a contentful structure" (Paul, 1967, p. 219). This 'empty' framework is generally assumed to be a representation or copy of a regularly occurring pattern of information which exists ready-made in an

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5 Just and Carpenter (1987) state that a schema is “a ready-made structure into which (a reader) can insert the new information he acquires from (a) text” (p. 243). But this statement begs the question. That is, a reader must first comprehend the information, in order to know where to insert it in his/her schema.
external world or, more explicitly, a representation, description or summary of
commonalities or typicalities of a number of things or events (Anderson, 1978;
Mandler (1985) a schema is an abstract representation “of environmental regularities” (p.
36-37). In this sense, the modern idea of a schema is like Kant’s concept of a universal
procedure or rule.

In the next section, explanations of comprehension and inference in schema theories will
be reviewed.

2.7.1 Comprehension and inference

In general terms, ‘to comprehend’ is “to grasp with the mind, conceive fully or
adequately, understand, ‘take in’ ” (OED).

In schema theories, comprehension, particularly during reading, is generally said to occur
when variables or schemata are filled by incoming information through the interplay of
bottom up and top down processing (Adams & Collins, 1979; Rumelhart, 1980;
Rumelhart & Ortony, 1977; Schallert, 1982). The term processing, however, typically
refers to the capacity of fixed pathways or relations to guide information toward
variables. That is, information is channelled, rather than transformed or processed.

Bottom up processing occurs as “aspects of the input directly suggest or activate schemata
which correspond to them” (Rumelhart & Ortony, 1977, p. 128). For Rumelhart (1980)
bottom up processing occurs when an event ‘automatically’ activates specific lower
schemata, the activation from which then excites the ‘most probable’ higher schemata.

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6 The filling of variables in a schema with specific information is called instantiation, from the word
‘instance’ (Pearson & Spiro, 1980) (i.e., a specific instance of a thing is comprehended).
But is unclear how higher schemata are determined to be 'the most probable'. Presumably, some sort of *summation* of activation by higher variables must take place.

Adams and Collins (1979) state that in bottom up processing, "features of the data enter the system through the best-fitting, bottom-level schemata" (p. 5). When activation from these schemata 'converges' (i.e., presumably, is summed) in higher schemata, the latter are activated. In this way, "information is propagated upward through the hierarchy" (p. 5).

Top down processing occurs as activation from an excited higher schema activates other subschemata. This type of processing is said to 'facilitate' the acceptance of information by variables in lower schemata (Adams & Collins, 1979). However, to say that 'aspects of the input', events, or 'features of the data' directly or automatically activate lower schemata does not explain exactly how these 'aspects' first locate the *appropriate* variables from among *all* the variables of lower schemata.

This problem is not solved by the claim that comprehension depends upon some sort of association, or 'binding', or information with variables (Rumelhart & Ortony, 1977) or match between information and variables, schemata or knowledge (Anderson, et al. 1978; Hacker, 1980; Pichert & Anderson, 1977; Rumelhart & Ortony, 1977; Samuels & Eisenberg, 1981; Thorndyke, 1984; Thorndyke & Yekovich, 1980). For example, Samuels and Eisenberg (1981) state that reading comprehension depends upon "a match between the incoming information from (a) text and the knowledge and information stored in (a) reader's mind" (p. 57). Such a claim overlooks the problem of how information can make contact with the correct elements of knowledge or variables in the first place. Also, it is unclear how incoming information differs from activation or from the activity which flows between schemata causing them to become 'active'.
Schallert (1982) claims that "information that cannot (fill) a variable is perceived as less important, irrelevant, or incongruous" (p. 29). But, logically, if comprehension or perception occurs when variables in schemata are filled with information, then we cannot comprehend or *know* information that does not fill a variable. As a result, we cannot perceive it to be 'less important' because we do not know about it.

Schema theories also attempt to explain how we make inferences in comprehension. For Rumelhart and Ortony (1977) inference occurs during bottom up and top down processing when, for example, empty subschemata are activated by higher schemata. Inference also takes place when a variable which is not filled takes on a default value (J.M. Mandler, 1979; Rumelhart & Norman, 1978; Rumelhart & Ortony, 1977; Schallert, 1982; Thorndyke & Hayes-Roth, 1979) or is filled by typical information (Chi & Glaser, 1985). Presumably this occurs automatically. For Fisher and Lipson (1985) "default values are often invoked subconsciously" (p. 49). The assignment of default values to variables is called 'default processing' (J.M. Mandler, 1979).

To conclude, comprehension and inference in schema theories are said to occur as information or activation is channelled or guided by fixed pathways or relations, toward variables. We comprehend a thing when information fills some or all of the variables of a schema. Variables which are left empty are filled by default values. The same schema, with its variable constraints, can 'guide' the perception (G. Mandler, 1985) or comprehension (Mavrogenes, 1983) of several different instances of the same thing (Ortony, 1980).

Let me now summarise some of the major problems which face schema theories in regard to comprehension.

First, there is the problem of how incoming information initially locates the correct variables from among all the variables and pathways of all a person's lower schemata.
This is essentially the crucial question of "how the correct, existing structure is activated" (Norris & Phillips, 1987, p. 304). That is, "a primary problem with schema theory is that it (does not provide a) way for (for example) a reader to 'get off the ground' in the comprehension process" (p. 292). I will call this problem the information paradox. Secondly, there are the problems of how we (i) 'comprehend' or 'understand' something novel (Bransford, 1984; Norris & Phillips, 1987) and (ii) 'know' that information is new (Brown, 1979, 1982) (i.e., we can ask the question, 'how can a person be aware that information is novel?").

Without making additional assumptions, it follows that new information which is not matched to a variable is ignored, whether or not a default value fills the latter. Also, a schema only contains general or typical relations. Thus we cannot be aware of unusual relations between things. That is, we must always think or infer that things are related in typical ways. Anderson (1977) thus claims that "the assimilative use of schemata must involve constructing interpretations, for every situation contains at least some novel characteristics" (p. 421). The term 'constructing', however, is not defined.7

Notwithstanding these problems, there is the more general question 'how does learning occur?'. In the context of schema theories, this is the problem of how new variables and relations (new schemata) are acquired.

2.7.2 Learning

For several theorists, schemata are gradually formed by abstraction or induction (Howard, 1987; Pearson & Spiro, 1980; Rumelhart & Ortony, 1977; Singer & Donlan, 1989; Thorndyke, 1984; Thorndyke and Hayes-Roth, 1979; Thorndyke and Yekovich, 1987; Bransford and Franks, 1976) also claim that "every event we experience is in some sense novel, that is, different from any previously experienced event" (p. 94). If this is the case, then any theory of learning must account for how a person can be aware that an 'event' is 'in some sense' novel, and how new knowledge might be formed, as it were, 'on the spot'.

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7 Bransford and Franks (1976) also claim that "every event we experience is in some sense novel, that is, different from any previously experienced event" (p. 94). If this is the case, then any theory of learning must account for how a person can be aware that an 'event' is 'in some sense' novel, and how new knowledge might be formed, as it were, 'on the spot'.
1980), or simply, through 'experience' (Anderson, 1981; Kintsch & Kintsch, 1978; J.M. Mandler, 1979; Mavrogenes, 1983) or 'repeated experiences' (Garner, 1987). For example, Howard (1987) claims that "schemata are (acquired) by abstracting information from actual instances" (p. 51). For Thorndyke and Yekovich, "schemata are formed by induction from numerous previous experiences with various exemplars of the generic concept" (p. 28). However, it is not explained how the process of abstraction or induction occurs.

Rumelhart and Ortony (1977) propose two types of learning, called specialisation and generalisation. Specialisation occurs "when one or more variables in a schema are fixed to form a less abstract schema" (p. 123). The process of 'fixing' is defined as narrowing the range of information which a variable will accept. Clearly, new constraints must be added to the variable(s) in question, though how this occurs is not defined.

Generalisation takes place when we repeatedly experience a situation which 'closely fits' a schema, "except for the one aspect" (p. 125). In time, this 'aspect' is "replaced by a variable" (p. 125). But exactly how the process of replacement takes place is not clarified. Presumably, because we cannot know about this 'aspect' or new element of information, it must gradually 'sink in' and somehow be transformed into a variable.

Rumelhart and Ortony also propose that when "radically new input is encountered, a schema without variables is constructed" (p. 126). But this statement overlooks the problem of how we are aware that input is new (Brown, 1979, 1982). It is also unclear how a schema can exist without variables.

Without regard to these problems, Rumelhart and Ortony claim that "when comparable inputs are encountered" (p. 126) a new schema is formed, in which "differences become variables and ... consistencies get built into the structure" (p. 126). Presumably, these 'consistencies' are typical relations. But it follows that we cannot know that information
is comparable or similar to the radically new input, because the variables which such information fills are themselves in the process of formation. Thus, these new variables (together with 'consistencies') must somehow be passively acquired, that is, they must somehow 'sink in' unbeknown to oneself.

Rumelhart (1980) and Rumelhart and Norman (1978, 1981) propose three different types of learning. These are called *accretion*, *tuning*, and *restructuring*.

Accretion, or 'fact learning' (Rumelhart, 1980), occurs when the variables in a schema are filled with specific information, and a 'representation' (Rumelhart & Norman, 1978) or 'mental trace' (Rumelhart, 1980); that is, a *copy*, of the instantiated or filled schema is formed and joined to the existing schema. In this way, information is 'built up' or accumulated in the space of memory. Accretion is "the natural side effect of the comprehension process" (Rumelhart & Norman, 1978, p. 45). It is the 'normal' (Rumelhart & Norman, 1978; Rumelhart, 1980) or 'most common' (Norman, 1982; Rumelhart, 1980; Rumelhart & Norman, 1981) type of learning.

Tuning is defined as the modification of variables (Rumelhart & Norman, 1978) or schemata (Rumelhart, 1980; Rumelhart & Norman, 1981). Variables or schemata can be modified as follows: (i) constraints can be added to a variable to restrict the range of information it will accept as with the Rumelhart and Ortony process of 'specialisation' (above), (ii) constraints of a variable can be removed to extend the range of acceptable information, and (iii) the default values of variables "can be discovered and added to the ... schema" (Rumelhart & Norman, 1978, p. 47). But how these kinds of tuning occur is not explained.

Restructuring can occur in two ways: "first, a new schema can be patterned on an old one, consisting of a copy with modifications ... this process (is called) *patterned generation* of schemata. Second, new schemata can be induced from regularities in the
temporal and/or spatial configurations of old schemata ... this process (is called) schema

Presumably, patterned generation consists, in part, of the same process of schema
copying which occurs in accretion. The modifications which take place during patterned
generation consist of adding constraints to, or removing them from, the variables in the
schema being copied (Rumelhart, 1980; Rumelhart & Norman, 1978). Patterned
generation is thus a combination of schema copying and tuning.

For Norman (1982), however, “the formation of (schemata) by copying old ones and
making appropriate changes ... is essentially the process of learning through accretion”
(p. 109). Thus the difference (if any) between accretion and patterned generation is
unclear. Also, it is not clear what happens to an ‘old’ schema once a copy with
modifications has been made. Presumably, it must somehow ‘fade’ from the space of
memory.

By contrast, “schema induction is a form of learning by contiguity. If certain
configurations of (activated) schemata tend to co-occur either spatially or temporally, a
new schema can be created, formed from the co-occurring configuration” (Rumelhart &
Norman, 1978, p. 46). Supposedly, new relations between activated schemata somehow
‘sink in’ to form a larger total schema.

For Rumelhart (1980) schema induction is “classical contiguity learning” (p. 54).
Rumelhart states that there is “no real need” (p. 54) for the concept of schema induction in
schema theories of learning. This statement, however, overlooks the problem of how
totally new relations are formed between variables. In each of the other types of learning
(accretion, tuning, patterned generation) the relations or links between variables do not
undergo alteration. Thus the concept of schema induction is necessary in schema
theories, because it accounts for how new relations are formed.
In summary, there are generally four kinds of learning proposed in schema theories. The first kind is the process of copying filled or instantiated schemata (Norman, 1982; Pearson & Spiro, 1980; Rumelhart, 1980; Rumelhart & Norman, 1978). This is the simple and relatively passive accumulation of bits of information, data or 'facts' in the space of memory. The second type is a process of adding constraints to, or removing them from, the variables of schemata (Pearson & Spiro, 1980; Rumelhart, 1980; Rumelhart & Norman, 1978; Rumelhart & Ortony, 1977). The third kind is a process of copying and modifying schemata and the fourth is the formation of totally new relations between schemata through induction (Rumelhart, 1980; Rumelhart & Norman, 1978). These new relations must somehow 'sink into' our minds over time.

Presumably, all these kinds of learning occur, perhaps together and to various degrees, during perception or comprehension. But the problem with these schema 'theories' of learning is that they do not provide an account of the so-called mechanisms of learning (Brown, 1979, 1982; Garner, 1987); that is, they do not explain exactly how copying takes place, or how the process of tuning or induction occurs.

2.8 Summary

Let me now summarise the problems associated with the theories of knowledge and learning reviewed in this Chapter.

In all these theories, which I will collectively call mechanical theories, knowledge is assumed to consist of irreducible elements (nodes, concepts, variables).

In network models of memory and schema theories, these elements are linked by fixed pathways, or associations or relations. The elements and pathways form a static or rigid network in the space of memory. Some sort of activity can travel along the pathways and
activate or excite the elements. Presumably, this flow of activity and the activated elements is thought. For example, Fisher and Lipson (1985) state that "we think along networks ... thinking in new ways typically involves accretion of new nodes ... and reordering some of the relational pathways" (p. 51).

In Chapter One, I posed the fundamental problem, 'how does learning occur?'. In Chapter Two, I have tried to show that the mechanical theories have not been completely successful in their attempts to answer this question and have, of themselves, introduced new and more difficult problems. Specifically, in network models of memory these include how (i) new elements of knowledge are linked with the appropriate or proper nodes (the link paradox), (ii) new links are formed between existing nodes, and (iii) existing links are 'strengthened'.

In the cognitive structure theories of Ausubel and Novak, there are the problems of (i) how new material or information is related or linked with relevant ideas or concepts in cognitive structure (the link paradox), (ii) how we know that a hypothesis is falsified (Novak), and (iii) how we acquire a new concept during hypothesis testing (Novak).

In schema theories, 'variable', 'value' and 'schema' itself are vague terms. There are the problems of (i) how a variable can be given values or be filled by incoming information, (ii) how a higher schema is determined to be the most probable during comprehension, (iii) how incoming information initially locates the correct variables from among all the variables and pathways of all a person's lower schemata (the information paradox), (iv) how information differs from activation, and (v) how we are aware that information is new. With respect to learning, the additional problems arise of (vi) how the process of abstraction or induction occurs, or (vii) how a schema is copied, and (viii) how constraints are acquired and added to, or removed from, variables.
Although it is likely, given an appropriate context, that some of these problems could be solved, the link and information paradoxes, in particular, appear insuperable. Perhaps, therefore, an answer to the question raised in Chapter One may best be sought by abandoning the underlying assumptions of the mechanical theories.

In Chapter Three, I will examine an alternative assumption about learning, which is called constructivism, and review two current ‘constructivist’ theories of learning.
CHAPTER THREE

3.1 Introduction

In the mechanical, 'information-processing type' theories reviewed in Chapter Two, it is commonly assumed that knowledge is acquired when, in general terms, information passes from an external world into our essentially passive and partly empty minds, and either fills specific locations, or is joined with existing knowledge. In contrast to this view of learning, is an assumption known as constructivism (Boden, 1979; Bodner, 1986; Kamii & DeVries, 1978; Kitchener, 1986; Reese & Overton, 1970; Wheatley, 1991) or 'radical constructivism' (von Glasersfeld, 1979, 1983, 1984, 1988, 1989). Strictly speaking, the term 'radical constructivism' refers to a metatheory (Mahoney, 1989) rather than to a single assumption and includes, for example, the ideas of 'fit' and 'viability' (von Glasersfeld, 1983, 1988, 1989; von Glasersfeld & Cobb, 1983).

3.2 Constructivism

Constructivism is the assumption that all knowledge is actively created from within. Knowledge, or information, is not 'taken in' from an external world.

Kamii and DeVries (1978) state that "knowledge and morality develop through a process of construction from within (a) child" (p. 40). Piaget (1960) claims that "thought, like life ... is essentially active because it constructs forms" (p. 83); that is, structures or the forms logico-mathematical knowledge. For Freyberg and Osborne (1985) "knowledge is acquired not by the internalisation of some outside given but is constructed from within" (p. 83).
It does not follow from constructivism, however, that an external world does not exist. That is, constructivism does not necessarily result in solipsism; the view that there is no world other than the one which is created by oneself.

Thus the term ‘constructivism’ is also used to refer to an assumption that knowledge is created by a person in interaction with a world as it is (Reese & Overton, 1970). But we can never determine that we know this world as it is, because we cannot ‘step outside’ our knowledge, which is always constructed from within. That is, we cannot ‘compare’ our knowledge with a world, nor can we “imagine the possibility or the meaning of such a comparison” (Einstein & Infeld, 1938, p. 31). A world “is always and necessarily (a) world as we conceptualise it” (von Glasersfeld, 1983, p. 51). It follows that our knowledge of this world can never be certain. The word ‘truth’ defined as something absolute, loses its meaning. Knowledge is ‘valid’ only to the extent that it endures unchanged.1

However, though the ‘absurdity’ of solipsism (von Glasersfeld & Cobb, 1983) can be dealt with by assuming, like Kant, that our knowledge begins in experience or in interaction with a world as it is, a constructivist theory must also answer the question, ‘how is it that we appear to share common knowledge?’ (Bodner, 1986; von Glasersfeld & Cobb, 1983). That is, ‘how is it that, as individuals, we seem both within and between generations, to construct the same knowledge?’ This paradox can be solved by assuming a world has form, the changeability of which, in line with ‘chaos theory’, is seemingly indeterminable. In interaction with a world, each of us can re-construct this form in our knowledge and, through language or (in part) arbitrary signs, which can generate other knowledge, ideas or images (i.e., ideational thoughts), make others aware

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1 This is known as an instrumentalist view of knowledge (Bodner, 1986). Simply put, “knowledge is good if and when it works” (p. 874). A similar statement was expressed by Osiander “who suggested in the preface to Copernicus’ De revolutionibus: There is no need for these hypotheses to be true, or even to be at all like the truth; rather, one thing is sufficient for them - that they yield calculations which agree with the observations” (quoted in Bodner, 1986, p. 874).
of our ideas; providing of course, that others also share the same 'signs' and these signs also generate, for them, the same ideational thoughts. (As I will show, this has crucial implications for classroom teaching and learning.)


For example, Bell, Watts and Wilson (1985) adopt "a constructivist view of learning, in which (a) learner is seen as actively constructing his or her own meanings" (p. 655). Driver & Erickson (1983) state that "learners actively generate meaning" (p. 39). For
Wittrock, learning "is a constructive, generative process" (Wittrock, 1974b, p. 193), and a "learner must actively construct meaning if he is to learn with understanding" (p. 195).

In the next section, Wittrock's theory of the construction of meaning (which logically, however, is a constructivist theory in name only), called the generative model of learning, is reviewed (Harlen & Osborne, 1985; Osborne & Wittrock, 1983, 1985; Wittrock, 1974a, b, 1978a, b, 1981a, b, 1985).

3.3 The generative model of learning

In the generative model of learning, the construction of meaning, or learning with understanding, occurs when we construct or generate links, associations or relationships (Osborne & Wittrock, 1983, 1985; Wittrock, 1974a, b) between stimuli, sensory or incoming information, or new information and 'stored' information, previous 'experience', previous 'learning' or schemata or knowledge (Osborne & Wittrock, 1983, 1985; Wittrock, 1974a, b, 1978a, 1985).

The construction of meaning, or learning with understanding, is thus like both Ausubel's and Novak's idea of meaningful learning (Section 2.5). The latter occurs when new material is related to ideas in cognitive structure (Ausubel) or when links are somehow formed between new information and concepts in cognitive structure (Novak).

Wittrock also claims that comprehension is a process of construction (Linden & Wittrock, 1981; Wittrock, 1978b, 1981b; Wittrock, Marks & Doctorow, 1975). For example, Wittrock (1981b) states that comprehension in reading occurs when readers generate meaning "by constructing relations between their knowledge, their memories of experiences, and the written sentences, paragraphs and passages" (p. 229). Comprehension is not a process of "fitting information into (the) slots (of) schemata" (Osborne & Wittrock, 1983, p. 492). The generation of a link or association occurs
through the operation or our ‘individualised abstract analytic and specific contextual cognitive processes’ (Wittrock, 1978b), ‘cognitive information processing strategies’ (Wittrock, 1981a) or ‘information processing strategies’ (Osborne & Wittrock, 1983).

In sum, the construction of meaning during learning or comprehension occurs when we create links between arriving information and knowledge in memory. For instance, a teacher is said to give information to students (Osborne & Wittrock, 1983). Learning occurs when students actively relate the “parts of (a) statement, or explanation” (p. 499) to their existing knowledge.

Osborne (1984) and Osborne and Wittrock (1985) qualify the theory slightly when they state that generated links and ‘sensory input’ are used to construct new meaning (see Osborne, 1984, p. 13; Osborne and Wittrock, 1985, p. 65). Thus learning consists of both a process of generation of links, and a process of construction. But precisely how the process of construction occurs is not explained. Also, Wittrock, like Ausubel and Novak, overlooks the problem of how links are created between input or information and the correct or relevant knowledge in memory (the link paradox).

Although the generative model of learning is put forward as a theory of the construction of meaning, in order to create the latter, it requires that we must always ‘take in’ or absorb (Osborne & Wittrock, 1983) input or information.

In the same way, Royer (1986) claims that construction of meaning occurs when “incoming information makes contact (and ‘interacts’) with prior knowledge” (p. 89). This ‘contact’ and interaction occurs in a place called working memory (Royer, 1986); that is, in a part of the absolute space of our minds.

Thus the generative model, and other theories like it based on the mechanical view or the information-processing approach, cannot be logically connected with constructivism.
Clearly, in evaluating increasingly common theoretical statements within the literature about the construction of meaning or knowledge, and accompanying recommendations for pedagogy, we should be mindful of whether such statements derive from a 'doublethink' assimilation of constructivism to the mechanical view\(^2\), or are logically tenable attempts to solve the learning paradox. In this context, I will next review Piaget's theory of the construction of knowledge, or *logico-mathematical structures*, called the *theory of genetic epistemology* (Piaget, 1936, 1968a, 1970a).

### 3.4 The theory of genetic epistemology

In the theory of genetic epistemology, logico-mathematical knowledge is progressively constructed by a child in interaction with a world (Piaget, 1970a). The forms of logico-mathematical knowledge, or 'categories of reason' (Piaget, 1936) or 'categories' (after Kant) (Piaget, 1980), are called logico-mathematical, logical or operational *structures*.

Piaget (1968a) defines a structure as "a system of transformations" (p. 5). A transformation which is reversible is called a 'thought operation' (Piaget, 1961) or an *operation* (Piaget, 1964a, 1972; Piaget & Inhelder, 1969). It is reversible, or reciprocal, in that it can 'operate' "mentally both ways (unite-dissociate, add-subtract, etc.)" (Piaget & Inhelder, 1969, p. 129). Operations combine to form a system (Piaget, 1947, 1981) or structured whole or dynamic totality (Piaget, 1961); that is, a logico-mathematical structure.

This structure is *self-regulating*, self-maintaining or closed, in that its reversible transformations never lead beyond the 'boundaries' of the total system (Piaget, 1968a). In so far as structures are themselves processes, reasoning is the functioning or operation

\(^2\) For example, Osborne (1984) claims that the generative model of learning "is based on both the constructivist and information-processing traditions" (p. 9), yet, logically, these two 'traditions' are irrelative.
of these structures (Piaget, 1961). The process of construction of structures is said to be explained by two main ‘factors’: (i) the perceived fact of maturation and (ii) equilibration (Piaget, 1961, 1970a) or self-regulation (auto regulation) (Piaget, 1970a).


Piaget proposes four types of equilibrium. The first type is that which is maintained between a child’s schemes and ‘objects’, or extended bodies, during assimilation. It will be recalled that a scheme is the common dynamic form of several actions. An action is a series of (voluntary) movements (Piaget, 1968b). Assimilation is defined as the integration or incorporation of extended bodies, external data, elements or ‘any sort of reality’, ‘into’ a scheme or structure (Piaget, 1960, 1964a, 1970a, 1977).

Specifically, in assimilation an ‘object’ (i.e., reality) is said to be ‘modified’, or structured, by a scheme (Piaget, 1936; Piaget & Inhelder, 1966; Boden, 1979). For example, Piaget (1936) states that assimilation is a “structuring through incorporation of external reality into forms owing to (a child’s) activity” (p. 18). In this sense, schemes are like Kant’s a priori forms of knowledge.

Assimilation is symbolised as follows:

(i) \[ a + x \ldots b \]

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3 For Rotman (1977) self-regulation is “self-maintaining equilibrium” (p. 34).
where \( a \) is a cycle of voluntary movements and, presumably, the underlying scheme, and \( x \) is a series of ‘external’ movements (Piaget, 1936) or movements of an extended body. The movements \( a \) produce \( x \) which, in turn, result in \( b \) or another cycle of voluntary movements, which produce the external movements \( y \), etc., which finally result in \( a \). In this way, as a child manipulates external bodies, the latter are assimilated into his/her schemes and equilibrium is maintained.

Accommodation, on the other hand, is “(the) modification of a scheme or structure by the elements it assimilates” (Piaget, 1970a, p. 708). Accommodation is symbolised as follows:

\[
\begin{align*}
(i) & \quad a + x^l \ldots b^l \\
(ii) & \quad b^l + y \ldots c \\
(iii) & \quad c + z \ldots a, etc.
\end{align*}
\]

where \( a \) is a cycle of voluntary movements and \( x^l \) is a series of movements of an extended body transformed from \( x \) into \( x^l \) by a ‘variation’ in (Piaget, 1936) or ‘modification’ of (Piaget, 1959) an ‘environment’. This modification of an environment is called an external intrusion (Piaget, 1959) or external disturbance (Piaget, 1964a; Piaget & Inhelder, 1966).

The external movements \( x^l \) result in a new cycle of voluntary movements, or a new action, \( b^l \), through the modification; that is, accommodation, of the underlying scheme, or the transformation of \( b \) into \( b^l \). This new action \textit{compensates} for the external intrusion, the process of assimilation completes itself - (ii) and (iii) above - and equilibrium is maintained (Piaget, 1959, 1964a, 1964b).
It is through the *coordination* of new or compensatory actions that operations are progressively constructed (Piaget, 1968b, 1970a). That is, the coordination of these ‘coarse’ compensations “finally bring about, *in thought*, exact reversibility” (Piaget, 1960, p. 81) or exact compensation.

However, it is unclear exactly what ‘coordination’ is in this context, although in general use, ‘coordination’ is “the action of arranging, or condition of being arranged or combined, in due order or proper relation” (OED). Logically, it must incorporate ‘reflective abstraction’ (see below). Nor is it explained how accommodation, that is, a change in a scheme or structure, takes place. For example, Phillips and Soltis (1985) raise the question “(Piaget) certainly has named the process (of change), but has he explained it?” (p. 48).

Specifically, operations are constructed by a process called *reflective abstraction* (Piaget, 1970a). In this process, a ‘property’ or ‘form’ of a presumably compensatory action (Kitchener, 1986; Piaget, 1970a), or ‘what is happening on a lower level’ (Piaget, 1975), is projected or transferred to a higher level or ‘plane’ (Kitchener, 1986; Piaget, 1970a, 1975). ‘Reflection’ is used here in a physical sense. This form is reconstructed, reorganised, or ‘re-thought’ (i.e., reflection in a mental sense) on this higher plane to form an operation (Kitchener, 1986; Piaget, 1975). Presumably, through coordination of compensatory actions and reflective abstraction, new operations are somehow combined into systems. However, crucially, it is not explained how the processes of coordination, projection and reconstruction (i.e., construction) actually occur(s).

The second kind of equilibrium proposed by Piaget is one which can exist between assimilation and accommodation. Used in this sense however, ‘equilibrium’ presumably means balance. Such an equilibrium “characterises a complete act of intelligence” (Piaget, 1970a, p. 708). By the latter statement, Piaget supposedly means that in the attainment of
an equilibrium (a balance) between assimilation and accommodation, the maximum progress is made by a child in the construction of operations.

The third kind of equilibrium is an equilibrium which is reached among a number of different systems of schemes. The fourth type is one which is successively attained between the parts and the totality of a person's knowledge (Piaget, 1977). Logically, the third type is a special instance of the fourth type of equilibrium.

To summarise, accommodation never occurs without a corresponding (attempt at) assimilation (Piaget, 1970a). That is, "learning is possible only when there is (an attempt at) active assimilation ... all the emphasis is placed on the activity of (a child) himself" (Piaget, 1964a, p. 18).

The construction of reversible transformations (operations) and their organisation into systems (structures) occurs through the accommodation of schemes, coordination of compensatory actions and reflective abstraction.

Operations are said to allow us (i) to 'anticipate' or 'represent' an external intrusion (i.e., we can 'imagine' the result of variation in an environment, Piaget and Inhelder, 1969), and (ii) through their reversibility, to compensate for in advance, or 'pre-correct' (Piaget, 1970a), such an intrusion (Piaget, 1964b). In this way, reasoning acquires its characteristic necessity.

But exactly how a new structure is constructed is not explained. For example, Williams (1984) claims that the problem "of how (the process of construction) actually works (is) not addressed (by Piaget)" (p. 115). Bruner (1966) states that Piaget's theory of genetic epistemology does not "constitute an explanation ... of the (process) of growth" (p. 7). For Robinson and Horn (1977) the theory "is much more adequate as a description of the
cognitive changes that occur during development than as an account of how these changes occur” (p. 29).

Nor is it clear in what way the concept of *equilibration* constitutes an *explanation* of construction (Boden, 1982). If equilibration is defined as some sort of process which produces equilibrium (Piaget, 1959, 1970a), then, to the extent that accommodation, coordination, and reflective abstraction achieve this, equilibration is superfluous.

### 3.5 Summary

Constructivism is the view that knowledge or a dynamic structure is actively created through our own functioning from within. But constructivism is beset with the so-called learning paradox, that is, the problem of how we construct new knowledge from existing knowledge or structures.

Within the literature, the only systematic constructivist theory, the theory of genetic epistemology, fails to explain exactly how construction occurs. Also, the latter theory is put forward as an attempt to explain how *logico-mathematical* knowledge, or the dynamic forms of reasoning, can be created. Piaget, pardonably, has relatively little to say about how an *idea*, or what he calls ‘figurative’ knowledge (i.e., the ‘content’ of operations, Furth, 1977), is formed. Furth, on this point, chides that “to some extent Piaget has neglected the figurative aspect of knowledge” (p. 66).

Thus, in so far as the mechanical theories reviewed in Chapter Two face several problems (some intractable), and a complete constructivist theory of learning does not exist, we can conclude that there is no logically flawless theory of how learning occurs. In support of this conclusion, Stenhouse (1986) states that “an unresolved problem in Science Education ... (is) how conceptual changes actually take place in individual students” (p. 413), while for Bereiter (1985), “there is no theory of cognitive learning - that is, no
adequate theory to explain how new organisations of concepts and how new and more complex cognitive procedures are acquired" (p. 201).

In Chapters Four and Five, I will propose a constructivist theory of learning, or explanation of the action of acquiring knowledge, which is based upon current neurophysiological and neuroanatomical theory. The theory is stated formally, as seven postulates, or fundamental assumptions.

In Chapter Six two postulates will be proposed which will provide a logical link between the specific, ‘neurophysiological’ explanation of a process of construction, and word meaning and intrinsic motivation.

This expanded theory will then be applied to a situation of a student learning by reading a passage of text, and a hypothesis derived which is tested in a study reported in Chapter Seven.
CHAPTER FOUR

4.1 Introduction

In this Chapter, I will depart sharply from psychological terminology which has characterised all the theories of knowledge acquisition reviewed in previous sections.

The following theory, though based on constructivism, also stands or falls on an assumption that knowledge, or a ‘schema’, is a pattern of activity, or nerve impulses (Hendry, 1985; Iran-Nejad & Ortony, 1984). The idea that nerve impulses form spatio-temporal patterns in our brain can be traced back to Thomas Young’s early nineteenth century theory of colour vision (Erickson, 1984). But since this time, with the exception of Erickson’s theory (Erickson, 1967, 1984), and the work of the Australian neurophysiologist, Eccles (1972, 1977) (who pioneered the theory of the synapse), and of course Iran-Nejad’s theory, the currency of this idea has remained relatively limited.

Within neurophysiology, the comparative obscurity of this idea can, perhaps, be principally attributed to the popularity of the ‘labelled-line theory’ (Erickson, 1984), or the view that “activity in a particular neuron has a constant meaning no matter what is happening in other neurons” (p. 234). By contrast, in Young’s view, in a receptor cell of the retina (now called a cone), nervous activity, or ‘vibration’, has ‘meaning’ only in relation to activity in other cells, and varies as a part of the total specific pattern of activity (Erickson, 1984).

Likewise, for Erickson, “information in the nervous system exists in the form of relative amounts of neural activity across many neurons. This form will be called here an ‘across-fibre pattern’” (Erickson, 1968, p. 459) (i.e., a spatio-temporal pattern). He also states that this is a “Gestalt-like concept” (p. 463), and that a stimulus is ‘represented’ by such a pattern (though the relation of information or ‘stimulus representations’ to
knowledge itself remains ambiguous). In a more recent paper, Erickson is more direct, when he rejects the idea that data or information is ‘read out’ from a pattern of impulses; rather, the former is “already in the brain’s native language: a population of activity” (p. 238), and “the power of Young’s logic is that the pattern is the message; it is the brain’s sensory code in its final form” (p. 239). Here he seems to be saying that patterns are our percepts.

For Eccles (1972) “the flow of specific information from receptor organs into the nervous system will result in the activation of specific spatio-temporal patterns of impulse discharges” (p. 59), while in a later publication, he states that impulses “traverse neurons weaving a pattern in space and time” (Eccles, 1977, p. 178), which he calls a dynamic engram (after Lashley). As well, this view has now emerged in psychology (see Section 2.6), in Iran-Nejad’s (1989a, b, c; Iran-Nejad & Ortony, 1984) biofunctional schema theory. Iran-Nejad has taken a crucial step, and postulated that knowledge is a pattern of activity; ideas or schemas are “impulse patterns that spread, like sound waves, throughout the neural network” (p. 180).

The following theory of how we acquire knowledge is formally summarised as seven postulates. In this Chapter, I will state the first two of these and present the remaining five in Chapter Five. The first postulate, after Iran-Nejad, is as follows:

Knowledge is a continuous spatio-temporal pattern of nerve impulses. A specific pattern of nerve impulses is specific knowledge.

The second postulate states that the kind of knowledge we have is determined by the area of the cerebral cortex in which a continuous spatio-temporal pattern of nerve impulses is generated.
The neurophysiological terminology in which the seven postulates are expressed is intended to evoke a specific meaning. On the point of clarity, in recent times, several authors within education (Esler, 1982, 1984; Powell, 1984; Robinson, 1988) have attempted to derive implications for pedagogy from current neurophysiological theory and research. Unfortunately, this exercise appears to be somewhat premature, not least because it is often characterised by misuse of terminology and a clouded understanding of neurophysiological principles (cf. Peterson, 1984).

Thus, in part, in order to dispel the reader's potential dubiety about the tenability of the following approach, I will spend some time in the following sections introducing a necessary minimum of current neurophysiological theory. Of course, I also do this in order to explain principles of the generation of a spatio-temporal pattern of impulses, and, though much less critically, provide definitions of terminology which will be used throughout this and the next Chapter.

In the first section below, for example, the cerebral cortex itself is briefly described; what it is and its three major functional areas. In Section 4.3, the neuron is described; the common parts of neurons and what they are called, in order, in Section 4.4, to explain what a synapse is.

In section 4.5, I will then define how a nerve impulse is generated; how it is re-generated in adjoining neurons through chemical synaptic transmission (Section 4.6), and how the generation of trains of impulses is a function of spatial and temporal summation (Section 4.7). In Section 4.8, principles are thus derived to account for the generation of spatio-temporal patterns of nerve impulses in our cortex. In Section 4.10, I will infer, from the latter principles, three processes by which a new pattern could be formed, and then review evidence for each process.
In Chapter Five, I will explain how ‘intensified’ neural activity in an ‘anatomical circuit’ in the brain, following an event I call reduction, results in protein synthesis, the creation of new synapses in the cortex, and the formation of a new pattern.

4.2 The brain and the cerebral cortex

The top two-thirds of our brain, which is called the cerebrum, consists of two cerebral hemispheres. Each hemisphere is subdivided into four lobes, “named, according to their position in the skull, the frontal, parietal, temporal and occipital lobe(s)” (Schmidt, 1978a, p. 269). The position of these lobes is illustrated in Figure 4-1.

The outer layer of tissue of each cerebral hemisphere is called the cerebral cortex (Barr & Kiernan, 1983; Noback & Demarest, 1981) and comprises 80 percent or more of our whole brain (Cotman & Lynch, 1989). It ranges in thickness from 1.3 to 4.5 millimetres in different areas (Schmidt, 1978a), and “is highly convoluted, its surface consisting of convex folds, or gyri, separated by furrows called sulci” (p. 269). That is, it is as if this large sheet of tissue, about 2.5 square feet in area (Kelly, 1985a), has been ‘folded’ into our skull by evolution.

The areas of the cortex to which sensory nerve fibres project are called (primary and secondary) sensory areas (Noback & Demarest, 1981) or sensory or specific cortex (Schmidt, 1978a). Other areas which cannot be classified as sensory or motor cortex are named association areas (Noback & Demarest, 1981) or association, or non-specific, cortex, for example, the cortex of the frontal lobe (Schmidt, 1978a).

1 By convention, the brain is classified into five divisions: (i) telencephalon, (ii) diencephalon, (iii) mesencephalon, (iv) metencephalon, and (v) myelencephalon or medulla oblongata (Barr & Kiernan, 1983; Noback & Demarest, 1981). The telencephalon consists of the cerebral cortex, medullary centre, corpus striatum and olfactory system. The diencephalon is subdivided into the thalamus, subthalamus, epithalamus and hypothalamus. The mesencephalon, or midbrain, comprises the tectum, basis pedunculi, substantia nigra and tegmentum (Barr & Kiernan, 1983). Finally, the metencephalon is subdivided into the pons and cerebellum (Barr & Kiernan, 1983; Noback & Demarest, 1981).
Figure 4.1 Lobes of the cerebrum and areas of the cerebral cortex. In the left hemisphere, Broca’s area and Wernicke’s area are associated with the production and comprehension of language respectively. Interaction between nerve impulses generated in the visual and auditory cortices is believed to occur in an area called the angular gyrus, situated in the parieto-temporal region (from Geschwind, 1979, p. 161).
4.3 The neuron

The tissue of our cortex is made up of three types of cells: nerve cells, or neurons, neuroglial cells and cells of the blood vessels (Barr & Kieman, 1983). (See Appendix I for a brief explanation of the function of neuroglial cells).

Neurons are separated from each other, and from neuroglial cells, by an interstitial space (Abbott, 1986; Davis, Holtz & Davis, 1985). The interstitial space is filled with interstitial, or extracellular, fluid. The fluid inside a cell is called intracellular fluid.

A neuron consists of a cell body, or soma, and cytoplasmic processes which extend from the soma called neurites. Neurites may be classified into dendrites (dendrons) and an axon, or nerve fibre. Dendrites characteristically branch extensively to form a dendritic tree (Williams & Warwick, 1975). An axon divides into terminal branches called teliodendria (Barr & Kiernan, 1983; Noback & Demarest, 1984), whose endings are termed boutons terminaux (terminal buttons) (Barr & Kiernan, 1983; Somjen, 1983), synaptic knobs, or presynaptic terminals (Davis, et al. 1985; Guyton, 1986).

4.4 The synapse

A presynaptic terminal of a neuron is separated from the adjoining membrane of another neuron by a uniform space, called the synaptic cleft, which is slightly wider than the interstitial space (Mountcastle & Sastre, 1980). The area of postsynaptic membrane which adjoins the presynaptic terminal is called the subsynaptic membrane (Noback & Demarest, 1981; Schmidt, 1978c). A presynaptic terminal, the synaptic cleft, and the subsynaptic membrane, taken together, are called a synapse (Eccles, 1977).

The most common types of synapses are those made by an axon and a dendrite (axodendritic), an axon and a soma (axosomatic) or an axon and an axon (Mountcastle &
In axondendritic and axosomatic synapses, presynaptic terminals typically synapse with small projections of a dendrite or soma called spines or gemmules (Noback & Demarest, 1981; Williams & Warwick, 1975).

The cell in which a nerve impulse is generated is called the presynaptic neuron, and an adjoining cell is named the postsynaptic neuron. These are relative terms.

In sum, a neuron consists of a body from which extend numerous processes called dendrites and an axon. An axon generally extends for some distance, before branching into finer processes, called teliodendria, which mainly form synapses with the dendrites and somas of other cells.

Though neurons are extremely small, and are measured in thousandths of a millimetre (microns) (a presynaptic terminal is about 1 micron in diameter) (Rosenzweig & Leiman, 1989), some axons extend for great distances, enter the ‘white matter’ beneath the cerebral cortex and re-emerge in another cortical area. These are called corticocortical fibres. Other axons or fibres entering the cortex, for example from a structure called the thalamus deep within the brain, are called subcortical fibres.

Within a specific area of the cortex, the teliodendria of all cells form synapses with many, sometimes hundreds, of other cells (the principles of divergence and convergence) (Mountcastle & Sastre, 1980; Schmidt, 1978b; Somjen, 1983). Generally speaking, the arrangement of neurons in our cortex is thus like an immense, three-dimensional, reticle.

The electrical activity generated in this vast web is minuscule, and voltages and the large, propagating change in voltage which is the nerve impulse, are measured in millivolts (mV), or thousandths of a volt.

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2 In the CNS, “divergent and convergent arrangements (of neurons) occur to degrees varying from the rare 1:1 relation to those in which the pre-post and post-pre ratios number several hundred” (Mountcastle & Sastre, 1980, p. 185).
4.5 The generation of a nerve impulse

In all cortical neurons, the intracellular fluid is negatively charged relative to the extracellular fluid outside. This results in an electrical potential difference, or voltage (a potential difference is a separation of positive and negative charge), across the membrane of a neuron. This potential difference is called the membrane or resting potential (Guyton, 1986), and the membrane of a neuron is said to be 'polarised' (Atrens & Curthoys, 1982; Davis, et al. 1985; Guyton, 1986; McClintic, 1985).

A decrease in the membrane potential of a neuron, or a change from negative toward positive (e.g., from -60 mV to -50 mV), is called a depolarisation, that is, the inside of neuron becomes less negative relative to the outside. An increase in potential, or a change from negative to more negative (e.g., from -60 mV to -70 mV), is called a hyperpolarisation, that is, the inside of a cell becomes more negative relative to the outside (Kandel, 1981a).

A depolarisation increases the ability of a cell to generate a nerve impulse, and is thus called excitatory, while a hyperpolarisation decreases this ability, and is therefore called inhibitory (Kandel, 1981a).

Within the membrane of a neuron are channels through which positive sodium and potassium ions can flow into and out of the cell. These channels are opened or closed ('activated' or 'inactivated') by sufficiently large changes in the membrane potential, and are said to be 'voltage-gated' (Guyton, 1986).

When a sufficiently large depolarisation of an area of the membrane occurs, sodium channels in this area open, and large numbers of sodium ions flow into the neuron resulting in a rapid increase in the membrane potential from negative towards positive.
Within fractions of a millisecond, this increase in potential causes the sodium channels to close, and the potassium channels to open. A rapid diffusion of potassium ions out of the cell occurs, resulting in a rapid decrease in potential back toward negative. Again, within fractions of a millisecond, the potassium channels close, and the normal negative membrane potential is re-established (Guyton, 1986).

This large change in the resting potential from negative toward positive (depolarisation) and back again to negative (repolarisation) is called an action potential (Guyton, 1986). The membrane potential value (in mV) to which a cell must be depolarised to produce an action potential is called the threshold. Different cells can have different thresholds (Mountcastle & Sastre, 1980; Rosenzweig & Leiman, 1989).

The production of an action potential typically occurs in a part of the neuron called the initial segment (Burke, 1987; Kandel, 1981a; Mountcastle & Sastre, 1980). ‘Local’ action potentials can also be produced in some dendrites (Kandel, 1981a; Mountcastle & Sastre, 1980).

When an action potential begins in an area of membrane in the initial segment, a circuit of electrical current (an electrical current is a flow of charge) develops between this area and the next. This local circuit of current causes further depolarisation, producing an action potential, which causes a local circuit of current still further along the axon, causing more depolarisation, and another action potential, and so on (Guyton, 1986). This wave of large change in potential which propagates along an axon into all the teliodendria at essentially constant velocity is the nerve impulse (Barr & Kiernan, 1983; Brinley, 1980; Guyton, 1986).

Within the vast, reticle-like arrangement of neurons in our cortex, a single wave-like impulse is like a fleeting point of starlight. Normally, several transitory impulses, or a train of impulses, propagate(s) in a single cell; these trains travel into all teliodendria,
subside at each synapse, and are rapidly regenerated by chemical synaptic transmission in adjoining neurons.\(^3\)

### 4.6 Chemical synaptic transmission

Within the presynaptic terminals of the teliodendria of a neuron are granular structures called synaptic vesicles, which contain a chemical substance named a neurotransmitter. When a nerve impulse reaches a presynaptic terminal, Ca\(^{2+}\) ions flow into the terminal from the extracellular fluid, and cause the synaptic vesicles within the latter to fuse with the terminal membrane.

The neurotransmitter in the vesicles is released into the synaptic cleft, diffuses rapidly across the latter and reversibly binds with receptor proteins in the subsynaptic membrane. This produces a *sub-threshold change*, a depolarisation or hyperpolarisation, in the membrane potential of the postsynaptic neuron, called a postsynaptic potential (PSP) (Ottoson, 1983; Somjen, 1983).

The amount of neurotransmitter contained in each synaptic vesicle "is called a quantum, and release is said to be 'quantal' in nature" (Somjen, 1983, p. 93). The size of a PSP is proportional to the number of quanta released (Gallistel, 1973; Shepherd, 1979), and the latter is *proportional to the frequency of arriving impulses*. Thus the magnitude of a PSP varies with the frequency of a train of impulses in a presynaptic neuron (Mountcastle & Sastre, 1980). This is an important principle of the generation of a *pattern* of impulses.

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\(^3\) Synapses at which chemical synaptic transmission operates are called chemical synapses. The latter are by far the most common type of synapse in the CNS (Davis, et al. 1985; Shepherd, 1983). Gap junctions between neurons, which are rare in the mammalian brain (Bray, Cragg, Macknight, Mills & Taylor, 1986; Eccles, 1982; Mountcastle & Sastre, 1980; Noback & Demarest, 1981), but common in invertebrates (Bray, et al. 1986; Davis, et al. 1985; Mountcastle & Sastre, 1980), are called electrical synapses (Mountcastle & Sastre, 1980).
A sub-threshold depolarisation of the postsynaptic membrane is called an excitatory postsynaptic potential (EPSP). A hyperpolarisation is called an inhibitory postsynaptic potential (IPSP). In the brain, “IPSPs are very large and have very long time courses” (Mountcastle & Sastre, 1980, p. 203). When appropriately timed, a single IPSP can prevent the generation of a nerve impulse (Eccles, 1972). This is another crucial principle of the generation of a pattern of impulses.

While different classes of neurons release different neurotransmitters, the same neurotransmitter can produce either an EPSP or IPSP depending upon the type of receptor protein in the subsynaptic membrane (Guyton, 1986; Schmidt, 1978c). For example, “norepinephrine released at some synapses in the central nervous system causes inhibition whereas at other synapses it causes excitation” (Guyton, 1986, p. 552). Thus synapses are said to be either excitatory or inhibitory on the basis of the type of PSP produced. Again, this latter statement is an important principle to bear in mind.

4.7 Spatial and temporal summation

If an impulse arrives at a presynaptic terminal and produces a PSP in the postsynaptic membrane, and a second impulse arrives at a different terminal and produces another PSP in the postsynaptic membrane before the PSP produced by the first impulse has completely decayed, then the two potentials will sum (i.e., add together). The summation of PSPs produced by the rapid arrival of impulses at many different terminals is called spatial summation (Guyton, 1986; Kalat, 1984; Noback & Demarest, 1981; Somjen, 1983).

If an impulse arrives at a terminal and produces a PSP in the postsynaptic membrane, and a second impulse arrives at the same terminal within a short period of time and produces another PSP before the PSP produced by the first impulse has subsided, then the two potentials will also sum. The summation of PSPs produced by the arrival of a train of
impulses at a terminal is called temporal summation (Guyton, 1986; Noback & Demarest, 1981). The total spatial and temporal summation of PSPs in a neuron is called synaptic integration (Shepherd, 1979, 1983).

Within the cortex, summed PSPs comprised of only EPSPs or IPSPs are rare; rather, “the PSPs observed are commonly diphasic, a combination of sequentially timed (EPSPs and IPSPs)” (Poggio & Mountcastle, 1980, p. 281). If a summed EPSP reaches the threshold of a neuron, then a train of impulses is typically generated (Poggio & Mountcastle, 1980). Importantly, the magnitude of a summed EPSP determines the frequency of impulses in a train (Mountcastle & Sastre, 1980).

To summarise, an impulse is a wave of large change in potential (depolarisation and repolarisation) which propagates in the membrane of the axon of a neuron. A train of impulses produces, by chemical synaptic transmission, a sub-threshold change (EPSP or IPSP) in the membrane potential of adjoining neurons. The magnitude of this PSP is proportional to the frequency of a train of impulses. The frequencies of trains of impulses are, in turn, determined by the magnitude of spatially and temporally integrated, diphasic, threshold EPSPs.

I have now briefly ranged over a wide area of neurophysiological theory. Hundreds of neurons in one small area of our cortex can make synapses with hundreds of other neurons, forming an immense, reticle-like structure. Cortical neurons have a variety of shapes, some very distinct, like the ‘giant pyramidal’ cells, others are ill-defined. However, in general, all cortical neurons are classified as either pyramidal or stellate (Kelly, 1985a). Some have very short axons, others long, and the dendritic trees of some neurons can be very large. Synapses can be formed almost anywhere over a cell, neurons can have the same or different thresholds, the same neurotransmitter can produce either an EPSP or an IPSP, PSPs can vary in magnitude, and the frequencies of trains of impulses can vary. It might seem that there are far too many variables to make sense of
how human cortical tissue can support what we call knowledge or thought. (For a more complete summary of the variability of cortical neuronal structure and processes, see Rosenzweig and Leiman, 1989, p. 167-168).

Following Erickson and Iran-Nejad, one way to make some sense is to assume that knowledge is itself a pattern of impulses, and by putting aside the great complexity of our generative tissue (at least for the present), principles which govern the generation of such a pattern can be derived.

4.8 The structure

It follows that if (i) the frequencies of trains of impulses determine the magnitudes of PSPs, (ii) the magnitudes of threshold EPSPs determine the frequencies of trains of impulses, and (iii) the number and type of synapses in a population of neurons are fixed in time, then (iv) a particular spatial pattern of impulses is a function of the timing of impulses.4

These statements (i) through (iv) constitute principles of the generation of a total pattern of nerve impulses which exists in space and time, and which I will call a structure (the latter term corresponds to Erickson’s ‘across-fibre pattern’, Eccles’ ‘dynamic engram’ and Iran-Nejad’s ‘schema’). That is, a structure is a continuous spatio-temporal pattern of impulses formed by trains of impulses of different frequencies propagating in neurons and producing, through synaptic integration, threshold EPSPs of different magnitudes which, in turn, produce trains of impulses of various frequencies in adjoining neurons. I will call this total population of neurons, the interstitial space, and the adjacent neuroglial cells, the region of a structure.

4 This was hypothesised by Hebb more than thirty years ago, when he wrote, “in a single system, and with a constant set of connections between neurons in the system, the direction in which an entering excitation will be conducted may be completely dependent on the timing of other excitations” (Hebb, 1949, p. 10).
Some axons extend for great distances through our brain. For example, a vast bundle of nerve fibres called the arcuate fasciculus reciprocally projects between the parietal, occipital, temporal and frontal cortex, and in particular, Wernicke’s area and Broca’s area (Barr & Keiman, 1983) (see Figure 4-1). Thus a structure need not be ‘localised’ to a circumscribed area of the cortex, but can ‘propagate’ from one cortical area, into the white matter, and re-emerge in another. The word ‘region’ (above) is therefore a relative term, and need not only refer to a limited area of cortical ‘space’.

Like the field in physics, a structure is continuous. Impulses propagate at almost constant velocity and cause a continuous process of neurotransmitter release, diffusion and synaptic integration. In physics, fields “are physical states of space” (Einstein, 1934, p. 281), and “the field, as determined by differential equations, takes the place of force” (Einstein, 1936, p. 308). In the same way, a structure is a ‘physical state’ of its region, and takes the place of Hume’s association, or the ‘gentle force which commonly prevails’. Use of the terminology, ‘physical state’, does not constitute equivalence with physical states as they are known in physics, but rather refers to a differential condition of nervous tissue which is different in kind, for example, from an imagined condition of space.

To restate the first postulate, a structure is knowledge (Iran-Nejad & Ortony, 1984). A specific structure, that is, a unique pattern changing in time, is specific knowledge. A structure which is generated in a particular area of the cortex, for example, in a sensory or association area, is a particular kind of knowledge (second postulate).

Given the algebraic spatio-temporal summation of PSPs, or synaptic integration, different structures in a region can variously integrate, or disintegrate, through the production of IPSPs, with the same structure in another region, or vice versa. That is, in disintegration, different structures can reduce the same structure in another region to a
part, or smaller continuous spatio-temporal pattern. For clarity, I will call the variable integration and/or disintegration of a structure in a region with a structure in another interaction.

From the first postulate, it follows that knowing is the completion of a structure. This completion, or flow, is thought. Several structures can merge to form a larger flow. Ideas "form and dissolve in (this flow), like ripples, waves and vortices in a flowing stream" (Bohm, 1980, p. 11). They "merge and fuse, with no sharp breaks between them" (Bohm, 1985, p. 128). That is, a structure, knowledge and an idea, and 'percepts' and feelings, are the same thing: flowing, 'physical states' of nervous tissue (cf. Iran-Nejad & Ortony, 1984; Iran-Nejad, Clore & Vondruska, 1984).

It might be that, in the near future, a new interdisciplinary approach in cognitive science, called the neurocomputational approach, or 'connectionism' or the 'parallel distributed processing (PDP) approach' (Phillips & Baddeley, 1989), will yield a systematic, detailed account of human cortical 'neural net design' and the typical form, or 'morphology', of spatio-temporal patterns of impulses generated in various areas of the cerebral cortex. For example, Phillips and Baddeley state that a 'clear and fundamental goal' of this evolving approach is "to specify what this (human cortical neural net) design is, what its computational capabilities are, and how (these) capabilities enable knowledge to be so effectively embodied in the (cortex)" (p. 78). (Though the idea of 'computational capabilities' is rejected here; neurons, or 'nets' of neurons, that is, a potential structure's region, do not 'compute', or perhaps more traditionally, process impulses, information or otherwise.)

In disintegration, potentially larger structures are reduced to parts or smaller spatio-temporal patterns. If each part is itself a structure which, relative to a part, is a larger structure, then all parts and structures are relative. Thus knowledge must remain necessarily limited, existing always as a system of parts relative to structures which are
yet to be formed. That is, knowledge is essentially a flow which is continually evolving.  

4.9 Reduction

Fundamentally, it is logically possible that a structure in a region can disintegrate reciprocally with a structure in another region. The reciprocal resolution of structures into parts, I will call reduction. That is, reduction occurs when potentially larger structures mutually 'inhibit' each other and cease to propagate or 'move through' the cortex.

Reduction corresponds to Iran-Nejad's ideas of dissonance and dissolution (Iran-Nejad & Ortony, 1984). Patterns which are "active at the same time" (p. 193) will tend to 'interfere', causing 'dissonance' and "a momentary state of dissolution" (p. 193). The latter is resolved by resolution, in which "a new ... pattern emerges to support a surviving and/or novel constellation of elements" (p. 193), though (since elements are neurons) it is not clear exactly what he means by this. In a recent paper, he states that learning and, presumably resolution (in part), or the "creative reconceptualisation of internal knowledge (is) a discontinuous change from a structure with one holistic character (or quality) to another structure with a different holistic character" (Iran-Nejad, 1990, p. 586).

As will be shown in Chapter Five, in our interaction with a world, it is following reduction that a process of construction, or the creation of a qualitatively different spatio-temporal pattern (Iran-Nejad, 1990), begins. That is, reduction or discontinuity is a

5 For present purposes, it is sufficient to say that the discovery of 'truth' is not a process of drawing closer, 'step by step' to some sort of absolute certainty. The word 'truth', defined as something absolute, loses its meaning. Knowledge is 'valid' only to the extent that it endures unchanged. The 'validity' of a law, or a scientific theory, is always relative to thoughts yet to be created. Put more picturesquely, "truth is not our destination, but only a romanticised direction in our journeying. Though our knowledge is fallible, it can still be functional. The object of the dance, after all, is not to finish; the object of the dance is to dance" (Mahoney, 1989, p. 188).
'catalyst' for the creation of new knowledge. It loosely corresponds to Piaget's idea of an external intrusion or disturbance (Section 3.4).

In the next sections, I will derive three ways in which a new structure could be formed, and then review evidence for each process.

4.10 Post-tetanic potentiation

It follows from principles of the generation of a structure, derived in Section 4.8, that if, for present purposes, I exclude maturation (e.g., the growth of axons or at specific points during our development, their progressive myelinisation), then a new structure, or new knowledge, must be formed through either (i) a lasting increase in the magnitude of PSPs, (ii) the creation of new synapses, (iii) a change in a synapse's type, or (iv) any combination of (i), (ii) and (iii).

To my knowledge, there is no evidence for (iii) (though Kandel, 1989, hypothesises that changes in the 'sensitivity' of postsynaptic receptors produced by mutant gene expression might underlie the psychotic illnesses of manic depression and schizophrenia). But in laboratory studies of animals, following high frequency electrical, or tetanic, stimulation of a presynaptic neuron, PSPs which are produced in a postsynaptic neuron are much larger compared with those produced before tetanic stimulation. This increase in the magnitude of PSPs is called post-tetanic potentiation (PTP) (Kandel, 1981b; McNaughton, Douglas & Goddard, 1978; Schmidt, 1978b; Somjen, 1983).

6 Logically, the growth of axons would multiply, by a large order of magnitude, the regions of potential structures. Thus genetically timed axonal growth in the left hemisphere of the brain in young children and a process of construction might thus account for the (normal) rapid and regular formation of structures of language (word structures and syntactical structures; see Section 6.2). For example, Hatch and Gardner (1988) claim that "despite a broad range of conditions - within a family or throughout the world - our brains allow each of us to begin to learn language at roughly the same time" (p. 37-38).
However, PTP decays within a period of a few minutes to a few hours (Goddard, 1980; Kandel, 1981b; Schmidt, 1978b; Teyler & DiScenna, 1984), depending upon the duration and frequency of tetanic stimulation (Schmidt, 1978b).

A second type of potentiation, which follows tetanic stimulation of a nerve (a bundle of nerve fibres), and which lasts for several days or several weeks is called long-term potentiation (LTP) (Abraham & Goddard, 1983, 1984; Bliss & Dolphin, 1982, 1984; Brown, Chapman, Kairiss & Keenan, 1988; Douglas, Goddard & Riives, 1982; Lynch & Baudry, 1984a, b; Morris & Baker, 1984; Shashoua, 1982; Somjen, 1983; Teyler & DiScenna, 1984, 1986; Thompson, 1986) or ‘enhancement’ (Goddard, 1980; McNaughton, 1982; McNaughton, et al. 1978; Morris & Baker, 1984).

4.11 Long-term potentiation

In animal experiments, LTP is commonly produced, or induced, in the hippocampal formation of rat or rabbit (Teyler & DiScenna, 1984).7

Pathways (i.e., nerves) used for the induction of LTP in the hippocampal formation include the perforant path to the dentate gyrus (Douglas, et al. 1982; Thompson, 1986), fascia dentata (Douglas, et al. 1982; McNaughton, 1982; McNaughton, et al. 1978), or dentate fascia (Shepherd, 1983) and the Schaeffer collateral to the CA1 pyramidal cells of the hippocampus (Shashoua, 1982). Following brief periods of concurrent tetanic stimulation8 of fibres of the perforant path (for example), there is an increase in the

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7 The hippocampal formation is generally divided into the subiculum, dentate gyrus and hippocampus (Barr & Keiman, 1983; Noback & Demarest, 1981; Teyler & DiScenna, 1986). The subiculum is an area of the parahippocampal gyrus which is adjacent to the hippocampus. The major afferent nerve of the hippocampal formation is the perforant path, so-called because its fibres pass through another path, called the alvear path. The perforant path projects from the entorhinal cortex, the anterior part of the parahippocampal gyrus, to the dentate gyrus and hippocampus (Noback & Demarest, 1981).

8 In the laboratory, induction of LTP in the dentate gyrus requires the concurrent stimulation of a large number of fibres (which, by definition, is achieved when a nerve is tetanised) (Abraham & Goddard, 1984; McNaughton, 1982; McNaughton, et al. 1978). This requirement for induction is called ‘cooperativity’ (Abraham & Goddard, 1984).
magnitudes of EPSPs generated in the dendrites of postsynaptic neurons, called granule cells, in the dentate gyrus that lasts for several days or several weeks (Douglas, Goddard & Riives, 1982; Thompson, 1986). However, like PTP, LTP also decays in time, though over a much longer period (i.e., several days or weeks) depending upon the conditions of the experiment (Teyler & DiScenna, 1984).

In sum, though high frequency electrical stimulation can produce an increase in the magnitudes of PSPs, this increase is not stable, and decays in time. Thus PTP and LTP cannot be the only processes by which a new structure is formed.

4.12 Synaptic growth

Alternatively, the hypothesis (Section 4.10, ii) that a structure is formed through the growth of new synapses, or synaptogenesis, is supported by evidence from studies in which animals have 'enriched' or 'differential experiences' (Rosenzweig, 1984) or are exposed to conditions of 'environmental complexity' (Greenough, 1984a; Stell & Riesen, 1987).

In studies of rat, two or three experimental conditions are generally used. These are "environmental complexity (EC), in which rats are group-housed in a large cage with play objects; social housing in pairs or larger groups in standard laboratory cages (SC); and individual housing in laboratory cages (IC). Litter mates are usually assigned to different conditions to minimise experimental variance" (Greenough, 1984a, p. 229).

Studies show that compared with SC and IC rats, in EC animals there is an increase in (i) the thickness and weight of the cortex (Bennett, Diamond, Krech & Rosenzweig, 1964), (ii) the size of the somas of neurons (Greenough, 1984a; Squire, 1986), (iii) dendritic branching (Greenough, 1984b; Rosenzweig, 1984; Squire, 1986), (iv) the number of dendritic spines, (v) the size of synapses (Rosenzweig, 1984; Squire, 1986), (vi) the
number of synapses per neuron (Greenough & Bailey, 1988; Turner & Greenough, 1985), and (vii) the density of glial cells per unit tissue area, particularly in the visual and surrounding cortex (Greenough, 1984a).

Specifically, EC rats have been found to have approximately 20 per cent more synapses per neuron than IC animals in the upper layers of visual cortex (Greenough, 1984a; Greenough, Black & Wallace, 1987; Greenough, Hwang & Gorman, 1985; Turner & Greenough, 1985).

Stell & Riesen (1987) investigated the effect of four different rearing conditions on the degree of dendritic branching of pyramidal cells in the motor cortex of stumptailed monkeys. The first and second rearing conditions were individual, deprived housing, the third condition was ‘enriched’, individual housing (a plexiglass cage which contained diagonal and horizontal ladders, a swing, a rubber cube and a ball), and the fourth was normal colony housing (with ladders, etc.). These authors found that “the mean numbers of dendritic branches for condition 3 animals (were) greater than or equal to the means (for) the other conditions at every branch order” (p. 343) (branch order corresponds to the number of times a dendrite bifurcates). For every branch order, the mean numbers of dendritic branches and, by implication, the number of new synapses, were greater for condition 3 than either condition 1 or 2 (see Table 3, p. 334). Rosenzweig (1984) claims that this capacity for neural growth, or plasticity, in animals is “present not only early in life but throughout most if not all of the life span” (p. 367).

If a structure is formed through the growth of new synapses, then during construction, there must be an increase in the synthesis of proteins in the cortex. This hypothesis, derived here from principles of generation of a structure (Section 4.8), is typically formulated within the literature as, ‘if long-term memories are formed by synaptogenesis, then during learning or training, there must be an increase in protein synthesis’ (see Renner and Rosenzweig, 1987). Evidence which supports such a hypothesis comes
from animal studies which have found that the formation of 'memories' is prevented when protein synthesis is inhibited (Eccles, 1981; Ganong, 1981; Goelet, Castellucci, Schacher & Kandel, 1986; Kandel, 1989; Renner & Rosenzweig, 1987; Rosenzweig, 1984; Rosenzweig & Bennett, 1984; Thompson, Berger & Madden, 1983).

4.13 Inhibition of protein synthesis

In studies of the effects of an inhibitor of protein synthesis (an antibiotic drug) on the formation of 'memories' in animals, the inhibitor is administered by injection to the experimental animals following training on a task. The ability of both the experimental and control animals to complete the task is later tested (e.g., after 1 day, 7 days) and compared (Rosenzweig & Bennett, 1984).

Early studies used "puromycin (PM) as the inhibitor of protein synthesis" (p. 266). Other inhibitors which were used included "cycloheximide (CXM) and acetoxy-cycloheximide (AXM)" (p. 266). However, PM, CXM and AXM are relatively toxic. This complicated the interpretation of findings in early research (Kandel, 1989; Renner & Rosenzweig, 1987; Rosenzweig, 1984; Rosenzweig & Bennett, 1984).

In recent times, anisomycin (ANI) has been used as an inhibitor of protein synthesis. ANI is of much lower toxicity compared with other inhibitors (Rosenzweig, 1984; Renner & Rosenzweig, 1987; Rosenzweig & Bennett, 1984). Studies show that following training, if the administration of ANI is delayed for a certain period of time, then subsequent administration of ANI (even if prolonged) will not prevent the formation of 'memories' (Rosenzweig & Bennett, 1984). This result indicates that there is a 'critical' period during which protein synthesis occurs.

Several studies also show that the 'stronger' the training on a task, then the longer the administration of ANI must be successively maintained immediately following training in
order to prevent the formation of ‘memories’ (Rosenzweig, 1984; Renner & Rosenzweig, 1987; Rosenzweig & Bennett, 1984).

To conclude, though PTP and LTP might be processes by which a new structure is formed, they cannot be the only processes; a structure formed through PTP or LTP would gradually ‘dissipate’ in time. Alternatively, recent studies of rat show that (i) ‘differential experience’ results in synaptogenesis, specifically, an increase in the number of synapses per neuron, and (ii) the formation of ‘memories’ can be prevented by administration of a drug which inhibits protein synthesis. However, if the formation of a new structure can occur through synaptogenesis, then there must be some physiological event, or sequence of events, that results in the growth of new synapses and which does not otherwise occur during the completion of a structure. Such a sequence of events, and the anatomical circuit in which they occur, will be proposed in the next Chapter.
CHAPTER FIVE

5.1 Introduction

In this Chapter I will propose how 'intensification' of neural activity in an anatomical circuit results in synaptogenesis and the construction of new structures or knowledge in our interaction with a world.

5.2 The production of sensory impulses

We can 'experience' a world, or be in 'contact' with a world, in so far as something in the latter causes a change in the membrane potential of a specialised neuron, or part of a neuron, called a sensory receptor. This 'something' is generally referred to as a stimulus. The change in the membrane potential of a sensory receptor which a stimulus produces is called a receptor potential (Guyton, 1986; Kandel, 1981a).

In most receptors, a stimulus causes a depolarisation, or a decrease in the membrane potential. If a stimulus produces a receptor potential which reaches the threshold of a sensory receptor, then a train of impulses is typically generated (either in the receptor cell, or indirectly, in an adjoining neuron). The higher the magnitude of a receptor potential, the higher the frequency of impulses in a train (Eccles, 1979; Somjen, 1983).

A 'stimulus pattern', for example a spatio-temporal pattern of light, produces trains of sensory impulses with different frequencies in a number of different parallel sensory nerve fibres (Eccles, 1979). It should be noted that 'stimulus' is a relative term. For example, it could conceivably be used to refer to a single photon, but is more commonly and reasonably employed in reference to patterns of stimulation like light flashes, clicks or tones or pressure on the skin.
5.3 The thalamus and hippocampus

All sensory nerve fibres, with the exception of those in the olfactory system, project to specific nuclei \(S\) of a sub-cortical structure called the thalamus. These nuclei, in turn, project parallel fibres, named thalamocortical fibres \(TC\), to sensory areas of the cerebral cortex (Guyton, 1986; Kelly, 1985a). Figure 5-1 shows the location of the thalamus in the brain and the major thalamic nuclei.

For example, sensory impulses are propagated from the retina of the eye in fibres in the optic nerve to neurons in the lateral geniculate nucleus of the thalamus, are re-generated, or 'relayed', and travel in the parallel axons of these neurons \(TC\) to the primary visual area. Impulses from the cochlea of the inner ear travel via the medial geniculate nucleus and are relayed in parallel fibres to the primary auditory area, and impulses arriving from the skin, viscera and muscles are propagated by way of the ventrobasal complex in parallel fibres to the somatosensory cortex (Shepherd, 1979; Ottoson, 1983). Figure 4-1 shows the location of these different cortical areas.

Other nuclei of the thalamus called association nuclei (Kelly, 1985a), or specific association nuclei (Noback & Demarest, 1981), project to association areas of the cortex. The pulvinar, which receives connections from the superior colliculus (a structure associated with vision) and the primary visual cortex, projects to the parietal-temporal-occipital association cortex (Kelly, 1985a). The dorsomedial (or medial dorsal) nucleus makes connections with the association, or prefrontal or frontal, cortex of the frontal lobe (Barr & Kiernan, 1983; Kelly, 1985a). (A specific hypothesis concerning the frontal cortex will be proposed in Chapter Eight, to indicate one direction in which the expanded theory could be developed as a result of the findings of a study reported in Chapter Seven. But the functional role of this cortex is not important at this stage.)

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1 A nucleus (plural nuclei) "is a compact region of grey matter of homogeneous cytoarchitecture and recognisable boundaries" (Somjen, 1983, p. 9).
Figure 5-1. Location of the thalamus in the brain showing the major specific (S), association (A), and non-specific (N) thalamic nuclei (from Kelly, 1985a, p. 233).

To summarise, in ‘being in contact with’ and perceiving a world, *temporal* patterns of trains of sensory impulses in parallel fibres transform, via the thalamus and parallel fibres, into specific *spatio-temporal* patterns of impulses in the cortex (Eccles, 1972).

When a particular total structure is completed a part of a world is perceived, or ‘known’. In visual or auditory perception, for example, a structure is completed in the visual or auditory cortex *relative* to a spatio-temporal pattern of light or deformed air. This structure is a person’s visual or auditory percept of a part of a world.
Thus the assumptions that: (i) something called information is in a pattern of light (Gibson, 1979) or a sound wave (Ellis & Young, 1988) or stimulation (Bengston & Cohen, 1979), or is carried in a pattern of light (Bruce & Green, 1985), and (ii) we must extract (Gibson, 1979; Bruce & Green, 1985) or 'transduce' (Bengston & Cohen, 1979), that is, process, this information in order to know a part of a world, are rendered superfluous.

As well as fibres which project 'forward' from the thalamus, each area of the cortex, in turn, projects fibres, called corticothalamic fibres (CT), 'back' to its corresponding specific or association thalamic nucleus. All TC and CT pass through a thin layer or sheath of tissue which overlays part of the thalamus, called the thalamic reticular nucleus (RN) (Kelly, 1985a; Noback & Demarest, 1981; Poggio and Mountcastle, 1980).

Neurons of RN form synapses with axon collaterals of TC and CT (Noback & Demarest, 1981; Poggio and Mountcastle, 1980), as well as neurons of the intralaminar nuclei (Noback & Demarest, 1981), and project their axons into S (Barr & Kieman, 1983; Poggio and Mountcastle, 1980). The intralaminar nuclei, it is hypothesised below, play a vital role in the construction of knowledge.

Animal studies show that impulses in the RN 'inhibit' the regeneration of impulses in S (Picton, Stuss & Marshall, 1986; Scheibel, 1980; Watson, Valenstein & Heilman, 1981; Yingling & Skinner, 1977). Specifically, trains of sensory impulses regenerated in neurons of S and propagating in TC generate short trains of impulses in neurons of RN which immediately inhibit further regeneration of the former (Scheibel, 1980). However, activity in the RN can, in turn, be inhibited by increased activity in the reticular formation of the brainstem (RF). This inhibition results in an 'enhancement' of the generation of sensory impulses propagated to the cortex (Scheibel, 1980; Watson, et al. 1981; Yingling & Skinner, 1977).
It might be that in perception, impulses within a structure travel in CT and, in part, selectively inhibit, via neurons in RN, arriving sensory activity in the thalamus. For example, Kelly (1985) states that these ‘recurrent projections’ (CT) “presumably (function) to allow the cortex to modulate its own input based on its ongoing activity” (p. 233). Following Kant, our knowledge or structures might thus ‘shape’ or organise a world as it is, and what we see or hear, for example, is always a function of what we already know. It is also interesting to note that in studies of cat, activity in the frontal cortex which, in humans, Luria (1973) associates with ‘plans’ and ‘intentions’ (see p. 198), can also selectively inhibit, via RN, arriving sensory activity in the thalamus (Picton, et al. 1986; Scheibel, 1980). However, the ‘effects’ of increased RF activation can ‘override’ (at least in cats) effects produced by the frontal cortex (Scheibel, 1980; see p. 85-86).

As well as fibres which link the cortex with the thalamus, other fibres project from the association areas of the cortex (including the visual, auditory, parietal and frontal areas, Rolls, 1989) to parts of the medial temporal lobe called the parahippocampal gyrus and the entorhinal cortex (Halgren, 1984; Rolls, 1989). The entorhinal cortex, in turn, projects fibres to a sub-cortical structure called the hippocampus (Rolls, 1989).

Pathways also connect the primary sensory areas with the medial temporal lobe (Ross, 1982). Presumably, the sensory areas, like the association areas, make connections with the entorhinal cortex and hippocampus (Bennett, 1987).

The third postulate states that during completion of a structure, impulses continuously propagate:

(i) back to specific or association thalamic nuclei and to the thalamic reticular nucleus (in CT).

(ii) to the hippocampus in an intermittent temporal sequence.
To summarise, the transformation of sensory impulses into spatio-temporal patterns and their completion is knowing, or perceiving. This completion is like Kant’s synthesis of multiple impressions and Piaget’s idea of assimilation.

By definition, reduction (Section 4.9), or the non-completion of a structure, is not knowing (to some relative extent). That is, in interaction with a world, if we begin to perceive a part of the latter, and parts of our potentially larger structures undergo reduction, then we cannot know this part of a world. To know it, we must acquire new knowledge, that is, a new structure or a qualitatively different (rather than more complex) (Iran-Nejad, 1990) ‘continuity’.

The fourth postulate states that in reduction, impulses:

(i) are not propagated back to specific or association thalamic nuclei or to the thalamic reticular nucleus.
(ii) are propagated to the hippocampus in short continuous temporal sequences

5.4 The reticular formation

As well as fibres which project ‘back’ from the hippocampus to each association cortex via the subiculum, entorhinal cortex and parahippocampal gyrus (Rolls, 1989), fibres from the hippocampus project ‘downward’ to the dorsal tegmental nucleus of the RF. This nucleus, in turn, makes connections with other RF nuclei (Goldberg, 1984).

The RF consists of a body of diffusely interconnected neurons (Henneman, 1980; Kelly, 1985b; Mountcastle, 1980; Rosenzweig, 1989) composed of many groups “that are well-defined morphologically and biochemically” (Kelly, 1985b, p. 560). (Coincidentally, neurons at this level of the brain do not support LTP, Eccles, 1989.)
Reticular nuclei called the central group form part of a system of connections known as the *ascending reticular activating system* (ARAS), which is associated with awareness and arousal (lesions of the RF, or inhibition of its activity by drugs, results in quiescence or even a coma) (Kelly, 1985b; Rosenzweig & Leiman, 1989). Within the ARAS, fibres project 'upward' to make connections with the thalamus and the cerebral cortex.

### 5.5 The ascending reticular activating system

Barr and Kieman (1983) divide the ARAS into:

(i) collateral fibres of sensory nerves (e.g., spinoreticular fibres).
(ii) the central group of reticular nuclei and the parvicellular reticular nucleus.
(iii) ascending fibres of the central group of reticular nuclei.
(iv) the *midline* and *intralaminar* nuclei of the thalamus and small fibres which pass from the latter nuclei to the cortex.

The majority of ascending fibres of the central group project to the midline and intralaminar nuclei. Of these fibres, most make connections with the latter.

The intralaminar thalamic nuclei project small fibres directly to the cortex, and also form connections with the specific thalamic nuclei, pulvinar, and dorsomedial thalamic nucleus, and anterior thalamic nuclei. The midline thalamic nuclei project to the hypothalamus and the dorsomedial nucleus (Barr & Kieman, 1983). The intralaminar nuclei and the small fibres which project to the cortex are referred to as the generalised thalamocortical system (Guyton, 1986; Mountcastle, 1980).

Other ascending fibres from the central group of reticular nuclei terminate in the hypothalamus and septal area. The latter are parts of a general system called the *limbic*
system, which is associated with emotions (Barr & Kiernan, 1983) or ‘emotionality’ (Kuhar, 1986).

The dorsomedial thalamic nucleus makes reciprocal connections with the association cortex of the frontal lobe, and several other areas of the brain, for example, the amygdala in the temporal lobe. This nucleus and its various reciprocal links form part of a system which is associated with “‘moods’ or ‘feeling tone’” (Barr & Kiernan, 1983). For example, psychosurgery and evidence from positron emission tomography studies indicate that the frontal lobes and amygdala are associated with anxiety (Kuhar, 1986), while electrical stimulation of the latter results in emotional responses which “seem to be a function of established personality patterns; that is, stimulation produces aggressive behaviour in an aggressive person and fearful behaviour in an insecure person” (Smith, 1987, p. 386).

The anterior thalamic nuclei form reciprocal links with the mamillary body and the cingulate gyrus. These nuclei, the mamillary body and the cingulate gyrus are also parts of the limbic system (Barr & Kiernan, 1983).

To summarise, the ascending fibres of the ARAS make connections with the cortex via the intralaminar nuclei (both directly, in the case of small fibres, and indirectly, via specific and association nuclei of the thalamus). As well, the ascending fibres make connections with those parts of our brain which are associated with emotions and feelings.

The fifth postulate states that the propagation of impulses in short continuous temporal sequences to the hippocampus results in the generation of high frequency trains of impulses in the ARAS.
The sixth postulate states that a high frequency train of impulses generated in the ARAS propagates via the intralaminar nuclei to a neuron in a specific or association nucleus of the thalamus to the cortex when impulses are not propagated back to this nucleus and the thalamic reticular nucleus (Section 5.3, postulate four i).

Finally, the seventh postulate states that a high frequency train of impulses in the cerebral cortex initiates the protein synthesis which is necessary for synaptic growth.

5.6 Summary of the process of construction

To summarise the process of construction of knowledge in the sensory and association areas of the cerebral cortex, it is assumed (the fourth, fifth, sixth and seventh postulates) that reduction results in the propagation via the entorhinal cortex of short continuous temporal sequences of impulses to the hippocampus. This, in turn, results in the generation of high frequency trains of impulses in the ARAS. A high frequency train of impulses propagates via a cell in a specific or association nucleus of the thalamus to neurons in the cortex. This train of impulses initiates the protein synthesis which is necessary for synaptic growth, and the formation of a new structure.

It follows that a lesion in part of this circuit must result in a reduction in a person’s capacity to construct knowledge in the sensory and association areas. This hypothesis is supported by evidence from studies of a single patient, known as case H.M., who following surgical removal of both his hippocampi, was tragically unable to remember what he had recently seen or heard (Milner, 1966, 1972). The clinical name for this condition is anterograde amnesia.

Case H.M. suffered from frequent, severe epileptic seizures which could not be controlled by medication. In an attempt to alleviate the seizures, H.M. underwent an
operation to remove the medial parts (the anterior two thirds of the hippocampus, the uncus, and amygdala) of both temporal lobes.

Milner (1966) states that “the patient was drowsy for the first few postoperative days but then, as he became more alert, a severe memory impairment was apparent. He could no longer recognise the hospital staff, apart from Dr. Scoville himself, whom he had known for many years; he did not remember and could not relearn the way to the bathroom, and he seemed to retain nothing of the day to day happenings in the hospital” (p. 113). H.M. was also found to have partial retrograde amnesia (loss of memory for events prior to the operation). His early memories were, however, “seemingly vivid and intact, his speech was normal, and his social behaviour and emotional responses were entirely appropriate” (p. 113).

Although the operation successfully reduced the frequency and severity of H.M.’s seizures, and the retrograde amnesia eventually disappeared (although he remembered “nothing of the period spent in hospital just before the operation” (p. 115), his severe anterograde amnesia remained virtually unchanged. For example, “ten months after the operation the family moved to a new house which was situated only a few blocks away from their old one, on the same street. When examined by Scoville and Milner, nearly a year later, H.M. had not yet learned the new address, nor could he be trusted to find his way home alone, because he would go to the old house” (p. 113).

In 1965, twelve years after the operation, H.M. would “do the same jigsaw puzzles day after day without showing any practice effect, and read the same magazines over and over again without ever finding their contents familiar” (p. 114). He had not learned the names of neighbours who had “been visiting the house regularly for the past six years” (p. 114), nor could he recognise any of these people if he met them in the street.
However, although H.M., and other patients with circumscribed hippocampal lesions, are unable to remember what they have seen or heard, studies show that these patients “perform well on tasks that require the gradual learning of a skill” (Morris, Kandel & Squire, 1988, p. 126). For example, Squire and Zola-Morgan (1988) state that “the severely amnesic patient H.M. exhibited day-to-day improvement in a motor skill task” (p. 171).

It might be that, as well as a circuit for the construction of knowledge in the sensory and association areas of the cortex proposed above, there is a second, complementary circuit which incorporates the motor cortex, which can support (though perhaps to a limited extent) the construction of new ‘motor’ structures.

In support of this hypothesis, Mountcastle (1980) states that the reticular formation (and presumably the central group of reticular nuclei) directly receives fibres “from the frontal cortex, particularly from the motor cortex” (p. 310). The task of solving the problem of how we acquire new motor skills in the context of the theory above, will not be taken up here. If, as Piaget assumes, logico-mathematical knowledge is acquired through actions, that is, voluntary movements, then this task will also necessarily incorporate solving the problems of how structures of reasoning are constructed, and how these structures interact with ideas.

5.7 Summary

Let me now summarise some of the major problems which face the theory above. These include: (i) how does the completion of a structure result in the propagation of an intermittent temporal sequence of impulses to the hippocampus? (ii) how does reduction result in the propagation of a short continuous temporal sequence of impulses to the hippocampus? (iii) how does the propagation of impulses in a continuous temporal sequence to the hippocampus result in the generation of high frequency trains of impulses
in the ARAS? (iv) what is the function of the generalised thalamocortical system in the
construction of knowledge? and (v) how does a high frequency train of impulses in the
cerebral cortex initiate the protein synthesis which is necessary for synaptic growth?

Logically, there is a period (measured in milliseconds) between the onset of reduction and
the arrival of a high frequency train of impulses in the cerebral cortex. It follows from the
fourth postulate that structures undergoing reduction must be regenerated (at least once) in
order for synaptogenesis to occur.

At first, this implication does not seem plausible, but it explains why, for instance, when
we become aroused during visual perception, we turn our heads and move our eyes
continuously ‘over’ a thing, as well as make voluntary movements like picking up and
handling the latter, that is, in order to regenerate structures undergoing reduction. In
speech perception, regeneration must clearly be attenuated, since a speaker continues to
talk. But normal speech in itself is based upon a high redundancy factor; that is, we often
repeat what we are saying (Singer & Donlan, 1989) and of course, we can always ask a
person to reiterate what he/she has just said (though he/she might not repeat exactly the
original wording). In reading, we can shift our eyes ‘back’ to, and repeatedly read over
and ‘around’, a part of a text which resulted in reduction.

In Chapter Six, I will propose two postulates, about word meaning and intrinsic
motivation, and logically link these to the theory above to form an expanded explanation
of how learning occurs which I will apply to learning situations in a classroom, and in
particular, to a situation of a student learning by reading a text.
CHAPTER 6

6.1 Introduction

In this Chapter, two postulates will be proposed and logically linked to the foregoing theory, to form an expanded explanation of how we acquire knowledge. The transmission view of teaching and learning, commonly held by educationalists, will then be critically examined and contrasted with this theory.

In a classroom most, though of course not all, teaching occurs through the use of oral and written language. Relatively more emphasis is placed upon the use of oral language in the early years of schooling, while in later years, both oral and written exposition are used as 'mediums' for instruction (Clark, 1983).

In the next section, I will postulate a general explanation of how meaning is formed from oral and written language.

6.2 Word meaning

It follows from the first and second postulates, that in speech perception, a 'word' is perceived when a structure in a listener's auditory cortex is completed relative to a patterned deformation of air. In reading, a word is perceived when a structure in a reader's visual cortex is completed relative to a pattern of light. For clarity, I will refer to this structure as a 'word' structure.

The eighth postulate states that in speech perception or reading, a word structure can generate a structure or idea in another area of the cortex, which interacts with a structure, generated by a following word structure, which interacts with another structure, and so on. This postulate is consistent with Iran-Nejad's view that 'a biofunctional pattern',
generated by a ‘pattern of sound waves’, “generate(s) the concept corresponding to (a) word” (Iran-Nejad & Ortony, 1984, p. 185). When structures generated by word structures integrate with following structures, knowledge, or meaning, is continuously created, and speech or writing is comprehended.

It has been mentioned earlier that structures and parts are relative and that different structures can integrate/disintegrate with the same following structure, or the same structure can interact with different following structures, to form various larger patterns (Section 4.8). It follows that the same or different word structures can generate different structures or parts which can interact with the same or different following structure or part, to form unique larger structures or ideas. The generation of meaning is thus completely relative, or contextually dependent.

It is a perceived fact that the same words do have different meanings when they are juxtaposed with other words, or are placed in different contexts (Adams, 1980; Anderson & Pearson, 1984; Anderson, et al. 1976; Bell & Freyberg, 1985; Pines, 1985). A word can also have different meanings in so far as the same word can generate different structures or ideas for different people.

However, the meanings of words are not solely determined by their context, or by the ideas which people hold. For it is also a perceived fact that arranging words in an utterance or sentence in a random order can render the latter totally meaningless. Thus word order is important. The particular conventions which govern the meaningful ordering of words are generally referred to in the literature as syntax (Adams, 1980; Stones, 1984).

A general hypothesis is that syntax is a function of the interaction of ‘syntactical’ structures with structures generated by words. A detailed account of how this interaction might occur is beyond the scope of the present theoretical argument. Suffice to say that
perhaps 'syntactical structures' always reduce other structures to parts, thus constraining the meanings which a person can create relative to a flow of words.

For present purposes, this general explanation of the generation of meaning is consistent with current linguistic theory, to the extent that three 'strata' are implicated. These are sound (word structures), meaning (other structures or ideas) and form ('syntactical' structures) (Halliday, 1975).[^1]

Although not critical for the expanded theory summarised below, consistent with the idea of 'top-down processing' in theories of reading (Garner, 1987; Singer & Donlan, 1989), it is suggested that regions in which ideational structures are generated may have reciprocal connections with regions of word structures. Ideational structures might thus generate (at least in mature readers) impulses which travel 'forward' to facilitate the generation of word structures during each saccade. (Saccades are rapid, 'ballistic-like' movements of a person's eyes which last about 20 milliseconds during reading, Singer and Donlan, 1989.)

To summarise, the eighth postulate is critical for the rationale of the study reported in the next Chapter. When a student reads a text (for example), it is assumed that a flow of word structures generate a flow of interacting ideational structures. This interaction may be characterised by a high degree of integration, or conversely, by some degree of reciprocal disintegration, or reduction, leading to the construction of new spatio-temporal patterns of impulses or knowledge, depending upon other factors which will be detailed below. That is, simply, pupils may create new knowledge from within by reading.

[^1]: Halliday (1975) claims that, in the past, structural linguists focused upon two 'levels' or 'strata'—sound and form. In more recent times, linguistic theorists generally refer to three 'strata' (sound, form and meaning). For Halliday, "Prague School theory, glossematics, system-structure theory, tagmemics, stratification theory and the later versions of transformation theory are all variants on this theme (of three levels)" (p. 4).
In the next section, a postulate about intrinsic motivation will be proposed. This postulate is derived, in part, from a solution to the problem (which is also faced by mechanical theories) of how, in the first place, we are aware that something in a particular stimulus situation is new or novel.

6.3 Intrinsic motivation

In Section 5.5, I described connections made by the ARAS with structures of the limbic system which are associated with emotions and feelings. Following reduction, high frequency impulses propagating in the ARAS could generate impulses in structures of the limbic system, including the hypothalamus, dorsomedial nucleus (which, in turn projects to the association cortex of the frontal lobe), and the amygdala. These impulses might contribute to one’s experience of a particular emotion or feeling. Thus a solution to the problem of how we are aware, in the first place, that something in a particular stimulus situation is new, is that following reduction, we will feel this newness, that is, we might feel aroused, or mildly surprised.

Regardless of this specific hypothesis, if several parts of a stimulus situation are new to a person, then, depending upon the situation and his/her structures or knowledge, the delay between each instance of reduction will vary.

The ninth postulate states that intermittent reduction is pleasurable, while continuous reduction is unpleasurable.

I will define the term, ‘intrinsic motivation’, as the desire to interact with a stimulus situation which results in intermittent reduction. That is, this desire is an inherent interest or curiosity, or a “felt need-to-know” (Biggs, 1989, p. 17).
In so far as people can have different structures or ideas, stimulus situations which result in reduction will differ for each person. That is, so-called ‘cognitive conflict’ “can exist only in relation to (a person’s) current knowledge” (Gottfried, 1983, p. 65). Thus in a classroom, if children hold different ideas, then at a specific point in time during a lesson, some students might become intrinsically motivated whereas others will not. Different pupils might become interested in different parts of a lesson, thereby exhibiting various performance outcomes. Logically, a teacher cannot expect all children to learn the same thing at the same time. For those students who do not become intrinsically motivated by parts of a lesson, it does not follow, of course, that they will not learn. They may become interested in and learn from an incident taking place beneath a window or at the very next desk. Alternatively, pupils might be listening to a teacher or reading a text and attempting to ‘learn’ by memorisation.

6.4 Memorisation

Within the literature, memorisation is also often referred to as ‘rote learning’ (Biggs, 1988; Biggs & Telfer, 1987; Bourke, 1989; Entwistle, 1984, 1985), ‘rote memorisation’ (Wertheimer, 1980) or ‘superficial learning’ (Bowden, Masters & Ramsden, 1987). Memorisation is generally defined as a type of learning in which we attempt to remember ‘material’ (usually written words or symbols) without attempting to create meaning from the latter.

For example, Bowden, et al. (1987) associate the term ‘memorising’ with the following: (i) to ‘skim material without thinking about meaning’, (ii) to ‘learn formulae, ideas, facts without bothering about meaning’ (though how a person can ‘learn’ ideas ‘without bothering about meaning’ is unclear), and (iii) to ‘concentrate on facts and details’. For

2 The same conclusion is drawn by Happs (1985) when he states that “what (children) each bring to the learning environment, largely determines how they select and attend to certain stimuli. This will inevitably lead to a variety of teaching outcomes, despite (a) teacher’s use of the same teaching materials and strategies for all learners” (p. 171).
Biggs (1988) memorising or 'rote learning' occurs when "(a) student concentrates on the surface features or 'signs' of learning, not on the meanings or implications or what is learned" (p. 198). That is, a student concentrates on 'signs' or the words used, rather than the 'signified' or meaning of the latter (Biggs, 1979). Biggs (1978a) and Biggs and Rihn (1984) associate memorisation with the avoidance, by a student, of 'personal or other meanings (a learning) task may have'.

Memorisation is also often contrasted to learning with 'understanding'. For example, Brooks (1987), referring to a text on the topic of photosynthesis, states that although pupils "are able to memorise this information (i.e., the wording of the text and a formula), most (students) understand neither the explanation (presumably in the text), nor the symbols in the equation" (p. 65).

By definition, during memorisation the generation of other structures or ideas by word structures must be reduced, and the potential for a person to become intrinsically motivated must, to some extent, be diminished. However, a thorough explanation of how memorisation occurs, and by implication, a unification of construction or learning, in the first instance, with memory or remembering, in the second, is plainly beyond the scope of this thesis.

It is worth presenting, however, the following hypotheses to demonstrate ways in which the present theory can be developed and extended to account for human learning and memory in a wider domain. It might be that in memorisation, structures are formed in the hippocampus. It was earlier noted that the latter projects back to each association cortex via the subiculum, entorhinal cortex and parahippocampal gyrus (Rolls, 1989). Upon recall, perhaps a structure in the association cortex generates a specific pattern of impulses in the hippocampus, which, in turn, generates a different structure in the cortex, and so on. Thus structures formed in the hippocampus might 'link' different structures in the association cortex. Rolls (1989) claims that through cortico-hippocampal anatomical
connections, 'events' in "different parts of the association areas of the cerebral cortex (could) be associated together to form a memory" (p. 17).

It may also be that hippocampal structures are constructed through some kind of LTP, rather than synaptogenesis, and would gradually 'dissipate' over a period of time from a few hours to days or weeks (presumably depending upon the level and duration of nervous activity generated). This would account for the classic 'curve of retention' or 'forgetting function' first described by Herman Ebbinghaus in his work on the memorisation of nonsense syllables (Wertheimer, 1980).^3

Given these hypotheses, during memorisation, a person cannot in any sense be said to acquire knowledge, since structures are formed in the hippocampus and not the cerebral cortex (postulates one and two). That is, during this process of 'learning', new knowledge is not constructed, rather, existing structures are 'associated' or flow together via our hippocampal formation in new ways.

To summarise, it can be generally hypothesised that, depending upon a stimulus situation and a student's structures, and thereby, the potential incidence of intermittent or continuous reduction, a pupil might alternatively construct ideas and memorise for various periods of time both within and between learning tasks. In support of this hypothesis, findings from recent studies of secondary and tertiary students' learning and motivation indicate that pupils adopt typical 'approaches' (Biggs, 1986, 1987a, b, 1988; Biggs & Telfer, 1987) or 'general orientations' (Biggs, 1989) (which, as I will try to show, are really typical ways of learning) to learning tasks. However, these typical approaches are not completely stable, and pupils will often vary their approaches both between and within learning tasks (Thomas & Bain, 1984; Thomas, 1987).

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^3 Wertheimer (1980) states that "the forgetting of memorised material occurs rapidly right after the time of memorising; the rate of forgetting gradually slows down, and the (curve of retention) eventually reaches an asymptote that is still somewhat elevated above zero retention" (p. 228).
For Biggs (Biggs, 1986, 1987a, b, 1988; Biggs & Telfer, 1987) a student's approach to a task is comprised of his/her motive for attempting to learn and the 'strategy' he/she uses to learn. Three types of approaches to learning tasks, called deep, surface, and achieving, or 'strategic', have been classified (Biggs, 1986, 1987a, b, 1988, 1989; Biggs & Telfer, 1987; Entwistle, 1987). In order to show how the theory above is consistent with the 'deep' approach, I will review the latter in the next section.

6.5 Approaches to learning tasks

In the deep approach, a pupil's motivation for learning is intrinsic motivation or interest (Biggs, 1986, 1987a, b, 1988; Biggs & Telfer, 1987) or curiosity (Biggs, 1988). The strategy which a student uses to learn consists of "relat(ing) the content (of a task) to personally meaningful contexts or to existing prior knowledge, theoris(ing) about what is learned, and deriv(ing) extensions and exceptions" (Biggs & Telfer, 1987, p. 149).

From the ninth postulate, above, it follows that the 'strategy' which a student 'uses' in the deep approach is, at least in part, the process of construction.

By contrast, in the surface approach, a pupil's motivation is extrinsic (i.e., a student's motivation for learning is to obtain 'pass' grades with the minimal expenditure of effort) (Biggs, 1986, 1987a, b, 1988). The strategy used by a pupil who adopts this approach consists of "focus(ing) (upon) what appear to be the most important topics, and reproduc(ing) them fairly exactly" (Biggs, 1988, p. 198). A student "relies on memorisation, attempting to reproduce the surface aspects of the task (e.g., the words used (or) a diagram)" (Biggs & Rihn, 1984, p. 281). That is, the 'strategy' employed by pupils who adopt the surface approach consist of learning by memorisation (for instance) what a teacher or lecturer says, or what they have read (Entwistle, 1987).
Thus, the ‘strategies’ used by students who adopt either a deep or surface approach are not strictly strategies, but types of learning. For example, for Biggs (1988) the kinds of processes ‘used’ (i.e., so-called ‘strategies’) in a deep or surface approach are ‘meaningful’ or ‘rote learning’ respectively (presumably after Ausubel).

In the achieving approach, motivation is achievement motivation (i.e., a pupil’s motivation for learning is to enhance his/her ego or self-esteem by obtaining high grades) (Biggs, 1986, 1987a, b, 1988). The overall strategy (in the proper sense of the word) used by students who adopt this approach includes “keeping clear notes, planning optimal use of time, and all those planning and organisational activities referred to as ‘study skills’” (Biggs, 1988, p. 199). In sum, in this approach, a pupil systematically organises her time spent and effort expended on a task in order to obtain the highest grades (Entwistle, 1987).

The achieving approach can be combined with either a deep or surface approach, that is, students can adopt ‘composite’ approaches (surface/achieving or deep/achieving) (Biggs, 1988; Biggs & Telfer, 1987). Thus a pupil “can rote learn in an organised or unorganised way, or seek meaning in an organised or unorganised way” (Biggs, 1988, p. 199).

Though it is claimed by Biggs, for example, that students typically adopt either one or the other approach (deep, deep/achieving, surface, surface/achieving), studies show that the actual approach taken by a pupil to a specific learning task can depend upon several factors.

Consistent with the theory above, existing knowledge is ‘important’ “in allowing a deep approach to be adopted” (Entwistle, 1985, p. 142).
Other factors which determined the approach a student adopts include (i) a pupil’s interest in a topic, or his/her perceived relevance of the topic (Entwistle, 1985; Thomas, 1987), (ii) a student’s ‘self-confidence as opposed to anxiety’ (Entwistle, 1985), and (iii) the type of assessment anticipated by a pupil (Entwistle, 1985), or his/her “perceptions of the aims and requirements of the task” (Thomas, 1987, p. 126).

In the case of (i) above, Biggs (1987c) claims that a student’s “interest in a particular task can either intensify, or over-ride, (a) general approach” (p. 123); that is, by ‘general’, Biggs presumably means ‘typical’. In the case of (iii) above, an emphasis on the accurate reproduction of ‘facts’ by a teacher or lecturer generally results in a pupil adopting a surface approach, even though the latter might ‘typically’ take a deep approach to a task (Entwistle, 1985; Ramsden, 1985). Entwistle (1985) states that “when factual tests are anticipated, even the best students shift from a deep to a surface approach” (p. 142-143). For Ramsden (1985) “students (can be) pushed towards surface approaches by forms of assessment which seem to invite, and reward, reproductive answers” (p. 60).

In a study of the effects of task conditions on learning and motivation, Grolnick and Ryan (1987) found that a “grade contingency created an atmosphere of evaluation apprehension that (was) effective in prompting a high level of rote learning” (p. 897). That is, presumably, the children in this study adopted a surface or surface/achieving approach to the learning task as a result of being told they would be graded on their performance.

To conclude, the ninth postulate states that in the process of construction, thought and feeling are interdependent. For example, Watts and Bentley (1987) claim that “the very act of learning is an emotional affair. The cognitive and the affective are not separate and distinct but are irrevocably intertwined” (p. 123). At the outset, a student is aware that something in a learning task is new because he/she can feel this newness. But whether a pupil constructs new knowledge (adopts a deep or deep-achieving approach), or memorises (takes a surface approach), attempts a combination of both or simply avoids a
task altogether will depend upon (i) whether reduction occurs intermittently or continuously, and (ii) (as previous research indicates) his/her interest in a topic and the type of assessment which he/she anticipates.

Language, or speech and writing, is incorporated in most learning tasks within a classroom. The eighth postulate implies that a ‘word’, of itself, does not possess meaning (Kulhavy, Schwartz & Peterson, 1986; Osborne & Gilbert, 1987; Osborne & Wittrock, 1985; Wheatley, 1991), rather, words (i.e, spatio-temporal patterns of light or moving air) generate ideational structures which interact; words evoke meaning. For example, Osborne and Gilbert state that “the meaning of a word lies in the mind of the hearer or reader” (p. 85). For Bransford, Barclay and Franks (1972) a sentence does not ‘carry meaning’, rather, “people carry meanings” (p. 207).

The expanded theory, incorporating the eight and ninth postulates, will be summarised and applied to a situation of a student learning from reading a text in Section 6.8 below. But first, a ‘common sense’ (Kamii, 1985) view of teaching and learning, which permeates the teaching profession, will be critically examined.

In contrast to the implication of the eighth postulate above, in the theories reviewed in Chapters Two and Three (with the exception of the theory of genetic epistemology) it is often tacitly assumed that spoken or written words ‘carry their meaning’. That is, it is presumed that meaning or information is ‘in’ words, or a text, and exists separately from speaker and listeners, or writers and readers (Anderson, et al. 1977; von Glasersfeld, 1988, 1989). von Glasersfeld (1983, 1989) states that this idea “of words as containers in which (a) writer or speaker ‘conveys’ meaning to readers or listeners is extraordinarily strong and seems so natural that we are reluctant to question it” (p. 51-52, p. 8).

It is, in part, from this assumption that an approach in the teaching profession called the transmission view (Bell, et al. 1985), cultural transmission approach (Pope, 1982; Pope
& Gilbert, 1983), ‘siphon model’ (Tobin & Gallagher, 1987) or ‘absorption approach’ (Vaughan, 1984) is derived.

6.6 The transmission view

The transmission view was first clarified and contrasted with another view, called ‘interpretation’, by Barnes and Shemilt (1974). The latter authors surveyed secondary school teachers about “the written work which they set” (p. 213), with the aim of exploring “teachers’ implicit beliefs about communication and learning as a whole” (p. 213). Four questions in the survey were open-ended and were made “deliberately vague, since in attributing a meaning to them (a teacher) would be compelled to utilise his own covert assumptions about written work” (p. 215). Following a factor analysis of the categories of teachers’ responses, it was found that teachers’ views “fell into a clear-cut pattern along one dimension, which will be called the Transmission-Interpretation dimension” (p. 216).

Teachers whose views were classified as ‘transmission’ generally believed that knowledge ‘exists’ in the form of public disciplines, and that writing tasks are associated with the accumulation by students of factual information within these disciplines. For these teachers, completed written work was mainly “a means of measuring (a) pupil’s performance against (their) own expectations and criteria” (p. 220), and they believed that their primary responsibility upon receiving students’ written work was to award a grade (Barnes & Shemilt, 1974).

By contrast, teachers whose views were classified as ‘interpretation’, generally believed that “as pupils write they can - under certain circumstances - reshape their view of the world” (p. 220), and in turn, saw their pupils “as already possessing systematic and relevant knowledge” (p. 223).
While teachers from different subject areas held a diversity of ideas about teaching and learning, it was found that Science teachers (Biology and Physics) commonly held a transmission view, while English teachers characteristically held an interpretation view (Barnes & Shemilt, 1974; Parker, 1988).

In more recent times, the transmission view has been described simply as the view that, in teaching, knowledge or information is transmitted from a teacher (or textbook, etc.) to children, and learning occurs when a child passively 'takes in', or absorbs, new knowledge or information (Bell, et al. 1985; Driver & Oldham, 1986). For example, Driver and Bell (1986) state that learning takes place, in part, "through the taking in of new information" (p. 444). Implicit in this view is the assumption that knowledge or information is in words (hence it can be transmitted through speech or writing to a student). Thus Gardner, Gray and Taylor (1981) claim that "for (a) teacher, language (i.e., speech and writing) acts as a vehicle for transmitting information" (p. 171), while for Gilbert and Watts (1983) language is, in part, "an instrument by way of which meaning is received from others" (p. 85).

The claim that this view is widely held in the teaching profession is supported by the comments and observations of several authors (Bell, et al. 1985; Biggs, 1989; Bodner, 1986; Christie, 1986; Fox, 1983; Gallagher, 1987). For example, Christie states that "many Australian classrooms do operate in ways in which the primary responsibility upon students is to be (passive recipients of information)" (p. 31). Gallagher (1987) claims that teachers "believe that there is a body of knowledge that everyone can/should

4 For Tiberius (1986) the dominant metaphor in education "for the process of teaching and learning is transmission" (p. 146). According to this metaphor, "the process of teaching and learning is essentially a transference of information from (a) teacher to students" (p. 146). Tiberius claims that this is a 'dead' metaphor. A 'dead' metaphor is one which is understood relatively literally (Bransford & Franks, 1976; Green, 1971, see p. 62). Accordingly, it can 'interfere' with one's ability to think about a phenomenon in new ways (Tiberius, 1986).

5 For example, Bodner (1986) claims that "until recently, the accepted model for instruction was based on the hidden assumption that knowledge can be transferred intact from the mind of the teacher to the mind of the learner" (p. 873).
receive. (Teachers believe that) it is (their) job as teachers to impart that knowledge - it is the role of learners to receive it” (Section K, page K-3).

For Biggs (1989), “many teachers, especially beginning teachers, see their task as one of transmitting knowledge” (p. 9), while Fox (1983) in a study of teachers’ ‘theories’ of teaching in a polytechnic in Britain found that the view of teaching held by the majority of newly appointed teachers was one in which “subject material (is seen) as a commodity to be transferred to (students’) minds” (p. 151). Fox calls this view a transfer theory of teaching.

A logical implication of the transmission view is that the functioning and unique ideas of a child are irrelevant. Therefore (to the extent that the transmission view is widely held by teachers) Barrett (1985) claims that “knowledge held in the mind of (a student) as s/he moves from one teacher to another, or from one stage of education to another, is implicitly if not explicitly ignored (by a teacher), if not rejected” (p. 73).

In order to ascertain how much new knowledge has been ‘taken in’ or absorbed, a teacher typically gives pupils a test (Pines & West, 1986; Vaughan, 1984). For example, Clark (1983) states that in a test “children can give evidence of how much they have absorbed” (p. 71), while Osborne (1984) claims that in the ‘teaching Physicists’ dynamics’ approach (a version of the transmission view held by some Physics teachers) a Physics teacher’s objective is “to effect the transmission of a body of knowledge” (p. 507). Tests are used to “assess how much Physicists’ dynamics is known” (p. 507).

These tests, typically know as summative, or achievement tests, are said to measure ‘achievement’ (Dunkleberger & Heikkinen, 1983). A child receives a score, or grade, which indicates his/her ‘level’ of achievement.
Biggs and Telfer (1987) claim that many teachers value ‘accurate’, verbatim answers on achievement tests. That is, teachers value the reproduction by a child of their own wording or the wording in a textbook. To the extent that some teachers do value verbatim answers, it follows that if some children seek to gain high marks in achievement tests, then this approach to testing must encourage these students to memorise, or to adopt a surface or surface/achieving approach to learning tasks.

Teachers who believe the transmission view often assert that ‘low achievers’ will not ‘work hard enough’ (Vaughan, 1984) or will not ‘pay enough attention’, where ‘attention’ is assumed to be some sort of power of concentration of which a child has much or little (Hebb, 1976). They tend to blame the failure of students on the students themselves (Biggs, 1980; Vaughan, 1984), rather than, for example, on their own pedagogical practices.

As mentioned above, the transmission view is, in turn, implicit in the contemporary mechanical theories reviewed in Chapter Two and the generative model of learning (Chapter Three). For example, Ausubel (1985) explicitly states that “(an) educational agency largely transmits ready-made concepts, classifications and propositions” (p. 72), and one function of a school is its “transmission-of-knowledge function” (p. 72). Presumably, ‘ready-made concepts’ are transmitted to pupils in words.

In schema theories, ‘facts’ or bits of information are accumulated in the space of memory through accretion, which is said to be the ‘normal’ (Rumelhart & Norman, 1978; Rumelhart, 1980), or ‘most common’ (Norman, 1982; Rumelhart, 1980; Rumelhart & Norman, 1981) type of learning. Again, presumably these ‘facts’ are transmitted in words; information is ‘carried’ via expressions into the space of memory and is virtually ‘emptied into’ skeletal schemata. Some authors claim that schemata themselves can be taught directly to students (Howard, 1987, 1988; Thorndyke, 1984) and can be “acquired from words” (Howard, 1987, p. 30).
In the generative model of learning, a teacher is said to ‘give’ information to students. Pupils then absorb this information (Osborne & Wittrock, 1983), which is, supposedly, carried in words.

To summarise, in the transmission view, teaching mainly consists of ‘transmitting’ knowledge in oral or written language, while learning essentially occurs by the passive absorption of this encapsulated ‘content’. Achievement tests are used as measure of exactly how much knowledge has been taken in, rather than as ways of finding out what a child knows, or of ascertaining her quality of understanding (in fact, it is doubtful whether achievement tests could be used in any other way, see Masters, 1987). Teachers who hold a transmission view will tend to value accurate or verbatim answers on such tests, because these answers indicate successful ‘learning’ (i.e., ideas are absorbed and transmitted back untainted). It follows that if children desire high grades, then they must at one and the same time be encouraged to memorise, or ‘surface’ learn, and disturbingly, dissuaded from expressing their own ideas and actively constructing new knowledge (Pope & Gilbert, 1983).

Preliminary research (Fox, 1983, above) suggests that a transmission view may also be favoured, to some extent, within teacher education institutions. Indeed, it is the view of one Australian educational psychologist and teacher educator that student teachers should “realise that much of the role of (a) teacher involves the transmission of detailed knowledge and particular theories” (Langford, 1989, p. 51). (I will return to the topic of the transmission view and assessment in Chapter Nine and, in Chapters Seven and Eight, will suggest a need for more research on teacher trainees’ developing ‘theories’ of learning.)

The expanded theory above, in which learning is said to be an active process of construction and people are said to generate meanings through the interaction of their
ideational structures relative to spoken or written words, stands in direct contrast to the transmission view. This expanded theory would have it that children do not have "'hollow heads' - with 'knowledge vacuums' waiting to be filled up" (Osborne, 1982, p. 22). A student "cannot absorb (a teacher's) meanings" (Osborne, 1984, p. 507). For Bell and Freyberg (1985) a teacher's "intended meaning - or that of the textbook author - is not automatically transferred to the mind of (a) pupil" (p. 33), rather, a child creates his own meanings for words (Bell & Freyberg, 1985; Wheatley, 1991).

In so far as the same word can evoke different structures for different people, a word can have different meanings. Thus it can be hypothesised that students might generate altogether different meanings than a teacher for the words used by him/her.

While teachers of English have long been intuitively aware of this implication, there is now considerable evidence from a well-explored area of education, namely science education, to support this hypothesis. In the latter area in recent years, children's ideas and meanings have been the subject of a focused but varied topical and international research effort.

6.7 Children's ideas and meanings in science education

Studies in science education have found that children hold unique ideas or views, or 'invented' or 'intuitive' ideas (Driver & Erickson, 1983), about 'natural phenomena' (Driver & Erickson, 1983), the 'natural world' (Driver & Oldham, 1986), 'scientific phenomena' (Bell, et al. 1985; Champagne, Klopfer & Gunstone, 1982; Driver, 1982) or 'scientific topics' (Osborne & Wittrock, 1983), which are different from the ideas that they are taught in the classroom (Champagne, et al. 1982; Driver, 1982; Driver & Erickson, 1983; Driver & Oldham, 1986; Gilbert, Osborne & Fensham, 1982; Gilbert & Watts, 1983; Gunstone, 1988; Osborne & Wittrock, 1983; Shapiro, 1988). (For reviews of these studies see Driver and Erickson, 1983, and Gilbert and Watts, 1983.)
Specifically, students generate particular meanings for words, for example, ‘force’, ‘animal’, which are used by a teacher to teach ideas in science (Gilbert, et al. 1982; Osborne, & Gilbert, 1980; Osborne, Bell & Gilbert, 1983; Tasker, 1989; Watts & Gilbert, 1983). Osborne, et al. (1983) state that these meanings “can be quite different (from) scientists’ meanings” (p. 3) (presumably, they are also different from a science teacher’s meanings).

For example, the meaning many pupils generate for ‘animal’ is ‘a large, terrestrial, four-legged creature’ (Osborne, 1983; Osborne, Bell & Gilbert, 1983; Trowbridge & Mintzes, 1985). This ‘everyday’ meaning is different from the formal meaning generated for the term ‘animal’ by biologists (and, supposedly, by science teachers).

Studies of children’s ideas about phenomena have also found that some of these ideas continue to be held by students despite having been ‘taught’ a scientific view (Carey, 1986; Champagne, et al. 1982; Driver & Bell, 1986; Driver & Oldham, 1986; Driver, Guesne & Tiberghien, 1985; Osborne & Wittrock, 1983; Stead & Osborne, 1980; Trowbridge and Mintzes, 1988; West, 1987). For example, Stead and Osborne (1980) found that the ideas about light travelling, held by Form 3 pupils who had encountered two formal teaching episodes on light in Forms 2 and 3, “were, in many respects, similar to those of Form 2 students who had not had any formal teaching on light” (P. 89). Stead and Osborne conclude that “teaching had not significantly moved some of the students’ concepts towards the scientific viewpoint” (p. 89).

Though pupils often pass achievement tests or examinations (Osborne & Wittrock, 1983), some (including ‘more able’ students) complete secondary science courses without having acquired ‘basic’ ideas in science (Bell, et al. 1985; West, 1987, 1988). To account for these findings, we could appeal to instructional ‘theories’ of the effective organisation of information (e.g., Gagne’s hierarchical theory of learning) or theories of
students' information-processing 'capacities'. The constructivist theory above, however, suggests several different hypotheses. Although these hypotheses are not critical for the present theoretical argument, they are nevertheless worth presenting at this point.

First, rather than construct new knowledge, some children might typically memorise 'lesson content' (i.e., they might typically adopt a surface approach), reproduce this 'content' in a test and then gradually forget it, retaining only their own unique ideas. For example, Foster (1986) claims that "some students habitually memorise facts" (p. 241). It might be that some students 'habitually memorise', not because of some inherent predisposition to do so, but rather, because, as a result of (i) their desire to obtain pass or higher grades, and (ii) specific pedagogical practices (e.g. an emphasis by a teacher on the accurate reproduction of 'facts'), they have formed a view (if only tacitly) that memorisation is the most efficient and expedient way to successfully complete learning tasks.

Support for this hypothesis comes from results obtained in an 'action research' project conducted in a secondary school by Mitchell and Baird (1986), who claim that "according to students, teachers give notes which contain right answers. Real work involves copying and memorising (these) notes for tests which measure the ability to state the right answers" (p. 6). That is, most students had formed a belief that memorising is the 'best' way to learn, and indeed, that this is what 'real school work' is all about.

As well, it might simply be that some students do not construct 'basic' ideas in science because they do not interact with stimulus situations which lead to intermittent reduction of their structures. For example, Stead and Osborne (1980) (above) hypothesised that "teachers (might have) assumed that the students had a concept that light travels great distances (and thus perhaps) no teaching was specifically aimed at this aspect of light" (p. 90).
To summarise, children’s ideas about phenomena are often different from knowledge of the same phenomena held by a teacher. Students frequently continue to hold their unique ideas despite having been taught (i.e., mainly told about) an orthodox view. It might be that, rather than construct new ideas, pupils regularly memorise as a result of their astute adaptation to predominant methods of teaching and assessment (rather than, for example, because of some inherent, stable ‘trait’ or ‘characteristic’, see Ramsden, 1987a, b; 1988), or that students might simply not encounter situations which lead to reduction of their own unique ideas.

In the next section, the expanded theory will be summarised and applied to a situation of student learning from reading a text, and a hypothesis will be derived which is tested in a study reported in Chapter Seven.

6.8 Summary of expanded theory

The postulates of the expanded theory are summarised and listed as follows:

(i) knowledge is a continuous spatio-temporal pattern of nerve impulses (cf. Iran-Nejad & Ortony, 1984).

(ii) the kind of knowledge we have is determined by the area of the cerebral cortex in which a continuous spatio-temporal pattern of nerve impulses is generated.

(iii) during the completion of a structure, impulses continuously propagate back to specific or association thalamic nuclei and to the thalamic reticular nucleus and to the hippocampus in an intermittent temporal sequence.

(iv) in reduction, impulses are not propagated back to specific or association thalamic nuclei or to the thalamic reticular nucleus and are propagated to the hippocampus in a short continuous temporal sequence.
(v) the propagation of impulses in a short continuous temporal sequence to the hippocampus results in the generation of high frequency trains of impulses in the ARAS.

(vi) a high frequency train of impulses generated in the ARAS propagates via a neuron in a specific or association nucleus of the thalamus to the cortex when impulses are not propagated back to this nucleus and the thalamic reticular nucleus.

(vii) a high frequency train of impulses in the cerebral cortex initiates the protein synthesis which is necessary for synaptic growth.

(viii) in speech perception or reading, a word structure can generate a structure or idea in another area of the cortex, which interacts with a structure, generated by a following word structure, which interacts with another structure, and so on.

(ix) intermittent reduction is pleasurable, while continuous reduction is unpleasurable.

Within the classroom, most teaching occurs through the use of oral and written language and during the later years of schooling students are increasingly required to learn by reading texts, both inside and outside a classroom (Singer & Donlan, 1989).

However, as I tried to show in Chapters Two and Three, several major contemporary theories of knowledge and learning fall short of explaining exactly how learning occurs.

In particular, 'schema theory' explanations of comprehension, widely accepted as useful explanations of reading comprehension in the schema, or 'schema-interactive', theory of reading (Garner, 1987; Singer & Donlan, 1989), are beset by the information paradox. That is, the claim that 'features' or information about 'features' of words fill(s) variables or slots and activates 'low-level' schemata overlooks the problem of how this information locates the appropriate variables in the first place. There also appears to be some confusion within the literature between information about 'features' and information or meaning which is in words, for example, "individual propositions ... convey new information" (Garner, 1987, p. 10); "(Some) texts are merely media by which
information is transmitted, as is the case when a student learns about geography from reading a chapter in a textbook” (Kintsch, 1989, p. 25).

For Garner, learning by reading, or (in part) the development of new schemata during reading, occurs “when the fit between old in-head information and new on-page information is good but not perfect” (p. 9); this regardless of the information paradox and the fact that schema theories cannot account for how a person is aware that information is new or novel. A student “can add pieces of information to an old schema (accretion), or (he/she) can modify existing (schemata) (tuning), or (he/she) can structure whole new schemata (restructuring)” (p. 9-10). Exactly how these processes occur is, however, not explained. Indeed, Garner admits that “the specific mechanisms involved in the acquisition and modification of schemata are not well established in the current research literature” (p. 10).

In contrast, according to the theory above, a child who is listening to a teacher or reading a text (for example) and who is not memorising, is generating interacting, continuous spatio-temporal patterns of nerve impulses or ideas, relative to the teacher’s or author’s, context (i.e., flow of words).

By definition, if these contexts evoke:

(i) the same structures in the same relations as those of the teacher or author, then a student will comprehend or understand. By ‘the same structure’, I do not mean that they are isomorphic. Though we all share the same gross brain anatomy, the convolutions of our cerebral cortices, and the fine histological arrangements within them, are as individual as our fingerprints. Rather, in speech perception or reading, it can only be said that the same knowledge is evoked in others when they use contexts which do not result in the generation of structures different from those we intended.
(ii) structures which are different from those of the teacher or author, and these structures integrate, then a student will comprehend, but from a teacher’s or author’s point of view, will misinterpret these words.

If a student chooses not to memorise and generates interacting structures relative to a teacher’s or author’s contexts, but at various points in time some of these structures reciprocally disintegrate or mutually ‘inhibit’ each other, that is, if intermittent reduction occurs, then he will become intrinsically motivated and construct new structures or meaning. In terms of Biggs’ theory, he will adopt a deep (or deep/achieving) approach. Depending on the interacting structures which a student generates, then she might construct new meaning which is either the same as or different from that intended by the teacher or author.

For clarity, a structure which a pupil generates for a word, that is the same as a teacher’s or author’s, will be called a prerequisite structure or idea. A structure that is different from a teacher’s or author’s will be called an alternative structure or idea.

Thus when reading a text (for example), if a pupil generates an alternative structure for a word, X, but generates prerequisite structures for other words, A, B, C, etc., which are used, in conjunction with X, to explain the intended meaning of X, then this student’s interacting structures may undergo reduction at various times as he reads X in conjunction with A, B, C, etc. That is, reduction may occur intermittently relative to various contexts. Alternatively, his interacting alternative/prerequisite structures may integrate, and he will misinterpret the text.

However, (according to previous research) if a student thinks a topic is irrelevant or she anticipates that she will be assessed, or both, then she might choose to memorise a teacher’s words, or part of a text, and by definition, will somehow limit the generation of
other structures or ideas by word structures. Neither intermittent reduction nor misinterpretation can occur, and this pupil will retain her existing knowledge.

Thus it can be hypothesised that if a student, regardless of his typical approach to a learning task, reads a text, which he thinks is relevant, that explains the meaning of a word, X, using other words, A, B, C, etc., and this student has an alternative structure for X and prerequisite structures for A, B, C, etc. and anticipates that he will:

(i) not be assessed, then he may become intrinsically motivated and construct new meaning for X.
(ii) be assessed, then he will choose to memorise.

In the next chapter, I will report a study designed to test this hypothesis.
CHAPTER 7

7.1 Introduction

The structures or meaning evoked in others by speakers or authors can be either the same as or different from (for example) an author's. It can only be said that the same structures are evoked in others when they use contexts which do not result in the generation of structures different from those we intended.

This implies, of course, that the contexts used by others directly correspond to their forming ideational structures as they speak or write. In this respect, the underlying methodological assumption of the study reported below is no different from that of 'pure' psychological research, in the sense that what a person says or writes represents accurately what they think, or the ideas that they hold (Lythcott & Duschl, 1990).

However, unlike the psychological theories reviewed in previous Chapters, the theory above implies that we can never be certain, without extended production of contexts, that others have the same structures or ideas as our own; this signifies, especially in the assessment of learning, that we must adopt multiple ways of ascertaining children's ideas. It is for this fundamental reason, to augment the use of surveys, that a clinical interview method is adopted in the following study of students' learning or ideational transformation through their reading of a text.

The grounds which are used to support conclusions drawn from clinical interview data have been thoroughly clarified by Lythcott and Duschl and will not be reviewed in detail here. For the latter authors, "conclusions are drawn from the data via warrants that are supported by backings. If the data are sound, and if the warrants are legitimated by the authority of acceptable backings, then we must at a minimum grant the interpretation drawn from the research" (p. 447). Warrants are "guarantees that make the steps we take
from data to conclusions safe” and are “of a general hypothetical form, that is similar to a major premise” (p. 451). Backings are equivalent to world views.

In the following study, my backing is a constructivist, psychobiological view of learning and the central warrants adopted for the analysis of students’ written responses and interview transcripts, and thereby, their structures, are as follows:

(i) if a student uses contexts which are different from the contexts she used prior to her reading which evoke meaning that is either acceptable (i.e., corresponds to the intended meaning of a text) or alternative, then construction has occurred.

(ii) if a student uses contexts (a) which are the same as those used in a text, but uses (or cannot use) other contexts, (b) which in explaining the meaning of (a) evoke meaning that is different from that intended, then she has memorised.

Recent studies in science education, referred to in Chapter Six, have found that children hold unique or ‘spontaneous’ ideas (Rauste-von Wright, 1986) about natural phenomena (Section 6.7). An aim of most of these studies has been simply to describe students’ ideas, or the meanings they have for specific words, for example, ‘force’, ‘animal’ (Bell, 1981). Like this previous research, in the present investigation students’ structures or ideas about a phenomenon are first ascertained (and classified as either alternative or prerequisite). Participants then read a text about this thing, and are later again asked what they think it is. At this point, if students use contexts which are different from those they used before their reading, then it can be said either that they formed new spatio-temporal patterns of impulses or ideas, or that they memorised these contexts.
In this respect, the following study is similar to research which has sought to describe pupils' ideas both prior to, and following, the teaching of a topic (Barker, 1981; Haggerty, in progress; Abimbola, 1984; Prosser, 1988). For example, a study by Abimbola “sought to describe the pattern of students’ alternative conceptions (of human respiration) both before and after instruction” (Abimbola, 1988, p. 180).

But in the present study emphasis is placed upon whether a student constructs new spatio-temporal patterns of impulses or ideas relative to contexts, or memorises the latter, that is, particular attention is paid to students' ideational transformations. As well, it is hypothesised that the ‘typical’ approach of a student to a learning task (like reading a text) is irrelevant, rather, he will either construct or memorise depending upon whether he thinks that (i) a text is relevant and/or (ii) he will be assessed or graded.

Students' typical approaches to learning tasks are measured by Biggs' Study Process Questionnaire, and ideas about the relevancy of what they read and how they will be assessed are evoked by written instructions. The phenomenon for which students' structures or ideas are ascertained is animal, and participants likewise read an expository text about the latter.

In previous research on this topic, only 59 per cent of 34 first year primary teacher trainees correctly classified, from a biologist's point of view, examples and one non-example of animal (Bell, 1981). For instance, 65 per cent categorised a spider as an animal, while 77 per cent answered that a worm was an animal (Bell, 1981; Bell & Freyberg, 1985; Osborne, 1982).

A study by Trowbridge and Mintzes (1988) on the same topic, with comparable subjects, but using different methods of measurement from those of Bell, found that of 100 tertiary students enrolled in introductory Biology courses for non-majors only 60 per cent and 50 per cent respectively classified a fish and a butterfly as an animal.
Accordingly, an adjunct aim of the present study is to attempt to replicate the findings of previous research on student primary teachers’ meanings for the word ‘animal’ (Bell, 1981).

To summarise, this research is designed to test the psychobiological expanded theory of learning proposed in Chapters Four, Five and Six. Specifically, it represents a clinical investigation of students' learning processes which occur, under particular conditions, as they read a text. Particular attention is paid to pupils' ideational transformation, their degrees of memorisation, their feelings and the ways in which they read the text.

7.2 Method

7.2.1 Participants

Ten first year student primary teachers enrolled in a Bachelor of Education course at the University of Wollongong volunteered to participate in the study.

7.2.2 Procedure

Two (2) weeks prior to reading an expository text about animal, all students were given (i) a survey in which they were asked about their meanings for the word ‘animal’ and several keywords used in the text, and (ii) a multiple-choice survey developed by Bell (1981).

As well as the 10 participating students, 38 other first year student primary teachers volunteered to complete the Bell (1981) multiple-choice survey (total N=48).
For the group of 10 students, the first survey of word meanings was used to obtain a measure of their alternative or prerequisite structures or ideas evoked by the word 'animal' and the keywords.

One (1) week prior to their reading of the text, all students were given the Study Process Questionnaire (SPQ) to obtain a measure of their 'typical' approaches to learning tasks.

On the day in question, all students read a short introduction about the relevance of the idea of animal to their course. Students then read one of two sets of instructions, A or B. All students read that they would be surveyed in the next week about the idea of animal.

Following Grolnick and Ryan (1987), in instructions A, it was emphasised that a student’s answers would not be evaluated or assessed, rather, the purpose of the second survey was to ascertain what they had learned from reading the text (see Appendix A).

In instructions B, it was emphasised that the answers they would give in the second survey would be assessed and graded, and this assessment was a way of measuring how much they had learned (see Appendix B).

All students were asked to read the text. The latter consisted of an exposition, constructed from a selection of relevant sections in current secondary biology textbooks, of the biological meaning of the word ‘animal’ (see Appendices A and B).

Following their reading of the text, all students were given (i) a short affect questionnaire to obtain a measure of their relative intrinsic motivation or curiosity, and (ii) a second survey of their meanings for the word ‘animal’.

In the week following their reading of the text, all students participated in individual interviews during which they were again asked about their meanings for ‘animal’. A
sample of other questions which were asked in the interviews is listed in Section 7.2.3 below.

To obtain a measure of memorisation, a student’s protocols from the second survey of meanings were divided into phrases and sentences which were compared with phrases and sentences from the text. A score of one (1) was awarded for each exact match.

According to the hypothesis (Section 6.8), a student who read instructions A, regardless of his typical approach to a learning task, who had an alternative spatio-temporal pattern of impulses or structure for ‘animal’ and prerequisite structures for the keywords, could become intrinsically motivated and construct new structures or meaning for ‘animal’. He would report feeling curious or mildly interested in the text. No specific hypothesis was formed about his memorisation score, except that it should be either 0 or much lower compared to a student who read instructions B. A student who read the latter, regardless of her typical approach and type of structures, would memorise phrases and sentences from the text, would not report feeling curious or mildly interested, and have a high memorisation score.

7.2.3 Measures

Survey 1

This survey is composed of open questions which ask students to describe what they think an animal is, as well as what they think specific keywords mean. For the word ‘animal’, students are also asked to give what they think are two (2) examples of animals and to explain why they think these two examples are animals (see Appendix C). Students’ structures or meanings for the word animal and the keywords were classified as prerequisite or alternative according to whether they were the same as, or different from, the intended meanings in the text. Appendix D lists these intended meanings.
Multiple-choice survey

In recent studies in science education (Section 6.7), a method which has been used by researchers to investigate children's ideas and meanings is the interview-about-instances technique or approach (Gilbert, et al. 1982; Osborne & Freyberg, 1985; Watts and Gilbert, 1983). In the interview-about-instances method, up to 20 line drawings on cards of familiar things, or situations, are said to depict several 'instances' or examples, non-examples (Gilbert, et al. 1982; Gunstone, 1988; Osborne & Gilbert, 1980a, b) and 'borderline cases' (or 'unusual' examples) (Watts & Gilbert, 1983) of a particular scientific idea evoked by a word, for example, 'force' and 'animal'.

Each card is presented to a student in turn and he is asked whether he thinks it 'contains' (Osborne & Gilbert, 1980a) or is (i.e., depicts) an example of his idea of 'force' or not (Gilbert, et al. 1982; Gunstone, 1988; Watts & Gilbert, 1983). The pupil's reason(s) for his answer is (are) then elicited (Gilbert, et al. 1982; Gunstone, 1988).

The time taken for each individual interview can range from 20 to 40 minutes (Osborne & Gilbert, 1980a, b; Watts & Gilbert, 1983). Each interview is audio-taped and is subsequently transcribed by the interviewer. Transcripts are then "analysed and the common elements and idiosyncrasies of children's ideas reported" (Osborne & Freyberg, 1985, p. 7).

Based on results obtained using the interview-about-instances method in a study of students' ideas about animal, Bell (1981) developed a six-question, multiple-choice survey for use with intermediate and senior secondary pupils (11 and 15 year olds respectively), and tertiary students. Each of the six questions consists of two parts, (a) and (b). Part (a) requires pupils to classify an example (a drawing) as an animal or not. The six examples used by Bell were a spider, a grass plant, a cow, a worm, a person and
a whale. That is, five examples of a biologist's idea of animal and one non-example (Bell, 1981).

Part (b) requires students to indicate their reasons for their answers to (a). Pupils are asked to select four reasons from a list of 26 provided. For senior secondary and tertiary students, the list consists of (i) eight 'scientific' reasons (A/B/G/H, K/L, S/T), (ii) twelve reasons used by pupils with a 'restricted' idea of animal (C/D, E/F, I/J, U/V, W/X, Y/Z), (iii) four 'classificatory' reasons (M/N, O/P), and (iv) the two reasons Q/R (Q is characteristic not only of animals, but of all living things) (Bell, 1981).

The examples and one non-example of an animal used in the multiple-choice survey in the present study included those used by Bell (above) and two other examples (a crab and a lizard) (see Appendix E). The list of reasons was the same as that used by Bell (see Appendix F).

**Study process questionnaire**

The Study Process Questionnaire (SPQ) is a 42 item questionnaire which yields scores on three motives for learning and three 'strategies' which are 'used' by a student to learn. As earlier indicated, for the surface and deep approaches to learning, these so-called 'strategies' are memorisation and (at least in part) construction, respectively (Section 6.5). Each item is a statement of a motive or 'strategy'. For each statement, students rate themselves "on a five-point (Likert) scale, from 5 ('This item is always or almost always true of me') to 1 ('This item is never or only rarely true of me')" (Biggs, 1987b, p. 10).

The three motives and three 'strategies', or six *subscales*, are listed as follows:

(i) surface motive (SM) (or extrinsic motivation)

(ii) deep motive (DM) (or intrinsic motivation)
(iii) achieving motive (AM) (or achievement motivation)
(iv) surface strategy (SS) (or memorisation)
(v) deep strategy (DS) (or, in part, construction)
(vi) achieving strategy (AS) (various organisational strategies) (Biggs, 1987b).

Items "are cycled so that every sixth item returns to the particular subscale in the order (above) from (i, above)" (p. 11). The questionnaire is scored by "adding every sixth response in the order indicated (above)" (p. 11). Raw scores for each of the subscales are then converted into deciles using tables of norms provided in the manual. Following Biggs (1979b), deciles were grouped as follows:

1 ‘well below average’. The score is in the bottom 10 per cent of the population. Designated as --
2 or 3 ‘below average’. The score falls within 11 and 30 per cent of the population. Designated as -
4, 5, 6 or 7 ‘average’. The score falls within the middle 30 to 70 per cent of the population. Designated as 0
8 or 9 ‘above average’. The score falls within 71 and 90 percent of the population. Designated as +
10 ‘well above average’. The score is in the top 10 per cent of the population. Designated as ++

Deciles for each of the subscales are then combined to obtain a student’s SPQ profile, or typical approach to learning. The different types of profiles and typical approaches are listed in Table 7.2.1.
Table 7.2.1. Study Process Questionnaire (SPQ) profiles and typical approaches (from Biggs, 1987b).

<table>
<thead>
<tr>
<th>Profile</th>
<th>Typical approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>00/++/00</td>
<td>Deep</td>
</tr>
<tr>
<td>--/+/+--</td>
<td></td>
</tr>
<tr>
<td>00/00/++</td>
<td>Achieving</td>
</tr>
<tr>
<td>--/--/++</td>
<td></td>
</tr>
<tr>
<td>00/+++/++</td>
<td>Deep/achieving</td>
</tr>
<tr>
<td>--/+/+/+</td>
<td></td>
</tr>
<tr>
<td>++/00/00</td>
<td>Surface</td>
</tr>
<tr>
<td>++/--/--</td>
<td></td>
</tr>
<tr>
<td>++/00/+-</td>
<td>Surface/achieving</td>
</tr>
<tr>
<td>++/--/+</td>
<td></td>
</tr>
<tr>
<td>00/00/-0</td>
<td>Low achieving</td>
</tr>
<tr>
<td>+-/--/-</td>
<td></td>
</tr>
</tbody>
</table>

Affect questionnaire

This questionnaire consists of two parts, (a) and (b). Part (a) requires students to select one alternative, describing how they felt as they read the text, from nine provided. Part (b) requires students to give a short explanatory answer as to why they felt this way (see Appendix G).

Survey 2

This survey, like Survey 1, consists of an open question which asks students to describe what they think an animal is. Students are also asked to give what they think are two (2) examples of animal and to explain why they think these two examples are animals (see Appendix H).
Interview

Each student participated in an individual interview which lasted approximately 25-30 minutes. The interviews were audio-taped and later transcribed. As well as being asked what they thought an animal was, students were asked a series of other questions, depending of course, upon their responses. A sample of such questions is listed below. In addition, all students were asked what they thought teaching and learning were.

Sample of questions:

(i) Do you think Biology is relevant to this course?
(ii) What did you do as you read the text?
(iii) Can you tell me what the instructions were?
(iv) Did the instructions have any effect on the way you read the text?

7.3 Results

The following figures and tables give an overview of results obtained.

For the Bell (1981) multiple-choice survey, Figure 7.3.1 shows the percentage of students who categorised each example of an animal as an animal. This figure also shows the total percentage of students (95.5%) who correctly classified all six examples; this is a much higher percentage than that obtained in the Bell study (59%).

Figure 7.3.2 shows the percentage of total reasons chosen of the five most frequently chosen reasons by students. It also shows the percentage of total reasons of the five most frequently chosen reasons by teachers' college students in the Bell study. A calculation of Chi-square (14.76) yielded a measure of discrepancy at a level of significance > 0.001. Thus Bell's (1981) findings were not replicated for this sample of primary student
Figure 7-3-1. Percentage of students (N=48) who categorized each example as an animal and the total percentage of students who correctly classified all six examples.

Figure 7-3-2. Percentage of total reasons chosen of the five most frequently chosen reasons by students. Also shows the percentage of total reasons chosen of the five most frequently selected reasons by Teachers' College students in the Bell (1981) study (see text for details of Reason categories).
The Reason categories in Figure 7-3-2 are as follows: Brea; It breathes, Move; It moves, Brain; It has a brain, Eats; It eats other living things, Cell; It has cells with no cell wall, Mamm; It is a mammal, Legs; It has many legs.

Table 7.3.1 lists students' SPQ profiles and typical approaches to learning tasks, as well as the set of instructions (A or B) which they read before reading the text on animal.

Table 7.3.2 lists the classification of students' structures or meanings for the keywords and 'animal' as either alternative or prerequisite. All students' structures for animal, prior to reading the text, were classified as alternative. All students also held some prerequisite structures for the keywords.

Table 7.3.1. Students' Study Process Questionnaire (SPQ) profiles and typical approaches to learning.

<table>
<thead>
<tr>
<th>Student</th>
<th>SPQ Profile</th>
<th>Typical approach</th>
<th>Instructions Read</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0/+0/++</td>
<td>deep achieving, though the decile for deep strategy, like surface strategy, is average.</td>
<td>B</td>
</tr>
<tr>
<td>2</td>
<td>00/+0/++</td>
<td>deep achieving, though the decile for deep strategy, like surface strategy is average.</td>
<td>B</td>
</tr>
<tr>
<td>3</td>
<td>0/-/-/-</td>
<td>low achieving.</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>0/-/0/00</td>
<td>low achieving.</td>
<td>B</td>
</tr>
<tr>
<td>5</td>
<td>+0/+0/00</td>
<td>deep, though the surface motive decile is above average.</td>
<td>A</td>
</tr>
<tr>
<td>6</td>
<td>0+/00/+</td>
<td>surface achieving.</td>
<td>A</td>
</tr>
<tr>
<td>7</td>
<td>0+/00/+</td>
<td>surface achieving.</td>
<td>B</td>
</tr>
<tr>
<td>8</td>
<td>+/-00/00</td>
<td>low achieving, though high on surface motive.</td>
<td>A</td>
</tr>
<tr>
<td>9</td>
<td>--/00/+0</td>
<td>achieving.</td>
<td>B</td>
</tr>
<tr>
<td>10</td>
<td>--/-+/++</td>
<td>achieving.</td>
<td>A</td>
</tr>
</tbody>
</table>
Table 7.3.2. Classification of students’ structures generated by ‘animal’ and keywords as alternative (A) or prerequisite (P).

<table>
<thead>
<tr>
<th>Structure/ Idea</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Student</th>
<th>4</th>
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In the following I will analyse, for each student, the protocols from the first and second survey of meanings (Surveys 1 and 2), and the transcript of interview. In extracts from the former, spelling and punctuation has been amended. Where sentences are broken, this is indicated by ..., and any insertions in either the protocols or the transcripts by the author are bracketed thus ( ). Any parts of an interview which could not be transcribed because of sound quality are bracketed thus [ ]. Student and interviewer are represented by (S) and (I) respectively.

For each student, Survey 1 is reported, followed by the Affect questionnaire, Survey 2, and the Interview transcript.

Student 1

Student 1 thought that an animal was “a living thing that isn’t human”, though she qualified this with “or I suppose it could be”. As well, she thought that an animal was a
"living body that can think for itself and has the ability to reproduce, and to adapt to its environment".

The two examples she gave were a cat and bird. She thought each was an animal because each had the capacity to ‘think for itself’ and ‘reproduce’. Another reason she gave was “it lives independently” or it is “able to live on (its) own, that is, (it) can survive without any interference from anyone else”.

In sum, Student 1’s forming structure for animal was a living thing which had the capacity to think for itself, reproduce, adapt and survive, or ‘live on its own without interference from people’.

She reported that the text made her feel curious, and she explained that this was because “I have never done Biology before and as I read the text it became clear to me that a lot of the ideas I had on cells, etc., (were) wrong. This made me curious to compare the facts (in) the text to my answers of a previous survey, and now having seen where I was wrong I am more interested in the subject and will look forward to learning more on it next year”.

The statements, (i) that “it became clear to me that a lot of the ideas I had on cells, etc., (were) wrong” and (ii) that she compared the “facts (in) the text” to her “answers of a previous survey”, as well as her report that she felt curious indicates that (a) some of her forming structures might have undergone reduction and (b) she might have, as a result, constructed new ideas while reading the text. This would be consistent with her typical deep/achieving approach to learning tasks.

Support for this interpretation comes from her Survey 2 protocol, in which she expressed, in often more succinct contexts than those of the text, a total of nine intended ideas. For example:
(a) "an animal is a living organism that has the ability to move from place to place".

(b) "its (an animal’s) body is made up of cells with a very thin membrane around them and (which) have no cell wall".

In her Interview, Student 1 expressed seven intended ideas. For example:

S. ... (an animal is) something that’s got a brain ... (and) can decide on where it moves ...

S. I can’t remember now what the cells are if they’ve got walls or what now. I always get them mixed up; I think that they don’t have in animals because plants have to because they’re thicker ...

The first extract indicates that she might have constructed a new structure for animal from interaction of her structures of ‘(an animal can) think for itself’ (Survey 1) (i.e., ‘decide’) and brain and motion. In the second extract, she seems to be specifically trying to recall a statement from the text, and then generates, from her idea that plants are ‘thick’, the thought that animal cells do not have walls. Nevertheless she does appear to have attempted to construct a new idea about animals and their cells, rather than memorise parts of the text. Other examples of her attempts at construction include:

S. ... the symmetry can be longitudinal um (an animal can have) ... a right and a left side that’s more or less the same or it can be, is it radial? Like in jellyfish?

I. Yes like ... your thinking of a circle?

S. Sort of like wheel things, yeah.

S. ... like they find food to give them energy to move um and ... they can use their senses to actually find their food and what’s right for them ...
Thus, from her statements that she was able to regenerate her previous ideas (i.e., by recalling her own contexts from Survey 1) and then compare these structures (by some process) with others, and that she felt curious while reading the text, as well as the number of acceptable contexts she used in both Survey 2 and the Interview which were different from those she used in Survey 1, it can be concluded that Student 1 constructed new structures or intended ideas as a result of reading the text.

This conclusion is also supported by her statement that "(I) read it (the text) through a quick once over to get the idea of it and then I read it through slowly trying to understand each new word or new [ ] that I hadn’t come across”. She also states that “if I come to a bit I don’t understand I spend longer until I can figure it out and then I’ll move on”. In the following extract, she elaborates on what she means by ‘figure it out’:

S. Oh um well ... I was following the sense of what was written. When I came to big words, sort of ... (I) can’t think of the word [ ] at the moment ... did it mention photosynthesis?
I. Yes, yes.
S. Right when I came to that I had to stop and think about the word so then I would read round it to see what it meant then I’d try and remember the word ... So long as I can understand it and I know (what the) word means then I can understand the idea that’s there and then just go on to the next one until I get stuck again.

That is, as Student 1 read the text she generated interacting structures or a continuous flow of meaning. When she came to a term with which she was unfamiliar, and for which she could not generate a structure, she began selectively to ‘read the words around it’, trying to construct an integrated spatio-temporal pattern of impulses for this term.

She appears to have taken a deep or deep/achieving approach to the task of learning about animal, despite having been given the set of instructions B. It became apparent in the Interview, however, that she may not have actually read these instructions. For example:
I. O.K. ... can you remember what the instructions said at the top of the page?

S. Of the page? ... No, I think (that) when you’d written on the board to put your hand up if you
don’t understand anything that’s when I thought oh well we have to remember this so otherwise
you wouldn’t tell us ... ‘if you don’t understand anything’, to ask. I remember that, but not
really what was on the page.

When asked how she would have approached the task if she had been specifically given a
set of instructions B, Student 1 stated that:

S. Oh I would (have) sort of read it through a lot more and if I had (had) a list of references I would
have gone (and) read more about it, just to try and get a better understanding. Sort of try and
learn it long-term instead of short-term.

Student 1 explained that learning something ‘long-term’ meant, with respect to the BEd
course, that “we’re not to learn it just for the exam; we’ve got to try and keep it so that it
can change our values or build up our own theories even when we leave here. So you try
to remember something so it’s always there”. Whereas she explained that learning
something ‘short-term’ meant, with respect to her schooling, that “(if) the teacher ... gave
us something and (said) ‘well your gonna have a test on this next week’, then you’d keep
reading it over until you could say it back almost parrot fashion, but then after the exam
you’d forget all about it and you wouldn’t bother about it again”. That is, for Student 1,
‘short-term’ learning is the process of memorisation, which she states later in the
Interview, characterised her learning of Latin at school.

Although Student 1 was given the set of instructions B, she expected the type of
assessment in instructions A. Thus for Student 1, the hypothesis was confirmed.
**Student 2**

Student 2 thought that an animal was "a biological being which reproduces and survives in a surrounding appropriate for survival". She also stated that "an animal can be wild, and of all different shapes and sizes" and "this animal (herself) is made up of cells, the units of living".

Though she states that animals are composed of cells (an intended idea), her structure for animal is classified as alternative. This classification was supported by the large number of different reasons (11) she chose for categorising examples as animals in the multiple-choice survey, in particular the reason, 'it makes a noise' (chosen four times).

Student 2 reported that the text made her feel curious, "due to the instructions stating that questions would be asked concerning the text next week. All sorts of questions triggered off in my mind. Will I remember this text?". That is, she was curious about the purpose of the study and apprehensive (rather than curious?) about the questions which would be asked of her.

She states after this that "as I began to read the text I felt a little curious to the subject matter. It reminded me of my old Biology lessons. I felt this emotion of curiosity for the lesson we will be encountering in science next year. What will we be learning?".

However, in the Interview Student 2 revealed that reading the instructions made her feel anxious:

S. ... there was something about (the instructions) ... I felt really frustrated, not about you; I felt anxiety because it said something like ... you’ll be tested on this next week or something; on the text that you read. It was something like that and I thought 'how am I going to remember this' ...
Student 2 became anxious upon reading the set of instructions B. This anxiety may have moderated when she realised, as she read the text, that the topic was one which she had studied at school. She had a score of 0 for memorisation and in Survey 2 expressed a total of three intended ideas in *slightly* different contexts than those of the text. For example:

(a) "an animal can move (locomotion)" (her brackets).
(b) "an animal is a living thing. It is made up of cells - the basic unit of all life. These cells contain a cytoplasm bounded in a membrane".

However, she had previously related the idea that an animal is made up of cells in Survey 1. As well, she expressed some ideas which were *not* in the text, for example, "an animal is active due to the energy of food" and an animal can "reproduce" (the latter idea was mentioned in her protocol in Survey 1).

In the Interview, Student 2 again expressed three intended ideas in slightly different contexts, and also recalled the words 'bilateral' and 'radial':

S. ... (An) animal is made up of cells; (it is) made up of units ... (it) needs energy (of food?) to ... function ... It can move around ... I'm trying to think now. It was something about ... that um I hadn't come across and I just read over that once or twice. I just wanted to make it sink in. I can't remember what now no ... oh bilateral and all that; radial ...

However, the following extract shows that, though she was able to recall the terms 'bilateral' and 'radial', she was unsure about their respective meanings:

S. ... we sort of did do a bit of that (presumably at school) ... bilateral and radial was it?
I. Yeah that's right.
S. The structure of an animal was it?
That is, Student 2 might have memorised these terms, rather than have tried to construct meanings for them.

She also recalled ideas from her high school Biology studies. For example:

S. An animal gets its food from other things and, um (I'm) trying to think back (to) my old Biology lesson(s), and um a plant, it makes its own ... food through the sun('s) energy. I'm trying to think of the two words that describe these two things ...

These two terms were heterotopic (animal) and heliotropic (plant); words which were not used in the text.

Student 2 tried to memorise specific terms from the text. Though she was aware that some words were new, or that parts of the text “didn’t make sense”, which implies that her structures could have undergone intermittent reduction, she did not persist, perhaps mainly due to her feelings of anxiety, in attempting to construct new ideas, preferring instead to rely on knowledge she had acquired in Biology lessons at school. For example:

S. Well first I read through it (the text) [ ] paragraph (by) paragraph just like normal reading, but terms that I didn’t quite (understand, or that) didn’t quite sink in, or I didn’t really know about, I had to read again ... Things that didn’t make sense I went over, but it ... was fairly familiar. I was familiar with (the text) because of year 11 and 12, and it was all right.

Student 2 read the set of instructions B, her structure for animal was classified as alternative and seven out of ten of her ideas for the keywords were categorised as prerequisite. For Student 2, the hypothesis was confirmed. That is, regardless of her
'typical' deep achieving approach, she memorised specific words from the text without trying to construct new structures or meaning for these terms.

Student 3

Student 3 thought that an animal was “any living thing that moves”. The two examples of an animal she gave were a human and a giraffe. These were examples because each “is alive, moves, eats, breathes (and has) body functions to maintain life”. That is, her forming structure for animal was a living thing which moves, eats and breathes.

Student 3 reported that the text made her feel mildly interested, and explained that this was because “Biology was a subject that I took last year and all the points in the text ... I have read ... before. Biology interests me a little and so reading the text just refreshed my memory of what I learnt at school”. That is, the text made her feel mildly interested because it was familiar. She had a memorisation score of 0. However, though she mentioned three intended ideas: “an animal is a living thing”, “animals move ...” and “they (humans) move (and) feed off others ...”, she had previously expressed the first two of these ideas, and “they (humans) ... (eat)” in her protocol in Survey 1. The remainder of her protocol in Survey 2 contained ideas which were not in the text.

Student 3 did not construct new structures for animal as a result of reading the text, nor did she attempt to memorise parts of the latter, rather, she expanded on her own ideas about animal from the first survey. For example, “all humans are animals” and “(humans breathe) (Survey 1) was expanded to “humans also respire to enable the inflow and outflow of oxygen and carbon dioxide. This is also a feature of an animal” (Survey 2).

It appears that her reading of the text resulted in the evocation and recall of more of her own ideas about animal which she had constructed during her secondary education.
In the Interview, Student 3 only mentioned three intended ideas, which she expressed in very terse contexts:

S. ... something about that lives and feeds off other things. That's all really. (Here she seems to be trying to recall the text, rather than saying what she thinks.)

S. ... an animal is something that moves, yes, yes right. (Again - she was looking away and up to the ceiling - she seems to be trying to recall a part of the text.)

She also stated that animals do not 'photosynthesise', but could not explain what photosynthesis was:

S. Isn't that taking in ... oh hang on I get confused with these (things). I remember from Biology one's taking in the oxygen isn't it? and letting out .. the carbon dioxide or whatever ...

S. (I) can't remember I just know the difference. I can't remember what it actually is.

That is, she could recall the correct terminology, but could not explain its meaning.

Student 3 did not construct new structures, nor did she memorise, but preferred to rely on the knowledge that she had acquired at school. This interpretation is supported by her statement that:

S. ... (I) read (the text) and sometimes when I thought that (something) was an important point I just went back and read that sentence again but that's about it ... I didn't go back and read it twice or anything ...
Student 3 read the set of instructions A, her idea for animal was classified as alternative and three out of ten of her ideas for the keywords were categorised as prerequisite. For Student 3, the hypothesis was not confirmed.

Student 4

Student 4 did not state what an animal was, and only gave examples. Nor did he write in sentences. The two examples he gave were a lion and an elephant. Both were animals because they were “untamed, instinctive, (and) reasonably uncontrolled by man (and are) not human or plant”. However, he thought that living was “breathing, moving, reproducing. If it (an animal) can do these, its alive”. As well, though he stated that a lion and an elephant were animals because they were not ‘human’, in the multiple-choice survey he categorised a person as an animal.

Student 4 did have a forming structure for animal, but he did not communicate this idea well in Survey 1. This interpretation is supported by the fact that he was able to express an idea of animal in Survey 2 which was different from that intended in the text.

He reported that reading the text made him feel mildly interested, though he also circled, with a dashed line, the alternative ‘mildly anxious’. He explained that he felt this way because “I know (very) little about Biology, other than (the) basics, as I didn’t do it at school”. He also stated that “the cells and their make-up were interesting as I didn’t know that before. Its hard to believe that we are full of them”, but that “the way that certain terms were used was somewhat cold (however precise) and unfeeling” (his brackets).

Though part of the text made Student 4 feel mildly interested, the remainder made him feel uneasy. While his memorisation score was 0, he only mentioned one intended idea: “an animal is a body that can move”. With the exception of “an animal ... feeds”, the remainder of his protocol was made up of ideas not in the text.
In the Interview, Student 4 again related that “an animal moves”, and repeated what he had written in Survey 2.

S. An animal - now I’m trying to remember what I wrote down ... I think I put it was something that breathes, um feeds, reproduces itself. I guess you could put plant under that category so its a bit ... general, um (an animal) ... moves.

S. ... (an animal) can make (a) decision ... It can decide I’m going to go down here or I’m going to go do that, and its adaptable to its environment in terms of just keeping itself alive, like a tiger or something (which) learn(s) ... as a young tiger to chase a gazelle or something, to kill it (and) eat it ...

In both Survey 2 and the Interview, Student 4 expanded on his own unique idea of animal. This idea was that an animal was something which was mostly wild and could move, breathe and feed. As well “it is able to sustain itself (its life). In the process of doing this it comes into contact with other living bodies and the ability to think (process) determines its ability to avoid confrontations and sustain itself”. He also stated that “a living animal has (an) ability to reproduce”.

Student 4 did not construct any new structures for animal from reading the text, nor did he systematically memorise parts of the latter, but instead preferred to rely upon an ability “to take in as much as he could”. For example:

S. I just read (the text) straight and then there (were) a few things I went back for just to make sure because I thought that ... the question(s) ... that you’d be giving us next (week) (Student 4 read instructions B) would be questioning like the comprehension of what we’d read so I tried to take in as much as I could, you know, especially things that I’d never seen before. I thought ‘I’ve got to remember that’ because there’s probably going to be a question about it ...
However, though he did not construct a new structure for animal, he appears to have constructed an idea for the term ‘photosynthesis’, a word which he indicated he had never seen before:

S. Um ... photosynthesis I’d never ... come across that before. I didn’t know much about that. I remember that word because I wrote it down on my wrist.

I. Right, did you go and look it up at all or?

S. Um it explained it in a way in the text and I asked my Mum when I went home about it ... I read it through again and um tried to understand it because when I first read it I thought right that’s cool, and didn’t quite understand ... the concept of it.

I. What did you try and do, you just tried (to) understand. Just looked at what the words were or?

S. Yeah and just tried to see exactly what they meant. I didn’t really know, I remember that distinctly because I didn’t know anything about it. (I’d) never heard of it before. I didn’t know that was ... important. I knew that ... if you don’t keep plants in the sunlight ... they slowly wither away, but I didn’t know ... how they get (their) energy from the sun. I didn’t know any of the process that sort of explained it.

I. Hmm well can you tell me what you think it is or?

S. Photosynthesis?

I. Yeah what you think it is.

S. Yeah um ... the plants use the sun in conjunction with ... the proteins and stuff they get from the soil, you know, like a chemical reaction, and the sun and ... what the plant’s already got; (the plant) puts (this) out on its leaves and the reaction of the sun on it or ... the um sun’s rays I guess you could call it. I don’t know if photosynthesis works through windows either. That’s one thing I was interested about: whether it works through windows because I don’t know if the energy you have to get is immediate or whatever ... That’s another thing I asked too, would photosynthesis work off mirrors and stuff? I don’t (know) if it would and um well I guess it wouldn’t because then its not directly in the sun ...
When Student 4 read the word 'photosynthesis' he became interested and re-read the sentence, trying to construct an ideational structure for the new term, and again later, when at home, he seems to have attempted to form a structure for photosynthesis (this interpretation is supported by his statement "puts it out on the leaves". A plant's leaves were not mentioned in the text).

However, the idea he constructed is an alternative one; that is, for Student 4 photosynthesis is a process in which the elements obtained from the soil by a plant are combined with the sun's rays to produce energy (rather than food, e.g., sugars), "like a fuel ... its (photosynthesis is) like a combustion ... that's how I interpreted (it) after I'd asked questions and sort of thought about it". He may have formed this alternative idea because of other alternative, perhaps everyday, ideas he has for light and energy (on the other hand he may have encountered an alternative meaning for photosynthesis at home). This interpretation is supported by his theorising about whether photosynthesis would 'work through windows' and his conclusion that photosynthesis would not 'work off mirrors'. That is, for Student 4, sunlight is not energy; light and energy are separate things, and for a plant to receive energy from the sun, it must be out in the open and 'under' the sun.

Student 4 read the set of instructions B, his idea for animal was classified as alternative and seven out of ten of his ideas for the keywords were categorised as prerequisite. For Student 4, the hypothesis was not confirmed. That is, he did not memorise words from the text. As well, he constructed an alternative idea for 'photosynthesis'.

Student 5

Student 5 thought that an animal was a "living being with none or very little intelligence regarding speech, writing and understanding". She did not give two examples of an animal, because "to me (examples) would not exist. For I believe every animal has intelligence ... which may not have been discovered yet".
That is, she thought that an animal was a living being with at least some intelligence or 'understanding', and attempted to contrast this unique view with a more formal, biological idea of animal (which does not incorporate the idea of intelligence).

Student 5 reported that the text made her feel curious. She explained that she felt this way for several reasons:

(i) "because I couldn’t quite see the reasoning for reading the text; especially) about animals". That is, she was probably curious about the purpose of the study.

(ii) "curious explained my understandings in comparison to those on the sheet outlined for me". Here she seems to be saying that she felt curious because her structures for animal were different from ideas evoked by the text.

(iii) "I was trying to consume all the information for next week's 'test (sic)' or questionnaire". It is unclear what she means by this. Perhaps, again, she felt 'curious' about the purpose of the study (supported by the fact that she called Survey 2 a 'test', when the instructions that accompanied the text specifically stated Survey 2 was not a test). On the other hand, she might have confused 'curious' with a feeling of apprehension or anxiety.

Student 5 obtained a memorisation score of 0. She expressed several intended ideas (a total of four) in more succinct contexts; for example:

(a) "it (an animal) is symmetrical in shape and form".

(b) "it (an animal) consumes energy through physical matter, that is, prey, plants, etc." (though there is some confusion here between obtaining energy and consuming food).

(c) "it (an animal) has a growth-life that ends at adulthood".
She also expressed her structure for intelligence, and integrated this idea with her structure for brain: “it (an animal) has a brain which reflects intelligence”. Though she states that “I’ve been converted”, clearly, she retained her structure for intelligence coordinated to the word ‘animal’: “humans are a little more intelligent than the general animal...”. Nor did she entirely accept the formal, biological view of animal: “wouldn’t it be interesting to see what another non-communicating animal or plant would characterise themselves as if they could communicate!”

In the Interview, Student 5 again communicated her structure for intelligence, and pointed out that this idea was separate from other structures she had formed for animal:

S. ... let me say one thing before I read that piece of paper (the text) I couldn’t really give you (a) biological definition to mean animal was something that had no intelligence ... But if you want me to talk in a biological sense its all these cells and membranes and whatever you want to call (it?) [ ]. Human life would be categorised under animal [ ] and the other differences a plant (has) as opposed to animal life.

Student 5 attempted to construct ideas about animal from the text. This conclusion is supported by her statement that:

S. Yeah I read it (the text) two or three times actually and if I ever read something I didn’t understand I went back and read it again. At the time I did understand it but to give you an explanation now you know I can give you a general one but ...

However, it is as if her new structures, constructed at the time of reading, somehow ‘dissipated’ over the period of time (a few days) from filling out Survey 2 to participating in the Interview. The duration of her process of construction was perhaps limited by the following factors: (i) a strong concern for the purpose of the study, (ii) her perception that the text was irrelevant, and a disinterest in Biology in general, (iii) her (erroneous)
anxiety about the ‘test’ the following week, and (iv) a belief about her ability to learn science topics. For example:

S. ... (the thought) just kept running through my mind ... ‘how is this relevant?’ . That’s all I kept asking myself, ‘why ... is he asking me these questions?’ . It wasn’t the actual information that went in because like I said my mind isn’t adapted to Biology and things like that. It just doesn’t appeal to me and therefore it just gets sifted ...

When asked what influence the set of instructions A had on her reading of the text Student 5 stated:

S. ... I wanted to take in every detail because I didn’t expect it to be this sort of questioning I thought ‘oh here we go he’s gonna give me some test’ ... so I did read it bit by bit and tried to take in all of it and then I thought well I can only take in so much when it comes to science ...

Student 5 read the set of instructions A, though because of her assumption about these directions, it was as if she had read instructions B. Her idea for animal was classified as alternative and three out of ten of her ideas for the keywords were categorised as prerequisite. For Student 5, the hypothesis was not confirmed.

Student 6

Student 6 thought that an animal was “a living creature which lives on earth. It can live on land, sea or fly in the air. The two examples he gave were a dog and an elephant. The former was an animal because “it’s not a human. It has four legs, (a) (human has two), a consistent amount of hair covering ... (its) body and generally looks like an animal”, while an elephant was an animal because “it’s got a trunk, four legs and lives in a zoo”.

His structure for animal was classified as alternative and ‘everyday’ (the idea that an animal is a four-legged terrestrial creature). This latter classification was supported by the
fact that (i) a reason he gave for both examples being animals were that they had four legs, and (ii) a dog "generally looks like an animal" (i.e., a four-legged terrestrial creature).

Student 6 reported that the text made him feel confused (he also circled with a dashed line the alternative 'bored'). He stated that "I thought the information presented was pretty hard to understand the first time I read it. I found the information just passed through my brain without me taking it in, understanding it, noticing any major points and liking what I read. The article didn't interest me much and I thought the second page especially was particularly hard to comprehend the first time reading it; even after 2 or 3 times reading a sentence I was still confused".

During his first reading Student 6 did not understand the text. It is not clear whether he gained an understanding during subsequent readings, but from his answer in Survey 2 (see below) it is likely that he did not.

In the first survey, he generated alternative structures for most of the keywords. For example, he described cells as "small molecules of shapes which makes up everything" (he seemed here to confuse atoms, molecules and cells), and locomotion as "a train". The meanings he gave for 'growth', 'adulthood', 'food' and 'brain' all related to a person. He thought that 'symmetry' was "something to do with maths" and 'sensory organ' was "something which relates to touch, sound, taste, sight and breathing (I'm not sure about this one)". Thus taking into account (i) his everyday structure for animal and these alternative ideas, and (ii) the way the text was written, during his reading he could not generate integrating structures from the contexts used. In his words, he could not 'take it in'.

Nevertheless, Student 6 did express one intended idea. As well as stating that an animal "is a living organism capable of reproducing" (an idea not in the text), he wrote that it "is
made up of cells which help it grow from infancy to adulthood”. However, the examples of an animal he gave in Survey 2 indicated that he had retained his everyday structure. A dog is an animal because it “... has physical features which plants don’t (i.e., a mouth, teeth, eyes, ears) and has four legs”.

In the Interview, he expressed this everyday idea again, but also incorporated the intended idea that an animal is made up of cells:

S. An animal ... (is) similar to a human being (because it breathes. Its ... got similar features like legs, eyes, noses, ears, etcetera. It um (has) fur, it eats and drinks [ ] (and lives?), it reproduces like humans, um (and it) moves around. Its made up of various cells which ... heaps of cells actually a lot of cells.

Student 6 could not generate integrating spatio-temporal patterns of impulses, or a flow of meaning, from the text. From some contexts he might not have been able to generate any structures, that is, comprehend, and thus felt confused and bored (i.e., the same way we can all feel when we try to read a foreign language, or something written in technical jargon with which we have no familiarity). Other parts of the text led to continuous reduction and an unpleasant feeling; for example, he stated that he did not ‘like’ what he read. From one part, however, he constructed the idea that animals are made up of cells. For example, he states in the Interview that “I learned a few facts from it (the text) which I didn’t know before”.

Student 6 read the set of instructions A, his idea for animal was classified as alternative and two out of ten of his ideas for the keywords were categorised as prerequisite. For Student 6, the hypothesis was confirmed.
Student 7

Student 7 thought that an animal was “a living thing or living organism that can live on the land or in the water. Some animals may live in both, for example, a frog (amphibian)” (her brackets). As well, she stated that “all animals belong in the animal kingdom. Animals are warm or cold blooded, have a covering (e.g., fur) and move around by their own free will. Some animals cannot think in abstracts like human beings”. The two examples she gave were a human and an earthworm. These were examples because they were both ‘living’ and both belonged to their respective phylum. A human was also an animal because it can “move around by (its) own free will” and is “covered by hair”.

However, the first reason is also characteristic of plants and the second is not a reason but a system of classification based on specific characteristics.

Student 7 reported that the text made her feel mildly interested because “I have been taught and have heard most of this before because I did Biology in year 11 and 12 and can remember most of this”. Though Student 7 obtained a memorisation score of 0, several sentences in her protocol from the second survey were only slightly dissimilar from sentences expressing the same idea in the text. For example:

(a) “when an animal has a bilateral symmetry that means that if a line is drawn down the middle of the animal then both sides are alike and are a mirror like image of each other (e.g., a spider has bilateral symmetry)”.

(b) “animals are capable of moving their whole body around (i.e., locomotion) to another site. There are some exceptions, though, as animals such as anemones are stuck to one site but they move around when they are young”.

She also related some intended ideas in different (though acceptable) contexts: “animals eat plants and other animals (dead or alive) to survive”.
As well, she expressed ideas which were not in the text. For example, “animals can be herbivores (plant eaters), carnivores (meat eaters), or omnivores (plant and meat eaters)” and animals “also have a respiratory and circulatory system”.

It is concluded that Student 7 memorised words from the text and at the time of recall reordered these words to form her answer. The contexts she used followed the same order as that in the text, and the examples she gave were the same as those used in the latter.

On the other hand, it might be that the text evoked many of the ideas she had acquired in her secondary Biology course. These ideas might have been the same as those in the text, resulting in a similar wording to the latter (though it is difficult to account for the similar order of contexts).

In the Interview, she expressed intended ideas in different contexts than that of the text, and also related some of her own structures. For example:

S. ... its (an animal is) living. It's made of cells and that's important in growth, um (it) reproduces, um (it has) either bilateral of radial symmetry, um it's got a nervous system, digestive cavity um circulation and (a) respiratory (system) and all that stuff ... its able to move around (unlike) plants' they're immobile ... what else ... animals are able to eat plants or animals but plants don't really eat animals.

However, Student 7, perhaps in part because of her varied, prior knowledge of animal and plant, did not construct new structures, but memorised terminology and the overall order or structure of parts of the text. This interpretation is consistent with her typical approach to learning tasks, classified as surface/achieving, and her statement that she thought reading the text “was like a test”, to “see how much you could remember”. It is
also supported by her statement that she “just read it (the text) once fairly slowly so I could remember it”. As well, though she stated in the Interview that she was aware that some words were new, she was unable to give a meaning for one of these words:

S. ... a couple of words were new, um I can’t remember what word it was. I think it was about the digestive cavity or something, (or the) nervous system ... Was (it) sephilism or something?

I. Cephalisation

S. Yeah something like that ...

I. ... what do you think that word refers to?

S. Um when I was talking about the digestive cavity and the nervous system and things like that.

(Cephalisation was defined in the text as the concentration of a brain and sensory organs in an animal’s head.)

*Student 7 read the set of instructions B, her idea for animal was classified as alternative and nine out of ten of her ideas for the keywords were categorised as prerequisite. For Student 7, the hypothesis was confirmed.*

**Student 8**

Student 8 thought that an animal was “anything that is not a plant, or (an) inanimate (sic) object that relies on food for existence, as well as the basics of living - shelter, sex and food”. The two examples of animals he gave were a horse and a cat.

Student 8 reported that the text made him feel mildly interested. He explained that this was because “being an animal (by definition from the text) I was interested in the summation given. It enabled myself to revise something that involves life and its subjects (creatures)” (his brackets). The fact that he stated that the text allowed him to ‘revise something’ indicates that he might have constructed new structures during his reading of the former.
Student 8 obtained a memorisation score of 1, and in his protocol in Survey 2, he expressed two (2) intended ideas in a different context:

(a) “it (an animal) relies on food for survival, be it animal or plant life”.
(b) “radial symmetry is equal around a centre”.
(c) “bilateral symmetry is equal in halves”.

However, with respect to (a) he had already made a similar statement (‘relies on food for existence’) in Survey 1, while as I will show below, he did not have an understanding of radial symmetry. Other sentences in his protocol were only slightly different from an equivalent wording in the text. For example, “an animal is a living organism that has cells, which is the basic component of a living organism” and “a bilateral animal usually has a head at one end which has a brain for controlling its bodily functions and capacities”. The idea expressed in the latter part of this sentence, that is, that a brain controls bodily functions, was previously expressed by Student 8 in his answer for the keyword ‘brain’ in Survey 1. In this survey, he stated that “a brain is the most complex organ in an animal which is the CPU which controls most functions of the animal”.

In the Interview, he only mentioned one intended idea (type of symmetry):

S. ... (an animal is) a living organism. It has appendages (and) ... a form of symmetry, whether its bilateral or sagittal I think, um (it) generally has ... (an) outer covering to protect it from whatever ... (it) generally eats food ... for survival ...

Student 8 memorised words from the text and at the time of recall reordered these words to form his answer. This conclusion is supported by the fact that in Survey 2, he incorrectly classified a dog and a fish as having radial symmetry, which indicates that he did not have an understanding of the latter. This interpretation is also supported by his
statement that he "just had a glance through it (the text) like front and back um (and I) just read through it and just remembered bits and pieces ... that I thought were more relevant than others". That is, he did not go back and re-read any sentences to try to create new structures for words which were new.

Student 8 read the set of instructions A, his idea for animal was classified as alternative and seven out of ten of his ideas for the keywords were categorised as prerequisite. For Student 8, the hypothesis was not confirmed.

Student 9
Student 9 thought that an animal was "any living thing which is not rooted (in) the ground (as is a plant), which relies on the ingestion of food for survival and is either a male or female in gender (sometimes both). It is not man-made" (his brackets). The two examples he gave were a cat and a dog. These were animals because they were living things and because "the science world has classed these things as animals".

Student 9 reported that the text made him feel mildly interested, "mainly because I (was already) aware of many of the facts contained in the article, while other facts I was unaware of".

But though he was aware of new 'facts' and thus could have constructed new structures, his protocol for Survey 2 was very short (one sentence) (memorisation score 0). He did express one intended idea (locomotion): "an animal is a living thing, able to move about, and able to survive by ingesting food", but by implication, he had already related this idea in Survey 1 (i.e., an animal "is not rooted in the ground").

In the Interview, Student 9 only expressed two (2) intended ideas:

S.   an animal ... is a living thing, well obviously, but um (it) can move about as opposed to a plant
But again, he had previously mentioned these ideas in Survey 1. He also mentioned photosynthesis, though his explanation for this process included ideas which were not in the text, for example, “water goes in through the roots” and “food goes up to the leaves”.

Student 9 was able to understand most of the ideas expressed in the text, and in Survey 2 and during the Interview preferred to relate structures he had already acquired at secondary school. Ostensibly, he did not learn anything new, either through construction or memorisation.

*Student 9 read the set of instructions B, his idea for animal was classified as alternative and eight out of ten of his ideas for the keywords were categorised as prerequisite. For Student 9, the hypothesis was not confirmed.*

*Student 10*

Student 10 thought that an animal was “a living thing that eats and breathes, is warm blooded”. She also stated that “a living thing grows, has some form of movement and requires air to exist”.

She reported that the text made her feel mildly interested “mainly because it brought back memories of my high school science. Something I haven’t done for about eighteen years. A few new facts were presented but most of the text was already known to me”. The fact that she was mildly interested and was aware of ‘a few new facts’ indicates that she might have constructed new structures from reading the text.

Her memorisation score was 0, and she expressed a total of five intended ideas in different, and very short, succinct, contexts from those of the text: “it (an animal) contains cells that have no cell wall, an alimentary tract - a brain and (a) nervous system. Animals are usually capable of movement and possess either radial or lateral symmetry.”
Again, in the Interview, Student 10 related four intended ideas in a different, succinct wording:

S. An animal is a living thing that ingests food that was once living, um it has no cell wall and it usually is capable of movement and when it reaches adulthood it stops growing; it doesn’t change its shape any more.

As well, when asked about ‘cells’ and radial and bilateral symmetry, it was clear that she had created structures for these terms:

S. ... a single cell ... has a nucleus and in plants (cells) have cell walls which is ar um I can see it ... I’ve got mental images of the two different cells but describing them is difficult.

S. Radial symmetry is like the cart wheel symmetry, um I’m drawing in the air (but) its not going on the tape.

I. That’s all right.

S. And er things like starfish and sea urchins and those sort of things ... have that sort of symmetry.

I. And what about bilateral?

S. Bilateral that’s it ... yes that’s along one plan of axis in living things. Usually it’s in proportion to the way it moves.

Student 10 constructed several new structures for animal as a result of reading the text. This interpretation is supported by her statement that she “read it (the text) through slowly in an effort to retain what it was saying and then when I’d read through once I went back through and read it through again paying particular attention to anything I found that was new, um like radial symmetry, although I knew it existed I’d never really given it much
consideration, especially pertaining to animals. I'd never stopped to think that starfish had lots of axes of symmetry um so I read that bit again”.

When asked how she would have approached the task of learning about animals from reading the text if her answers had been assessed, she stated that “I might have read it through a few more times and really consciously repeated and repeated the bits that I didn’t know that I wanted to remember”. That is, she would probably have tried to rehearse and memorise parts of the text.

*Student 10 read the set of instructions A, her idea for animal was classified as alternative and seven out of ten of her ideas for the keywords were categorised as prerequisite. For Student 10, the hypothesis was confirmed.*

### 7.4 Discussion

#### 7.4.1 General

Students’ memorisation of parts of the text did not take the predicted form of remembering, ‘word for word’, phrases or sentences. Thus students’ memorisation scores were always 0, or at the most, 1. Instead, in response to the open question in Survey 2, some students were able to recall single words from the text, and using these words, were able to generate slightly ‘re-ordered’ sentences which evoked intended meanings (in hindsight, it would have been interesting to compare these students’ answers and their Interview responses with their performance on a closed question test, e.g., a true/false statement or multiple-choice test).

These answers contrasted with students who were able to evoke intended ideas using different (though acceptable) contexts than had been used in Survey 1, which were often
more ‘compact’ and terse than the equivalent wording in the text. They also contrast, of course, with alternative, unintended structures that some students constructed.

### 7.4.2 Instructions A

A total of four students (3, 6, 8, 10) read instructions A. Student 1 did not read instructions B, but anticipated the same type of assessment as outlined in A, while Student 5, though she read instructions A, anticipated the same type of assessment as outlined in B.

This latter result confirms a claim by Ramsden (1985) that it is not the type of assessment, *in itself*, which encourages (for example) a surface approach, but rather “students’ perceptions of what the assessment requires” (p. 59).

Of the four students (3, 6, 8, 10) who read instructions A, along with Student 1, the hypothesis that each would construct new spatio-temporal patterns of impulses or structures for animal was only confirmed for Students 1, 6, and 10. However, while Students 1 and 10 constructed *several* new structures or ideas, read though the text slowly and often ‘went back’ to re-read parts of the latter which they considered to be ‘new’, and felt curious or interested, Student 6 only constructed one structure (that animals are made up of cells), did not comprehend the majority of the text, felt confused and bored, and did not ‘like’ it. This result does suggest, though, that even a Student who has a large number of alternative structures relating to a topic (eight for Student 6), and who is not assessed, can construct new ideas.

For Students 3 and 8 the hypothesis was not confirmed. That is, neither student constructed new structures for animal, even though they both held an alternative idea for animal, prerequisite ideas for some of the keywords and were given instructions A. However, neither student could remember what the instructions before the text said.
Both students proceeded as though assuming, like Student 5 above, that they would be assessed in a way outlined in B.

While Student 8 memorised words from the text and re-ordered these words to form some of his answers, Student 3 did not, and in the Interview, could only express ideas which she had acquired at school. Both students only read the full text once (Student 8 also 'skimmed' through it twice), and though both re-read some sentences, they did this because they thought these parts made ‘important points’ or were ‘more relevant’, rather than because these sentences were ‘new’, or because they did not understand the latter. These students believed that if they just re-read parts of the text, they would be able to recall this ‘content’ (perhaps in response to what they thought would be a closed question test) at a later date. Also, it might be significant that the typical approach to learning tasks of both students was classified as low achieving.

A student who adopts a low achieving approach is more likely to have a strong desire to avoid failure (Biggs, 1987b; McMeniman, 1989), and “a weak motive to achieve” (McMeniman, 1989, p. 218) or a weak desire to enhance his or her self-esteem by obtaining high grades (Biggs, 1987b).

In a recent study which bears upon this point, Dreyfus, Jungwirth and Eliovitch (1990) found that in their attempts during individual interviews to produce ‘cognitive conflict’ for students, some pupils, who were classified as ‘unsuccessful’ (i.e., presumably low achievers, see p. 556), felt “unsafe and threatened (and) tried to avoid conflicts. They were most characteristically apologetic when confronted with a conflict which, to them, seemed to represent just another failure” (p. 565-566). That is, these students appeared to associate failure with ‘cognitive conflict’ itself. By contrast, “bright, successful students reacted enthusiastically to cognitive conflicts. They liked the ‘flabbergasting effect’ of the method” (p. 565). Dreyfus et al. conclude that these attitudes toward a
learning task influence a student's "ability to be involved successfully in (a) constructive process of learning" (p. 567).

Though it is unclear exactly what is meant by 'cognitive conflict' in this study, it is not unreasonable to suggest that Students 3 and 8 above have associated failure with intermittent reduction, and held a desire to avoid the former, and thereby the latter, with the result that they did not construct new structures.

7.4.3 Instructions B

A total of four students (2, 4, 7, 9) read instructions B (recall that Student 5, though she read instructions A, anticipated the same type of assessment as outlined in B).

Of these four students (2, 4, 7, 9), along with Student 5, the hypothesis that each would memorise parts of the text was only confirmed for Students 2 and 7. Both students memorised some words, but as well, Student 7 memorised the overall order or structure of parts of the text. Both students read slowly through the text once; Student 2 did this because she "thought it might stick there so I could regurgitate it all", whereas Student 7 did this "so I could remember it". It is perhaps significant that while Student 2 (typically a deep achiever) felt anxious as she read the text, Student 7 (typically a surface achiever) felt mildly interested, even though both had done Biology at school. The organised way in which Student 7 approached the task of learning from the text effectively reduced any test anxiety that she might have felt.

The hypothesis was not confirmed for Students 4, 9 and 5. These students did not learn anything new about animal, either through construction or memorisation. Student 4 did, however, construct an alternative structure for 'photosynthesis'. All students persisted with their own ideas about animal; ideas they had either acquired at school or through everyday experience. While Student 9 was diffident about his approach to the task (he
simply seemed not to bother), Students 4 and 5 both tried to ‘absorb’ as much of the text as they could, for example, “take in as much as I could” (Student 4), “I wanted to take in every detail” (Student 5).

Both students commented that they had not expected the type of open questioning they encountered either in Survey 2 or during the Interview. For example, Student 4 stated that, “I’m going to read it, because there’s going to be a lot of questions on it, but it wasn’t; it was more just personal opinion”, while Student 5 admitted, “I didn’t expect it to be this sort of questioning; I thought ‘oh here we go he’s gonna give me some test’”.

Perhaps both students tried to memorise various parts of the text in the hope that when they read questions, which they may have anticipated would be ‘factual’, in the impending ‘test’, the former would ‘trigger’ recall of the correct wording. For example, Student 5 stated that she adopted a specific type of learning process when reading about a topic for which she anticipated a multiple-choice test: “Oh I’ve got this memory thing that I’ll read something and once I see it again on paper (I) automatically know what it is do you know? [ ]”.

7.4.4 Summary

The expanded theory above, compared to the mechanical theories reviewed in previous Chapters, constitutes an alternative account of learning processes which occurred as students read the text about animal. All students could generate several prerequisite spatio-temporal patterns of impulses or ideas in conjunction with their alternative structure or idea for ‘animal’. Thus all students could potentially construct new structures coordinated to the word ‘animal’. However, consistent with previous research, students’ anticipations about whether they would or would not be assessed determined the way in which they approached the task of learning about animal and thereby determined their ‘performance outcomes’.
As a result of some students thinking that they would \textit{not} be assessed, their structures underwent intermittent reduction as they read the text, activity increased in structures of the limbic system associated with emotions or feelings and they became interested or intrinsically motivated. That is, they tried effortfully to understand new, or 'difficult', sections of the text. By generating specific motor structures they were able to re-read specific parts of the text and form new structures coordinated to words which later formed their answers on the second survey and in the Interview (1, 6, 10).

By contrast, students who read that they \textit{would} be assessed generated intentions and strategies, or spatio-temporal patterns of impulses, which somehow limited the generation of their ideational structures relative to words in the text, and led to these students reading the text in ways which (they considered) would allow them accurately to reproduce parts of the former (Students 2, 4, 5, 7, 9, and perhaps, 3 and 8). Although Students 3 and 8 read that they would \textit{not} be assessed, it might be that upon becoming interested following intermittent reduction, they generated, in turn, feelings of anxiety and ideas about failure which prevented further generation of ideational patterns.

Significantly, some students (4 and 5), plainly did not \textit{exclusively} learn by construction, or by memorisation, rather they combined, or attempted to combine, to various \textit{degrees}, these processes. This result is consistent with previous research on students' approaches to learning tasks (Thomas & Bain, 1984: Thomas, 1987). For example, Thomas and Bain (1984) conclude from their research that "deep and surface approaches (are) not mutually exclusive ... on the contrary, any combination of them (is) possible" (p. 229).

It is concluded that the theory above must be developed to incorporate a single process of 'classroom' learning which can consist of a combination of construction and memorisation that reconfigures, resulting in an 'intensification/reduction' of either of the
latter, as a student thinks about assessment and generates intentions, and perhaps, as he/she thinks about his/her own ways of learning.

On this latter point, within the literature, students' ideas about the way they learn, or knowledge of their 'learning strengths and weaknesses', is typically termed 'metacognitive knowledge' (Baird, 1988) or 'metacognition' (Baird, 1988; Baird, Fensham, Gunstone & White, 1991). The claim that pupils do hold this 'metacognitive knowledge' was supported by the comments of several students. For example, Student 2 states that "if you really understand something then you ... don't have to learn it off by heart; you can put it in your own words" (Student 2). For Student 4 it is better "to pick out what I (think is) important or interesting ... because it makes me study easier" (Student 4), while Student 5 believes that she has "this memory thing that I'll read something, and once I see it again on paper (I'll) automatically know what it is" (Student 5). Of all the students, Student 1 held the most developed explanation of how she learned:

S. ... when something's caught your interest um then you'll want to know more about (it) so you read up all you can and you sort of find out information because you're interested and you remember it so you learn about it, but um there's times when you're told what to learn and you've got to. Well learning then, I think, is more memorising ... because if you're not really interested you can take it in, but you're not worried about remembering it you know ... I did higher level Latin in Scotland and we would work on a piece; we'd translate it, but then you had to remember the translation and background theory and notes for it and the only way you (could) do it was to keep going over it and over it until you'd memorised it rather than learned it and it was just sort of frustrating and boring because you knew that you had to do it ...

To account for the construction of a new structure, the theory above must also account for how a person forms a new word structure which can generate this idea. As well, it should be noted that the students only had one opportunity, lasting about 20 minutes, to
attempt to learn about animal from reading the text. For a study of this kind the data was indicative and while caution is required, generally there is encouragement to continue with this line of research.

Not directly connected with the hypothesis of the study, but significant, was the large variation in students’ ideas about animal held prior to (and following) their reading the text. These ideas ranged from ‘everyday’ (Students 4, 6) to a more scientifically acceptable view (Students 2, 7). This result is consistent with evidence from a study in Britain of primary school teachers’ ideas about materials, energy and forces (Kruger & Summers, 1988). In this study, “nearly all of the teachers interviewed held views of science concepts that were not in accord with the generally accepted scientific interpretation” (p. 263). As I will try to show in Chapter Nine (Section 9.2.2), one implication of the theory above is that the ‘quality’ of a teacher’s ‘subject’ knowledge is an important factor in the process of helping children to construct their own ‘subject’ knowledge.

Overall, the results reported above suggest clear implications for teaching. These implications, together with those of the expanded theory in general, will be discussed in detail in Chapter Nine and are presented only briefly here.

Firstly, teachers should be aware that the presentation by a student of contexts which evoke intended knowledge does not necessarily indicate that pupils have acquired this intended knowledge. Secondly, if a goal of teaching is to help students acquire intended knowledge, then, given (i) variation in the students’ ideas above, (ii) construction of new knowledge by Students 1, 6 and 10, and (iii) formation of alternative ideas by Student 4, teachers should be aware of the prerequisite/alternative structures or ideas which pupils have for phenomena. Thirdly, teachers should be aware of the influence which specific assessment procedures have upon students’ learning processes. If a goal of teaching is to promote understanding, then typical assessment methods may have to be changed.
Finally, as mentioned above, teachers also need to be mindful of the ‘quality’ of their own knowledge.

Of particular importance in this context are trainee teachers’ novice ideas about teaching and learning. Provision for ascertaining these novice ideas was made in the present study, and the results are reported in the next section.

7.5 Students ideas about teaching and learning

Like the idea of animal, students ‘novice’ ideas about teaching and learning also varied. For teaching, these ideas were classified into two main categories: a ‘showing/demonstrating’ view and a transmission view. Students’ ideas about learning were less clearly defined, but ranged from a constructivist-like view to a transmission approach.

For students classified as having a transmission view, teaching is:

S. passing knowledge onto young children and just enhancing their knowledge (Student 3)

S. like a transfer; like transferring culture across ... teaching is more trying to get a specific point across (Student 4)

S. a projection (of) a person’s knowledge onto someone who’s not as knowledgeable to someone who needs more ... help (Student 5)

S. (the) transference of knowledge; (it is) building up social attitudes that are relevant (Student 8)
S. sort of like passing on knowledge, not necessarily what you know ... yourself, (but) just ...
passing on the knowledge to the kids so they can learn and grow up and find their own careers
(Student 9).

S. imparting knowledge onto other people (Student 10).

That is, for these students, teaching is mainly the transmission, or the ‘passing on’ or ‘transfer’ of knowledge, to or ‘onto’ children. However, while Students 3 and 8 seemed to hold the view that a teacher is responsible for and controls pupils’ learning, Student 10 also thought that teaching consisted of “encouraging the people I think to learn for themselves ... to want to learn ... I don’t think that teaching stops at a person saying this is how it’s done or this is what it is. I think a teacher really needs to encourage children to want to go out and find out things for themselves” (Student 10). Similarly, Student 1 believed that “teaching is not just filling a child up with information but certainly showing them and guiding them to find out for themselves” (Student 1). That is, for Students 1 and 10, children can be responsible for their own learning and an awareness of this responsibility can be encouraged by a teacher.

For Students 6 and 7 teaching is mainly ‘demonstrating’ or ‘showing’. For example, teaching is:

S. explaining and demonstrating and showing ... things ... to the kids. Like telling them what’s right (and) what’s wrong (and) demonstrating how to do things (Student 6)

S. just showing ... like you could teach them about um ... different rules ... it’s just really showing them what’s ... um the required behaviour (Student 7)

Only one student (Student 2) held a view of teaching which could be classified as ‘constructivist-like’: 
S. (teaching is) helping children, well ... not (just) children, anybody really, (to) understand; not just understand, but um (to) give ... knowledge to ... I've never really thought about it before ... you're not just there to teach knowledge ... (you're there to) generate this knowledge and to help develop an understanding of things and personality, but um also ... (you're) there to be a friend or someone to talk to (Student 2)

But she could not easily express an idea about learning: "learning is um ... its taking these different things which [ ] like about the environment or issues I don't know how to put it ... I don't know, truly I can't, I can't answer that" (Student 2).

Although six out of ten students held a transmission view of teaching, with the exception of Student 10, and possibly Student 3, these students could not be clearly classified as having the same view of learning, that is, as having the idea that learning is the reception or 'taking in' of knowledge or information. Instead, most of these students simply stated that learning is the acquisition of knowledge; it is:

S. getting information about more and more things and widening our ... knowledge capacity (Student 3)

S. a progression from one stage to another ... it's going from a stage where you don't know about something or you know (a) little (about something) (and) progressing to knowing more or all about it (Student 5)

S. the acquiring of knowledge, social skills, social attitudes ... um (it's) repetition ... through ... everyday experiences ... (its) just modelling off other people ... yeah modelling/repetition. (It's) just ... picking up ... information (through general experiences) (Student 8)
S. an acquisition of knowledge ... either through sitting down (with) a book and reading it ... or just through experience (Student 9)

S. taking in information and storing it away for later use (Student 10)

Student 4 stated that learning is “an individual taking (an) idea and using it for his own purpose”, but it was unclear exactly what he meant by this. He also expressed the view that learning could be ‘trial-and-error’:

S. (learning) how to ride a bike ... (consists of) making mistakes and stuff, and saying ‘well it doesn’t work if I do that’, ‘(it) doesn’t work if I do (this)’, so I learn through experience that this is the way it works (Student 4)

Of the two students who held a ‘showing/demonstrating’ view of teaching, Student 6 was classified as having a transmission view of learning, while Student 7 held a ‘constructivist-like’ view:

S. (learning is) the process whereby someone um takes in new information or expands the ... brain. Like if someone ... learns or knows more about animals that means he or she has learned more because ... they’ve taken in more information to their mind which hopefully stays there (Student 6)

S. (learning occurs) by observing and listening (to) um things around you and then just making meaning out of what you are seeing and listening and then acting on it. Like you might ... think oh that’s something good to learn or its not good to learn or you just sort of take responsibility for your learning um (and) just learn what you want to learn (Student 7)
To summarise, another finding of the study was that, as well as having specific structures for the ways in which they themselves learned, these beginning teacher trainees also held more generic ideas about teaching and learning.

A question can be raised therefore, as to whether, and to what extent, students' ideas about teaching and learning change during their teacher education course. This question becomes especially crucial if we consider it in the light of findings, from research in science education, that many children complete their secondary schooling without acquiring 'accepted' scientific ideas. It may be that “teacher education courses (are no) more successful than science courses in changing (some students') personally constructed concepts or theories” (Coles, 1984, p. 99).

Clearly, there is a need for more research in this area. Other future research, both applied and basic psychological investigations, which could be undertaken to inform and test the theory above, will be outlined in the next Chapter.
CHAPTER EIGHT

8.1 Introduction

In this Chapter I will suggest future psychological and physiological studies which could be conducted to test the theory above and further inform its development.

A crucial implication of this theory, supported by the results of the foregoing study, is that in measuring learning we cannot assume that if a student can recall contexts which relate an intended idea, then he/she has also acquired the latter.

However, Marton and Ramsden (1988) claim that in many “studies (of the effectiveness of) teaching methods and (of presumably the efficacy of) learning skills” (p. 270) within the literature, researchers consider whether or not ideas have been acquired “in terms of whether the words representing them have been retained” (p. 270). These authors claim that underlying such a methodological assumption is a view of teaching and learning in which the former “is about transmitting ... information and the techniques that will enable it to be remembered efficiently” (p. 270), while the latter is about “gathering (this) information and retaining it” (p. 270). That is, it appears that some members of the educational research community, like many teachers, may be sympathetic toward the transmission view.

We should thus take care when we evaluate the findings of research which (for example) purports to test the effectiveness of specific teaching strategies in promoting students’ ‘understanding’, when that research is in part derived from a methodological assumption that information is in words, or that a text ‘contains’ ideas which can be transmitted, more or less ‘complete’, into a reader’s mind.
8.2 Future psychological research

In the study reported in Chapter Seven, some students adopted a 'low intensity' form of memorisation in which they re-read parts of the text in the hope that when they sighted questions in what they thought was an impending, closed question test, words in the latter would 'trigger' their recall of a correct answer. Obviously, ways of determining whether a young person understands a topic, or is only superficially familiar with relevant terms and limited facts or statements, are vital in education (there are contexts, of course, in which superficial knowledge is sufficient). This is especially the case in science education, in which, in recent times in this country, the 'quality' of teaching and learning is increasingly of major concern.

In the past ten years, research on children's unique ideas in this latter discipline has relied upon measures of knowledge or understanding which have mainly consisted of variations of the interview-about-instances technique (Section 7.2.3) (Bell, Brook, & Driver, 1985; Masters, 1987). A complete review of methods for ascertaining what people know will not be undertaken here (see Driver and Erickson, 1983, Masters, 1987, and Sutton, 1980, for more detailed accounts), but some methods, for example, the word association technique, are severely if not totally disabled by the implication (Section 8.1) above. The variations include:

(i) showing a student drawings of phenomena, events or situations and asking him to explain or describe what each picture is or is not, or what is happening in each drawing,

(ii) requesting a pupil to manipulate an apparatus to obtain a specific effect, and asking her to comment upon and explain her actions, and

(iii) asking a student to manipulate simulated rigid bodies on a computer screen to achieve particular effects, and observing his performance (Masters, 1987).
In general, however, these methods are individualised, time-consuming and researcher- (and potentially teacher-) intensive. But this is not to say that they are of little or no value in a classroom. In fact, methods (i) to (iii) above, could be creatively incorporated in two general practices or teaching strategies derived in the next Chapter (b and c, Section 9.2.1), specifically, in a method called a classroom profile (Shapiro, 1988), and used as both a way of helping children to construct knowledge and assessing the kind and extent of the latter.

Nevertheless, one aim of future psychological research must be to determine and evaluate ways of measuring students' degrees of construction/memorisation and their resulting 'levels of understanding’ (Masters, 1987), which can then be used in research and in particular, in a classroom toward the end of a unit or sequence of lessons, in ways that are both quantitative and time-saving.

One way of measuring a student’s level of understanding might be simply to ask him (with accompanying, appropriate instructions and an example) to describe the ways in which two things are both similar and different; for example, ‘how is an animal similar to/different from a plant?’ A pupil could then be asked also to explain what he means by the words which he used to describe similarities and differences.

As well, students could be given a test consisting of multiple-choice/verbatim or fill-in/verbatim items (Foos & Fisher, 1988) (i.e., questions composed of phrases or sentences from a text). For students who had mainly adopted a process of memorisation during a learning task/unit, the wording of these questions should stimulate accurate recall.

By attributing a maximum possible score to a post test on ‘similarity/difference/meaning’ and dividing this by the maximum score obtainable on a fill-in verbatim item test, an arbitrary factor could be derived which could be compared to the same factor calculated
for each student. Clearly, the smaller a student’s factor compared to this arbitrary maximum, the lesser is her (total) degree of construction. The administration of such tests could conceivably be undertaken using a personal computer, and the results conveniently recorded. Such a method might thus satisfy the requirements of quantification and ease-of-use.

We also need to conduct more research on students’ (i) structures or ideas and feelings generated relative to different instructions given prior to a learning task, and (ii) ‘attitudes’ generated during these tasks, that is, pupils’ feelings and ideas about ‘cognitive conflict’ itself (Dreyfus, et al. 1990).

Importantly, do low achieving students have the same feelings about ‘cognitive conflict’ generated in interaction with ‘non-academic’ stimulus situations outside of a classroom? It might be that some low achieving students assume (like some teachers) that teacher talk, or a text, contains meaning. For example, Gunstone (1988) claims that many pupils believe that “(teacher) notes are meaningful” (p. 81), and that understanding “can be (‘given to’) them by (a) teacher” (p. 80). Thus such students might become anxious when reduction occurs and they cannot comprehend something, because they immediately conclude that they are failing to ‘learn’, or take in or absorb what they are required to.

8.3 Future physiological research

Notwithstanding clinical interviews, or the systematic production of extended contexts, in order to test more directly the theory, we would have somehow to measure a person’s spatio-temporal patterns of nerve impulses. The most likely candidate for such a measure is the event-related potential. Obviously, this measure must be favoured over the use of the vastly more accurate real-time, video-rate imaging of voltage-sensitive dyes in vivo in vertebrates (see Kauer, 1988, 1991, and Blasdel and Salama, 1986 for reviews).
When small, flat electrodes are placed at various standardised points on a healthy person’s scalp, a spontaneous, rhythmic oscillation in voltage, or potential (difference), can be measured (in microvolts, or millionths of a volt). This oscillation, or ‘brain wave’, though it changes in frequency depending upon whether a person is either awake or asleep, excited or relaxed, is always present and is called the electroencephalogram (EEG) (Andreassi, 1989; Martin, 1985; Naatanen, 1987; Noback & Demarest, 1981; Ottoson, 1983; Rosenzweig & Leiman, 1989). A very small change in the EEG which occurs following a presentation of a stimulus, for example, a flash of light or a click, is called an event-related potential (ERP) (Andreassi, 1989; Naatanen, 1987; Rosenzweig & Leiman, 1989).

Normally, it is difficult to identify a single ERP in a person’s EEG recording. Thus in a typical experiment, several EEG recordings are made over a specific period of time (e.g., 500 or 1000 ms) immediately following presentations of the same stimulus. Using a digital computer, the various potentials in each recording are then averaged over time; the random potentials of the EEG sum toward zero, while single ERPs summate to yield an averaged ERP (Andreassi, 1989; Loveless, 1983; Martin, 1985).

Like the EEG itself, averaged ERPs consist of ‘peaks and troughs’ (Brandeis & Lehmann, 1986; Naatanen, 1987) or positive and negative waves, which are called components (Andreassi, 1989; Brandeis & Lehmann, 1986; Hillyard, 1987; Naatanen, 1987). Different components “range in latency from short (up to 10 ms) through medium (10-100 ms) to relatively long (over 100 ms)” (Rosenzweig & Leiman, 1989, p. 171) (latency is time elapsed from stimulus presentation).

Within the literature, evidence indicates that various components are produced by activity in populations of neurons in different areas of the brain. For example, in a human auditory averaged ERP, which is commonly recorded following a brief click or tone, it appears that the first components (0-8 ms) are produced in the brain stem; one of these, a
positive wave (at 2 ms) is "related to activity in the auditory nerve" (Andreassi, 1989, p. 85). Later components seem to be produced "in the trapezoid body and (fibres) ascending toward the superior olive ... a structure called the pons ... (in an area) near the inferior colliculus" (p. 85) and in thalamocortical fibres (Andreassi, 1989) (the trapezoid body, superior olive and inferior colliculus are parts of our ascending auditory pathway).

Andreassi states that auditory ERP components of the largest amplitude "are a negative peak occurring at 80-90 ms, and a positive one at around 170 ms. This negative-positive sequence is referred to as the 'N1-P2' complex, and it appears to be generated (in) the auditory cortex (of) the temporal lobe" (p. 85).

In a human somatosensory ERP, a negative component (at 55 ms) "appears to be generated in the postcentral gyrus" (p. 85), while a peak at "around 200 ms has been localised to (the) primary somatosensory cortex through electrical and magnetic field recordings" (p. 85).

Visual ERP components of the largest magnitude seem to be generated in the primary visual cortex (Andreassi, 1989). For instance, in a recent study, Farah, Peronnet, Gonon and Giard (1988) found that if a participant was first told to imagine a letter H or T, then systematic variations in the amplitude of his/her ERP components following presentation on a screen of a H or T, half a second later, occurred around 170 ms and 260 ms, and were "localised at the occipital and posterior temporal regions of the scalp, that is, directly over (the) visual cortex" (p. 248). For these authors, this finding provides support for the claim that (i) visual images and percepts "share some common representational locus of processing" (p. 253) and (ii) the former are themselves 'visual representations'. It is also consistent with postulates one and two of the theory above.
In sum, physiological research indicates that the majority of later components of auditory, visual and somatosensory sensory averaged ERPs are generated in sensory areas of the cortex (Andreassi, 1989; Loveless, 1983).

If it is assumed that the pattern of later components, or waveform, of an averaged ERP corresponds to the form or shape, or ‘waveform’, of a structure, then hypotheses can be derived from the theory above which could be directly tested in a laboratory using ERP recording techniques. However, this methodological assumption must always be qualified by the fact that an averaged ERP is a statistical measure of a pattern of neural activity (Loveless, 1983).

For example, from the first and eighth postulates it follows that following the presentation of different words, different ERPs for each word should be recorded (presumably over Wernicke’s area. See Figure 4-1).

Though ERPs for words, recorded over several seconds, have been made in a number of studies (Van Pattem & Kutas, 1987), it appears that no research specifically designed to test such a hypothesis has been undertaken. However, in a study of the connotative meaning of words, Chapman, McCrary, Chapman and Martin (1980) found that the ERP for a term reliably varied from another depending upon which of six orthogonal scales of Osgood’s ‘semantic differential’ a word belonged to.

From the third and fourth postulates it follows that during reading (for example) relatively late components of an ERP for a word should vary depending upon whether a person’s structure for this term integrates with a structure generated by previous word(s), or the former and the latter structures undergo reduction. Support for this hypothesis comes from research which shows that a negative peak, at around 400 ms (called the N400), is produced in an ERP for a ‘semantically incongruous’ word at the end of a sentence (Andreassi, 1989; Van Pettern & Kutas, 1987), while a “semantically appropriate (term)
typically produce(s) a broad positive shift" (Van Petten & Kutas, 1987, p. 191). That is, presumably, semantically incongruous words lead to reduction and to the transformation of intermittent sequences of impulses propagated to the hippocampus into short, continuous sequences, or momentary 'bursts' of impulses (postulate four).

The amplitude of an N400 component is larger for a highly incongruous word than for a moderately novel one (Andreassi, 1989). An example of 'moderately novel' is "he took a sip from a waterfall" (p. 115), and 'highly incongruous' "he took a sip from the transmitter" (p. 115). An N400 "is not specific to the (sensory) modality of presentation, and appears following incongruous words in speech and American sign language" (Van Petten & Kutas, 1987, p. 191). As well, it is not 'sensitive' "to experimental manipulations which do not involve linguistic variables" (p. 191).

However, if the N400 does correspond to a measure of the neural activity which occurs following reduction, it is not clear, from the theory above, as to why it should be negative. As well, it should also occur during perceptual learning, or the presentation of 'perceptually incongruous' stimuli.

Logically, a person's ERP for a word which generates an ideational structure should be different from his/her ERP for the same term following his/her construction of a new idea or meaning for this word. For example, it can be hypothesised that, in the study reported in Chapter Seven, the ERPs of students 1 and 10 for 'animal' prior to their reading of the text would have been different from their ERPs for 'animal' following their reading. For those students who memorised words from the text, their pre- and post-ERP's should have been the same.

But compared to the total number of ERP studies reported in the literature, only a few have focused upon human learning. In all of these studies, either a classical or operant conditioning paradigm, that is, a behaviourist methodology, has been adopted (see
Andreassi for a review of research prior to 1989). To date, no ERP studies which investigate what might loosely be termed 'cognitive learning' have been carried out.

To summarise, if we adopt the methodological assumption that averaged ERP recordings represent a measure of a structure's waveform, then research utilising the latter, together with a clinical interview technique, has the potential both to test the theory above and to inform its development. In addition, the refinement of other statistical techniques which improve the 'signal-to-noise' ratio of ERP recordings, such as Wiener filtering and discriminant analysis (Loveless, 1983), "would greatly enhance the scope" (p. 93) of such research.

Another (though much less 'portable' and extremely expensive) technology, use of which has the potential to test more directly the theory above, is positron emission tomography (PET) (Heiss, Herholtz, Pawlik, Wagner & Wienhard, 1986; Martin & Brust, 1985; Parks, Loewenstein & Chang, 1988). Only a brief explanation of PET will be undertaken here. See Parks, et al. (1988) for a thorough explication.

PET can yield a "regional and three-dimensional quantification of glucose metabolism in the human brain" (Heiss, et al. 1986, p. 141). Since the rate of glucose metabolism is directly related to levels of activity in nervous tissue, changes and patterns in activity can be measured and visualised with this technique (Heiss, et al. 1986; Martin & Brust, 1985). Ordinarily, several 'slices', or transverse scans, of the brain from top (dorsal) to bottom (ventral) are made. These slices are colour-coded, with red representing the highest metabolic rate, and violet the lowest (Martin & Brust, 1985).

Research shows that when a healthy person at rest is presented with white-light illumination, activity increases in the primary visual cortex. When a person views a complex scene (in the study concerned, looks at a park through a window), activity in the
visual cortex "increases further, and the visual association cortex becomes active as well" (p. 268).

In one study, participants listened to a Sherlock Holmes detective story, and were instructed to remember specific phrases. Neural activity was observed to increase (compared to control participants who heard no story) in the primary, secondary and association auditory cortex, the hippocampus (Martin & Brust, 1985), and in the left frontal cortex and the left thalamus (Parks, et al. 1988).

It follows that during construction, an increase in activity should be observed in the hippocampus, brain stem and thalamus, as well as in the cortical area which corresponds to the type of knowledge being constructed. Like the previous study, an investigation could be designed in which participants are asked to read a text, and are informed that they will or will not be assessed on what they learn from reading the text. When combined with follow-up clinical interviews, PET scans would be expected to reveal particular areas of the brain which become active depending upon whether participants construct or memorise.

It is important to note that in the 'Sherlock Holmes' study above, activity increased in the frontal cortex. It was mentioned previously that, in cats, activity in the frontal cortex can 'inhibit', or modulate, via the thalamic reticular nucleus, the 'enhanced' regeneration of impulses in specific thalamic nuclei (Section 5.3) (i.e., presumably, the generation of a high frequency train of impulses during construction, as highlighted in postulate seven).

From evidence obtained in extensive research on the effects of frontal lobe lesions in humans, Luria (1970, 1973) concludes that the frontal cortex "is involved in the formation of intentions and programs for behaviour" (Luria, 1970, p. 68), and serves primarily to regulate "the state of activity (of the brain)" (Luria, 1973, p. 197) or "attention and concentration" (Luria, 1970, p. 68).
Thus it might be that structures generated in a person’s frontal cortex during learning are his *intentions* to learn in a specific way. It is not unreasonable to suggest that this hypothesis could be tested in an ERP study modelled upon the research reported in the previous Chapter. In such a study, students who anticipate they will be assessed should present with different ERPs measured over the frontal cortex than those who think they will not be assessed.

### 8.4 Summary

Writing in 1967, Ausubel deplores the “retreat of educational psychologists from the classroom” (p. 2) and criticises them for applying the findings of basic research, undertaken by experimental psychologists, to learning in schools (Ausubel, 1967).

Today, we can say that educational psychologists have since begun an advance to the classroom and the number of applied research studies are increasing. Perhaps some of the best examples of this applied research tradition are the Children’s Learning in Science Project (see Children’s Learning in Science Project, 1987a, b, c; Needham & Hill, 1987), the Project to Enhance Effective Learning (PEEL) (see Baird & Mitchell, 1986; White, 1988; West, 1988), research on students’ approaches to learning tasks in higher education (for a review see Ramsden, 1985), and continuing research being conducted at James Cook University on what teachers think about as they are teaching (Mitchell & Marland, 1989).

However, given the theory proposed above, it does not follow that the findings of, for example, experimental psychologists’ ERP laboratory studies, will be irrelevant to ‘classroom’ learning. Such basic research could proceed in concert with applied research in schools and tertiary institutions, with both guiding the development of theory.
As well, further studies of synaptogenesis and basic research, utilising computers, on 'neural net design', in cooperation with PET and post-mortem laboratory investigations of human cortical anatomy and cytoarchitecture, would also guide the development of a neurophysiological theory of construction/memorisation. Such a developing theory could be simultaneously tested in educational institutions in further applied research on students' approaches to learning tasks and their construction of knowledge.

Many more applied investigations of the theories and ideas of teaching and learning held by both experienced and trainee teachers in all types of educational institutions, and how these beliefs influence their practice are also needed (Hewson & Hewson, 1988; Tobin & Gallagher, 1987). For example, Tobin and Gallagher (1987) state that further research is needed on how teachers' "pedagogical knowledge and beliefs about teaching and learning influence the implemented curriculum (i.e., the curriculum as taught by teachers)" (p. 559), while for Hewson and Hewson (1988) "there is not the same volume of literature on science teacher thinking that there is on students' conceptions of natural phenomena or on instructional strategies in science (education)" (p. 608), and "more research in this area is needed" (p. 608).

Much more research on how teachers subject knowledge of topics influence their lesson planning and practices, or 'classroom interactions', is also required (Baird, 1988).

Fundamentally, we also need to evaluate the effectiveness of teaching practices or strategies which can be derived from the theory above, and contrast these evaluations, if need be, with evaluations of existing pedagogical methods (e.g., the way in which teachers use textbooks, the way they implement and monitor activities, and the various ways they have of asking questions).

In the next and final Chapter, I will derive from the theory above implications for teaching, and infer several general pedagogical strategies.
CHAPTER NINE

9.1 Introduction

In Chapters Four, Five and Six I proposed a theory of learning which is based on the assumptions that knowledge is constructed in interaction with a world (constructivism), and is a continuous spatio-temporal pattern of nerve impulses (cf. Iran-Nejad & Ortony, 1984). New patterns of impulses are constructed through a change in nervous activity in the brain and the growth of new synapses. That is, our nervous system has a self-regulatory capacity to alter in interaction with a world, or as a result of 'experience' (Morris, Kandel & Squire, 1988; Squire, 1987).

In Chapter Six, the theory was contrasted with the transmission view. Many educationalists who adopt the latter view of teaching practice a kind of doublethink, in which they believe that learning is a process of change in students' ideas, but teaching is the transmission of knowledge or information (Marton & Ramsden, 1988) (in words, or diagrams, etc.). A logical implication of the transmission view of teaching is that pupils' own ideas are irrelevant, and thus teachers who adopt the former approach are often confused or uneasy "about how transferring quantities of information (to students) can result in conceptual change" (p. 276). It is perhaps the case that this paradox is glossed over in many classrooms, not least through the sheer 'busyness' of classroom activities and press of disciplinary requirements.

According to the theory above, knowledge "is not a transferable commodity" (von Glasersfeld, 1983, p. 66); it is not an aggregate of transmittable 'quanta' of which a child is a passive recipient (Biggs, in press). Knowledge is always and only within. In the next section, I will discuss several implications for teaching which follow from the theory proposed in previous Chapters and research reported in Chapter Seven above.
9.2 Implications for teaching

The most general implication for teaching which follows from the theory and research reported above is that a teacher must first ascertain the structures or ideas which a child generates relative to words used in instruction, in order to help him construct new knowledge which it is intended he should know.¹ For example, following the study in Chapter Seven, if a teacher had wanted to help student 4 to construct intended knowledge about photosynthesis, then he/she would have had first to find out more about student 4’s structures for sun, light and energy, and help him form new acceptable ideas for these terms.

Consistent with this implication, several authors have claimed that the more a teacher knows about children’s own ideas, the better he or she will be able to help students to ‘change’ or ‘modify’ their ‘cognitive structures’ (Osborne & Gilbert, 1980a), or ‘conceptions’ (Ramsden, 1988; Watts, 1983), that is, to construct new ideas.

However, this implication raises two fundamental problems. The first of these, of course, is ‘how can a teacher ascertain the meanings which pupils give to words?’ Clearly, a teacher cannot adopt to the same extent the clinical interview method employed in the previous study.

Essentially the same question has been raised by Tamir (1984) (in relation to Ausubel’s principle, see footnote 1.), who asks “how can teachers find (out) what their students already know?” (p. 163). Stead and Osborne (1980) also ask “how (does a teacher) gain some knowledge and understanding of concepts which students already possess about particular phenomena?” (p. 85).

¹ A similar claim was first made by Ausubel (1968) twenty years ago, when he wrote, “the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (p. vi).
Several authors have claimed that teachers simply do not have the time to ascertain what their students know (Freyberg & Osborne, 1981; Osborne & Gilbert, 1979; Osborne, Bell & Gilbert, 1983; Stenhouse, 1986). For example, Osborne, et al. (1983) state that "unfortunately, there is, as yet, no simple way for classroom teachers to establish children’s views with respect to topics which have not been investigated by researchers. Most current research methods are time consuming, for example, clinical interviews, and teachers do not have the time to adopt them" (p. 6).

However, as will be seen below, there is at least one practicable way for a teacher to ascertain children’s ideas. In any case, it may be that if ‘time’ itself was reorganised in schools, then teachers would have more opportunity to adopt various strategies.

In secondary education, Wignell (1987) claims, “there is something about dividing a day up into forty minute units that makes it difficult to get a whole lot done in a single period between the time the stragglers roll in and everyone gets their books out and the time everyone gets edgy near the end and wants to pack up there’s not much time left in the middle ... it seems ... to be an organisation of time that’s designed to get as little as possible done” (p. 19). Perhaps an indirect implication of the constructivist theory is that the organisation of time in schools should be more flexible and dynamic. The creation of situations which result in construction of knowledge by students might lead them to want to arrive at class early, and stay behind late. However, current organisational practices encourage expediency. Students often cope by learning through an efficient (relative to existing classroom situations), though emotionally barren, process of memorisation.

The second problem raised by the general implication above is, plainly, ‘how does a teacher help children to construct new knowledge which it is intended they should know?’. That is, as well as knowing about children’s own knowledge, a teacher must have knowledge of practical strategies which he or she can use to help students construct new knowledge.
I will examine several general strategies, in the context of the theory, some of which are already established in educational practice and some that have been recently proposed in the literature, in the following section. It should be emphasised that these strategies are general only, and no attempt will be made to discuss in detail what teachers can actually do from minute to minute, or for that matter, from lesson to lesson. Such explicit analysis and clarification of pedagogical practice, it is argued, should be made with respect to particular domains of subject knowledge, and is beyond the scope of the present discussion.

9.2.1 General teaching strategies

Strategy (a)

It follows that if people generate meaning relative to words, then a strategy that a teacher could use would be, of course, to tell pupils that the same words can have different meanings. For example, Osborne, Bell and Gilbert (1983) state that teachers should “emphasise continually to children that words have multiple meanings” (p. 7).

Strategy (b)

A teacher could ask all children to describe, or explain, in writing, what they think a specific thing is, or how they think a specific thing occurs. For example, Driver and Bell (1986) state that a teacher should “(encourage) students to make their own ideas explicit” (p. 454), while Marton and Ramsden (1988) argue “for making students aware of the different conceptions they hold” (p. 277) (though a teacher cannot ‘make’ students aware, rather, he or she can only encourage students to become aware).
In a teaching sequence designed to help children construct new ideas, the use of a general strategy like (b) is called an *elicitation phase* (Driver, 1988; Driver and Oldham, 1986) or ‘explication’ (Watts & Gilbert, 1983). In the former, “pupils make their ideas explicit” (p. 118) through “a variety of activities such as group discussion (see below), designing posters, or writing” (Driver & Oldham, 1986, p. 118), while for Watts and Gilbert students make their ideas explicit either verbally, in writing or graphically “or in combinations of these” (p. 167).

A specific example of strategy (b), which is different from current research methods used to investigate children’s ideas, has been devised by Shapiro (1988). In this method, called a *classroom profile*, “each child is asked to provide an explanation (presumably written) telling (for example) why (a) pencil in a beaker of water (looks) as if it (is) broken” (p. 117). Children's explanations are then categorised by a teacher (or a researcher) and each category listed on a ‘class profile’ chart along with the name of each child who gave the corresponding explanation.

Shapiro reports that a classroom profile “makes it very clear to the class that the most popular response is not always the response which most closely resembles (a) scientist’s (or, presumably, a teacher’s) (view)” (p. 117). As well, a profile “helps (a) teacher understand how individual children are thinking about the ideas presented to them and shows how groups of them are thinking along similar lines” (p. 117).

It is conceivable that many of the pictorial situations and events used in research employing the interview-about-instances technique (Section 8.2), could be incorporated in the development of (a) classroom profile(s). This need not only be achieved through teacher talk or writing, and by children using pencils and paper, but could also be

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2 Shapiro (1988) also reports that on one classroom profile ‘three (children) made descriptive statements when they had actually been asked to provide an explanation. (In a case like this) the distinction between an explanation and a description could thus be made a matter to clarify with (a) class’ (p. 118).
implemented by designing a computer program (or adapting existing software), which, with networking, could provide a means of disseminating to the whole class and a teacher (in the same way that scientific journals do) each child's ideas or explanations.

**Strategy (c)**

Following a strategy like (b) a teacher could discuss with all students the ideas which they hold about a phenomenon, or the meanings different pupils have for specific words, before explaining a formal, intended idea. For example, Shapiro reports that a classroom profile can be 'shared', that is, presumably discussed and considered by both a teacher and children. She states that this allows students to "(i) reflect on their own ideas about the nature of phenomena, (ii) become aware of how fellow classmates are thinking about the same phenomena, (iii) to compare (and perhaps reconsider) their own ideas about phenomena with those of their classmates, and (iv) eventually to consider the plausibility of (an) explanation put forward by (a teacher, or textbook, etc.)" (p. 118).

For Driver and Oldham (1986) the use of a strategy like this is called a *restructuring phase*, in which 'clarification' and 'exchange' of children's ideas (i.e., attempts by students to generate meaning from others' contexts) occurs through classroom discussion. This 'exchange' of ideas "may lead to spontaneous disagreement among pupils and the challenging of particular perspectives" (p. 118) and gives students an opportunity to "develop an appreciation that there can be a range of different notions to (describe or explain) the same phenomenon" (p. 118).

But during the 'sharing' of a classroom profile, or an 'exchange' of ideas, some children might feel anxious, or threatened (Driver, 1988) (these feelings could be obviated somewhat through the use of computers). A teacher must thus be aware of and sensitive to pupils' feelings in these situations.
For Driver (1988), during this phase, a teacher must avoid closed questions and accept "a range of suggestions from children without requiring premature resolution of a point" (Driver, 1988, p. 142). At this stage, he or she must be "non judgemental and non evaluative" (Wheatley, 1991, p. 18). As well, a teacher's talk and behaviour must be "free of ridicule, supportive and empathetic of individuals' ... emotions" (Watts & Bentley, 1987, p. 123).

In this way, students will learn that their ideas can be valued (Shapiro, 1988) and that their desire to make sense and construct new meaning can be respected by a significant other. Perhaps most importantly, they will develop an expectation, or predisposition, to 'think for themselves', that is, they will develop intellectual autonomy (Wheatley, 1991).

**Strategy (d)**

If children hold different ideas about a specific thing, then stimulus situations which result in reduction will differ for each student. Thus in explaining a new idea, or the meaning of a new word, a teacher should introduce many different examples and non examples of the idea, in order to provide a variety of stimulus situations, which might result in reduction, at different points in time during a lesson, for all students.

This strategy is consistent with research on concept learning which has shown that 'concept acquisition' is 'facilitated' by the use of a teaching method which consists "of explanations of matched examples and non examples (of a concept)" (Dunn, 1983, p. 647).

**Strategy (e)**

A teacher could organise students to freely talk to each other in small groups about new ideas and meanings for words which they might have formed. For example, Driver and
Bell (1986) claim that a teacher should "(give) students opportunities to explore (ideas) in informal and unthreatened ways, particularly through small-group discussion" (p. 454).

These small-group discussions might result in reduction and the construction of new knowledge for those pupils for whom reduction did not occur during an explanation by the teacher (though, of course, the knowledge they construct might not be that intended).

In this way, perhaps all, or at least most, pupils will interact with a stimulus situation at some time during a lesson which results in intermittent reduction and the construction of intended knowledge. (It also means that a classroom will become, on various occasions, a very noisy place; something which appeals neither to some teachers, nor, usually, to most administrators.)

*Strategy (f)*

Most children will need to participate in classroom and small-group discussion, as well as one-to-one conversations with a teacher over several days or even weeks, before they construct *all* intended knowledge. For example, Driver and Bell (1986) claim that "students do not necessarily construct a 'complete' understanding of a (topic) when they are first introduced to it" (p. 454).

By *progressively* 'taking account' of children's evolving ideas (e.g., through classroom profiles, and the use of open questions in tests) a teacher could continue to provide stimulus situations which will promote students' construction of new knowledge (Driver & Bell, 1986). This general strategy will be further examined below in discussion on 'curriculum' and assessment.
9.2.2 Implications for teachers’ subject knowledge

Logically, to use the general strategies above, a teacher must hold ‘accepted’ knowledge of a topic, and be able to differentiate between the latter and children’s own unique ideas.

However, in primary science education (for example), primary teachers’ ideas of scientific topics are often similar to children’s own ideas (called children’s science) (Osborne, et al. 1983; Tasker, 1989). Presumably, this is because primary teachers do not acquire ‘basic’ scientific ideas during their secondary education, and study “very little or nothing of (the) natural sciences” (Osborne, et al. 1983, p. 11) in their teacher education courses. Osborne, et al. state that what is taught by primary teachers is frequently an admixture of their own unique ideas “and textbook quotations of scientists’ science, or curricular science” (p. 11).

Secondary science teachers, on the other hand, “usually appreciate that they have deficiencies in certain areas of their knowledge, and (that) they have access to school colleagues who can help them with specific deficiencies” (p. 11). But these teachers “are largely unaware of children’s science and are frequently not sensitive to the viewpoints children bring with them to science lessons” (p. 11).

As well, if a teacher has accepted structures or ideas which are varied and flow together with many other ideas related to a topic, then the probability that he or she will be able to offer an explanation which minimises continuous reduction for children will be increased. The likelihood that he or she will be able to give many examples and non-examples of an idea, for example, ‘animal’, will also be heightened.

This implication is supported by the claim by Biggs (1989) that ‘deep learning’ (i.e., the construction of knowledge) is promoted by teachers who have a “well-structured knowledge base” (p. 17). For Biggs (1989), “content that is taught piecemeal, isolated
from other related content, does not lead easily to deep learning” (p. 18). It is also supported by the finding from a study of ‘exemplary’ secondary science teaching (Tobin & Fraser, 1988), “that exemplary teachers had strong knowledge of the subject matter they were to teach and techniques for teaching it” (p. 28).³

Yet despite this finding, Kruger and Summers (1988) report that for some instructors of student primary teachers, the level of ‘conceptual understanding’ which the latter have for a topic “is of little importance” (p. 264), and “it is only necessary (for primary teachers) to keep a step ahead of the children” (p. 264).

To summarise, if teachers in science education are to use the general strategies above, trainee primary teachers should be encouraged to construct ‘accepted’ scientific ideas, while both trainee primary and secondary (science) teachers should be taught what is currently known about ‘children’s science’, and should be encouraged “to clarify where their own views lie in respect to (the latter and the ‘accepted’ view)” (Osborne, et al. 1983, p. 11). In line with this implication, a major recommendation of a report on teacher education in mathematics and science, prepared by the Commonwealth Department of Employment, Education and Training (cited in National Board of Employment, Education and Training, Commissioned Report No. 6, 1990), is that there should be “an increase in the amount of time given to mathematics and science in pre-service courses and more specific attention to the pre-service students’ own understanding of mathematics and science” (p. 49). Likewise, in the latter report, it is “strongly recommended that the time available in pre-service courses be used to improve (students’) own knowledge base in the subject matter to be taught” (p. 49).

In the next sections, I will examine implications which follow from the theory and research reported in Chapter Seven for ‘curriculum’ and assessment.

³ An ‘exemplary’ teacher was one who had been nominated more frequently than others as being ‘above average’ by ‘key’ educators, including other teachers, State Education Department personnel and University staff.
9.2.3 Implications for curriculum

A traditional definition of 'curriculum' is "that which is taught or transmitted to someone else" (Driver & Oldham, 1986, p. 111). By contrast, it follows from the theory above that 'curriculum' refers to, at least, three different things. These are (i) the knowledge of a topic held by authors of textbooks and teacher resource documents, (ii) the meanings evoked by a teacher when he or she reads the latter, as well as his or her own unique knowledge of a topic, and (iii) the stimulus situations which include exposition, resources and activities (Driver, 1988) that a teacher provides for children.

Ultimately, it is in interaction with the latter that students can construct new spatio-temporal patterns of impulses or knowledge. As I have shown, depending upon a child's structures or ideas, stimulus situations which result in intermittent reduction will differ for each student. Recall that student 1 constructed intended knowledge about animal, while student 6, because he generated many alternative structures or ideas, was unable to construct all intended knowledge. If a teacher's goal is to help children to learn, then he/she must continually review and revise a 'curriculum' relative to what he/she knows about pupils' own ideas (Brooks, 1987; Driver, 1988).

That is, according to the theory above, a curriculum is not a fixed body of knowledge which 'exists' separate from a teacher and students only to be 'negotiated' between adults (Driver & Oldham, 1986), but rather, it is both fluid and discontinuous, and is always "something with a problematic status" (p. 112), which must be 'negotiated' by and between an adult or adults and interested, active young people. Thus for Driver and Oldham, "in the last analysis the suitability and effectiveness of selected ... activities is an empirical problem" (p. 112). That is, teachers must progressively research students' progress in acquiring knowledge, in order to introduce talk, writing and activities which will promote their ideational (and perhaps, as a result, emotional) development.
However, it follows that the formulation and introduction of activities is characterised by an inherent indeterminateness. Teachers, at best, can only make probable predictions about the knowledge which pupils might construct. For Driver and Oldham (1986) "we can specify those experiences which students should be exposed to and we can suggest what ideas they may construct from these experiences but we cannot be tightly prescriptive about the ideas they will acquire" (p. 112). Even in the current study, an example will be recalled from Chapter Seven, about student 4's new and unforeseen idea about photosynthesis. Similarly, Dreyfus, et al. (1990) conclude from their research on students' processes of 'conceptual change', that 'the direction' and 'scope' of pupils' construction of knowledge "cannot be entirely predicted or controlled" (p. 559).

As well, an obvious implication of the theory above is that children are ultimately responsible for the way in which they learn, and just as we cannot be 'tightly prescriptive' about the meanings students might make, nor can we accurately predict the specific approach which they might ultimately adopt toward a task or an activity.

Even if students know that the only purpose of an ungraded test is to find out what they know and understand, their current mood when they arrive from home, the 'pressure' or anxiety generated by the imminence of a standardised exam, and other incidental factors like availability of texts, can all determine how they will approach a learning task.

Thus precise, predictive theories of teaching and learning are logically untenable (Marton & Ramsden, 1988; Ramsden, 1988), and cannot, by definition, be 'useful' (West, 1987).

In summary, if children are given the opportunity to construct knowledge, it is likely that the latter will develop gradually over a period, and may 'move', at various times, in some unintended directions. Thus a teacher must likewise engage in a progressive process of
curricula research and review, in order to diagnose the formation of alternative ideas which may later hinder students' ideational development. It follows that the ways in which we might assess students' progress in learning about a world are of prime importance.

A general claim made by several authors is that the way in which tests and exams are currently used by teachers in schools and tertiary institutions encourages students to memorise or adopt surface approaches to learning tasks (Bowden, Masters & Ramsden, 1987; Entwistle, 1984; Osborne & Wittrock, 1983; Ramsden, 1987a, b, 1988). It can be hypothesised that this is because a view commonly held by teachers and administrators of the *purpose* of assessment is, in part, based upon the transmission view, in which knowledge or information is transmitted to students in words. Teachers use tests and exams, usually at regular intervals, to *verify* that their students have in fact absorbed or retained, that is, held in their minds, the correct information. For example, Ramsden (1988) claims that “many items on standard achievement tests assess students' (ability) to recall and apply facts and routines presented during instruction ... other examination items, although supposed to assess higher-level learning outcomes such as 'comprehension' and 'application', often require little more than (an) ability to recall formulae and to make appropriate substitutions to arrive at a correct answer” (p. 25).

Not surprisingly, students soon acquire a belief, or perception, that teachers (and presumably researchers) administer tests in order to obtain accurate, or the 'right', answers, and as a result adopt memorisation as the most effective way to learn. Thus the latter is not a fixed 'characteristic' (Ramsden, 1988) or an inherent 'style', but rather is simply an adaptation to a prevailing situation.

For Ramsden (1988) “most students try to deliver what they predict their teachers will reward” (p. 21), but it is more than unfortunate that for many children this means 'delivering', or being able to recall accurately, facts or definitions and specific routines or
formulae. For example, in a study of classroom learning, Shapiro (1988) reports that one student, "Amy, who was regarded by her teacher as the top student in the class ... was guided by a strong orientation to achievement, not for the purpose of understanding, but for the sake of achievement itself ... The important thing for Amy was to figure out what was to be done in the task assigned, and to complete the worksheet with the correct answers. Though she had the correct answers on all of their worksheets at the end of the unit, Amy never grasped the idea of reflection of ‘non-visible’ light rays, nor did she understand refraction, colour vision, or how a prism and light created a rainbow" (p. 113-114). That a young person like Amy is subtly coerced into coping with educative situations such as this, is disturbing if not objectionable. (To be sure, no ‘blame’ is being attributed here; just as we cannot blame Tycho Brahe for perceiving the sun rising in its revolution about the earth, we cannot reproach a teacher or principal about educational practice, unless of course, he/she is fully aware that what they do is malpractice.)

Logically, if the way teaching and assessment takes place in schools is changed, then students' perceptions of the latter and their ideas about learning will also, over time, begin to alter.

9.2.4 Implications for Assessment

An implication for assessment, following from the theory and from research reported in Chapter Seven, is that tests must be viewed by a teacher as a method of finding out what knowledge a child has constructed; what he/she thinks, rather than as a way of measuring how much ‘accepted’ knowledge a student has ‘taken in’ and retained. In assessing students’ ideational development, teachers could construct tests with open questions which “ask for explanations of phenomena” (Bell, Brook & Driver, 1985, p. 209), rather than questions which ask for specific facts or require pupils to make a selection (see Bell, Brook and Driver for some examples of the former). The following extracts from
transcripts of interview in the study reported in Chapter Seven suggests that pupils can find this type of assessment to be non-threatening:

S. I noticed that the first lot of questions that you had I didn’t find hard because they all said what do you think and I mean you can’t get that wrong if its what you think (whereas other students) ... tend( ed) to get a bit anxious didn’t they and some of them didn’t come back (student 10)

Whereas typical assessment methods tend to evoke anxiety. For example:

S. ... you know as soon as somebody says to you that this is a test that’s going to get marked against your name you automatically freeze up and you want to take everything in but when you get told that this is a survey to see how much you learned from it now whether you get it right or wrong its what you've learned it what's you've consumed at that moment its not something you've forced yourself into learning ...

(student 5)

That is, some students might have perceived the first survey of meanings as a traditional (and threatening) type of assessment, which was intended to measure the ‘accuracy’ of their knowledge.

A teacher need not grade tests, but instead could provide relevant and supportive comments, and could utilise students’ responses to determine the types of educative situations that he/she will introduce during lessons. It is evident from the study by Barnes and Shemilt (1974) (Section 6.5), that many teachers, to a certain extent, already do this. Teachers whose views were classified as ‘interpretation’ characteristically “write replies as well as comments” (p. 220) on students’ written work, and allow this work “to influence the direction of lessons” (p. 220).
However, teachers need time, of course, to accomplish the latter. All too often, because (in part) of the size of their classes and the range of curriculum 'content' they are required to 'cover' (i.e., transmit), teachers are forced to mark for 'accuracy of wording' (Biggs & Telfer, 1987), and would not be free to spend time or to be able to expend considerable effort carefully evaluating each pupil's potentially open response. Again, 'time' seems to be a problematic factor in the way we educate. (As hypothesised above, some teachers also mark for accuracy of wording because they hold the transmission view, while other teachers are unsure "of their subject matter", p. 51, and thus are unable to responsibility evaluate students' work.)

9.3 Summary of implications

We must always try to understand the ideas or meaning which young persons bring to, and actively make from, educative situations which we can provide for them.

In a classroom, if a teacher adopts a view of a child as a learner who attempts to make meaning, then this child "becomes a co-architect in the teaching and learning process" (Shapiro, 1988, p. 115). That is, children are ultimately responsible for their own learning (Driver, 1988; Driver & Bell, 1986). We must come to respect and value children's feelings and ideas, before we can competently take on a responsibility to help them construct new structures or knowledge (Driver & Oldham, 1986).

Teachers must hold integrated, 'accepted' structures or knowledge for topics, be able to discriminate between the latter and children's unique ideas, and progressively explore students' progress in constructing new structures or knowledge, in order to introduce talk, writing and activities which will promote pupils' intended ideational (and perhaps, as a result, emotional) development.
Just as an aside, these implications heighten the appreciation of the ‘formidable damage’ (von Glasersfeld, 1989) wrought by methodological and Skinnerian behaviourism. For von Glasersfeld, the rejection of thought and feeling in favour of a concentration upon ‘observable’ stimuli and responses by behaviourists “has been appallingly successful in wiping out the distinction between training and education” (p. 12). We can imagine how a future historian might dryly comment upon the fashionableness, or at least quaintness, of the way in which these theorists fanatically wrestled with such unapt questions and proposed such ‘mindless’ solutions.

Unfortunately, it is an open question as to just how much, and to what levels, a ‘mindless’, ‘blank slate’, or ‘empty bucket’ view of students still pervades educational administrations and the teaching profession.

However, contrary to implications of the theory above, Bell, Watts & Wilson, (1985) claim that it is currently “not a widespread practice” (p. 653) to ‘take account’ of children’s own ideas. For example, in one ‘classroom-based’ study, Haggerty (in progress) found that “virtually no opportunity was provided during instruction for (children’s own) beliefs to surface and be examined by either the students or the teacher” (Driver & Erickson, 1983, p. 50).

Nor does it seem to be a ‘widespread practice’ for teachers to take account of how students approach learning tasks. Tobin and Gallagher (1987) report that in interviews with secondary science teachers, “seldom was the form of student engagement mentioned as an important variable (in learning)” (p. 559). Moreover, these teachers “viewed the curriculum in terms of content to be covered” (p. 559), that is, as a fixed body of knowledge to be transmitted to pupils, rather than a continuously evolving process of experimentation with educative situations.
It is unwarranted to assume that all teaching in schools contrasts with implications for practice of the theory above. Many teachers may employ most of the general strategies identified in Section 9.2.1 at least some of the time. Indeed, Biggs (1989) claims that the ‘exemplary’ teachers identified in the Tobin and Fraser study thought that meaning is not something imparted by a teacher, “held high expectations of their students ... and were themselves open to changes in their teaching” (p. 22). However, it is disturbing that such teachers are labelled ‘exemplary’, when they should be the ‘norm’.

For Johnson (1982), a question we must ask “is whether ... students are learning because of, or in spite of, our instructional practices” (p. 49) (also see Sylwester, 1986, p. 16). That is, it might be that only young people of so-called ‘better than average ability’ (Sylwester, 1986), regularly construct knowledge in a classroom; not because of their ‘ability’, but because they work without the assistance of a teacher (Sylwester, 1986).

It is a little worrying to think that many teachers ‘practice’ alone in single rooms; that some participate “in little professional interchange” (White, 1988, p. 123) or “read much about theory or innovations in education” (p. 123), and that “few return for further training after obtaining their initial qualification” (p. 123). If and when evaluations of current practices in classrooms are carried out by members of, or committees from, administrative departments, “they do not often find fault” (Anderson, 1987, p. 224) and “tend to laud traditional activities, and rationalise these against criticism” (p. 124). The conclusions drawn by these investigators are often that ‘adverse influences’ on children’s learning are “located in the individual, the home, society, or anywhere outside the educational system” (p. 224). Yet this is a system of mass education which we sanction with a task of helping young people develop their knowledge of a world, and, if the theory above is seen as a plausible and useful solution to the learning paradox, with the very development of children’s nervous systems.
To date, research on the effectiveness of general teaching strategies like those identified above in promoting children’s construction of knowledge has been limited. In one classroom study, Snively (in progress) developed a ‘metaphorical interview technique’ which was used to ascertain, in part, children’s beliefs about the ‘seashore and seashore animals’. It was found “that in those instances where the instruction made significant contact with (students’) preferred orientations and beliefs ... then the desired instructional objectives on ecological relationships were achieved and remained stable as assessed in a subsequent interview seven months after completion of the unit” (Driver & Erickson, 1983, p. 50) (though it is unclear what is meant by ‘significant contact’ and ‘desired instructional objectives’).

Hand (1988) used several ‘conceptual change’ strategies to teach a unit on acids and bases. These strategies included “(i) (giving) students opportunities to make their own ideas explicit, (ii) (providing) experiences which interact(ed) with (a) student’s prior knowledge in a range of ways, (iii) (providing) opportunities for conceptualising, modelling or thinking about these experiences, (iv) (providing) opportunities for students to use ideas, and (v) (providing) a supporting learning environment” (p. 22-23).

Hand found that most pupils held five major alternative ideas about acids and bases. Following the unit, students were given a test (though it is unclear what type). Of the five alternative ideas, results were that “(presumably in all pupils) three had successfully changed, while partial understanding had occurred with the other two ... these results were confirmed in (subsequent) interviews (with students)” (p. 23). Pupils commented that “they enjoyed this method of learning” (p. 24), and those “who were not normally involved and tended to become bored were no longer desirous of being non-participants” (p. 25). Hand also reports the comments of some students on their involvement in small and whole group discussions, for example, “you learnt more the new way because you did your own learning. The other way was too boring. The student concepts are a good
idea because you get your meaning for an acid and a base, not what is in the book. The meanings in books are complex and you don't understand them” (p. 25).

Hand concludes that “the opportunity to express concepts in their own words appeared to improve the self confidence of ... students which in turn resulted in improved self-discipline and an improved attitude to learning” (p. 26). Though this may seem too good to be true, and perhaps some of the results were due more (but nevertheless not critically) to the newness of methods, and the novelty of an ‘activity-based’ program, than to the teaching strategies themselves (Hand, 1988), there were, at least, apparently no negative outcomes.

If results of future, systematic applied research undertaken to evaluate the implications for pedagogy and the effectiveness of the teaching strategies in promoting construction inferred above prove to be as positive, then schooling must change. Yet given the traditional conservatism of members of the bureaucracy, and if a recent statement, made by an assistant director of education, viz. “I subscribe to the view that learning is an activity which takes place within the mind of a learner” (sic) (Parkinson, 1987, p. 24) is representative, the path of change will likely be long.

9.5 Conclusion

The main import of the view in the foregoing is that knowledge is a condition of an area of the cerebral cortex relative to a ‘condition’ of a world. In perception, in listening and reading, a spatio-temporal pattern of nerve impulses flows relative to a spatio-temporal form in a world. An extra ‘condition’, or even a ‘substance’, called information is an expendable idea, much like the idea of an ether. Equating knowledge with a condition of our nervous system means that knowing and the creation of new knowing occurs during the total, self-regulated interaction of conditions in the brain relative to a world; extraction and processing of information is redundant.
Perhaps we can finally put the 'machine metaphor', originally so creatively employed by
Descartes and eventually re-enlivened by information-processing theorists, to one side.
The vast richness of evidence in the fields of neuropsychology, neurophysiology,
neuroanatomy and psychophysiology seems to hold much more promise for guidance in
the light of explanations which identify knowledge and learning with conditions of human
neural tissue. It is not unfortunate that psychology and cognitive science has extended the
use of the 'computer analogy' to, in many areas, its logical limits. We can now
appreciate these limitations and search for new solutions. After all, "we weren't designed
by a cognitive scientist, we just grew" (Mortensen, 1989, p. 130).

Potentially, qualitative rather than accumulative growth should be our guiding theme in
education, in theory building, in listening to a young person tell us how the sun works.
Such a guiding theme, if invoked often enough, could help to free us at propitious
moments from our conceit of knowing.
REFERENCES


Bennett, T.L. (1987). Hippocampal-collicular interactions: an example of input linkages to the hippocampus, Behavioural and Brain Sciences, 10, 1, 119.


Biggs, J.B. (in press). The lack of impact of research on improving student learning: A question of methodology?
References


References 213


Morris, R. & Baker, M. (1984). Does long-term potentiation/synaptic enhancement have anything to do with learning or memory? In L.R. Squire & N. Butters (Eds.), 


Appendix A

The following text is about the idea of animal.

You will encounter this idea in your second year in the subject EDPS 201 Sciences in Education II, when you do 'The biological environment: animal and plant studies; native plants; playground studies'.

Next Wednesday, I will ask you to fill in a short survey about the idea of animal outlined in the text. This form is not a test and you will not be evaluated or given a mark or grade. It is simply a way of finding out what you have learned from reading the text.

Please read the text.

Biology is the science of living things. Biologists divide living things into two major groups: animals and plants.

All living things are composed of basic units called cells. A cell consists of a fluid-like substance called cytoplasm, which is surrounded by a membrane.

As well as a membrane, plant cells have a thick, hard outer wall made mostly of cellulose, called a cell wall. The cells of animals only have a thin, soft membrane, or at least a limiting surface, and do not have a cell wall.

Growth in living things occurs through cell division and the creation of new cells. In animals, growth generally occurs simultaneously in all parts of the body, but ceases when an animal reaches adulthood. As adults, animals are thus fixed in shape and size, unlike plants, which often continue to grow and change shape throughout their entire life.

All living things require materials and energy to continuously renew their cells, and to grow. Living things obtain these materials and energy from their food.
All foods are chemical compounds which contain the elements carbon, oxygen and hydrogen. Some foods also contain other elements, such as nitrogen, sulphur and potassium.

Plants take up these elements from the air and soil, and using the radiant energy of the sun’s light in a process called photosynthesis, combine the elements to form foods such as sugars, proteins and fats. That is, plants manufacture their food.

Animals obtain their food by eating plants, or preying on other animals which have eaten plants. Animals are thus dependent upon other living things or on their dead remains for their food supply.

Most animals are capable of locomotion, that is, movement of their whole body from one area of their environment to another. However, there are some exceptions. For example, most anemones and sponges, which are animals, are stationary. But such animals usually begin life as free swimming young which later attach themselves to a site.

This capacity of most animals to move around is important, because it allows them to search for and obtain food. Because animals can move around, their bodies are necessarily compact, whereas plants usually have a branching shape for maximum exposure to light, air and soil.

Animals are further characterised according to their type of body symmetry. There are two kinds of body symmetry: radial and bilateral. Radial symmetry is the arrangement of the parts of an animal’s body like the spokes of a wheel about a central axis. Jellyfish, anemones and corals have this type of symmetry.

Bilateral symmetry is the arrangement of body parts about a central longitudinal axis. That is, if an animal has bilateral symmetry, it has right and left halves which are largely mirror images of each other. For example, spiders have bilateral symmetry.

Most animals capable of locomotion are bilaterally symmetrical and elongated in the direction of their locomotion. Bilateral symmetrical animals generally have a head at the leading end of their body, in which is located a brain or a brain-like organ and sensory organs. This concentration of a brain and sensory organs in a head is called cephalisation.
The possession of sensory organs allows animals to sense many stimuli, for example, light and sound, as well as chemicals, which often indicate food, while having a brain enables them to coordinate their movements. Food particles or solid pieces of food are taken in through an opening in the head, the mouth, and digested or broken down in a body cavity called the alimentary tract. Waste products are eliminated at the other end of the animal.
Appendix B

The following text is about the idea of animal.

You will encounter this idea in your second year in the subject EDPS 201 Sciences in Education II, when you do ‘The biological environment: animal and plant studies; native plants; playground studies’.

Next Wednesday, I will ask you to fill in a short survey and some multiple-choice questions about the idea of animal outlined in the text. Your answers on these forms will be assessed, and you will be given a mark out of 30. Assessment will be as follows:

Survey  - 10%
Multiple-Choice Questions  - 20%

This assessment is a way of measuring how much you have learned from reading the text.

Please read the text.

Biology is the science of living things. Biologists divide living things into two major groups: animals and plants.

All living things are composed of basic units called cells. A cell consists of a fluid-like substance called cytoplasm, which is surrounded by a membrane.

As well as a membrane, plant cells have a thick, hard outer wall made mostly of cellulose, called a cell wall. The cells of animals only have a thin, soft membrane, or at least a limiting surface, and do not have a cell wall.

Growth in living things occurs through cell division and the creation of new cells. In animals, growth generally occurs simultaneously in all parts of the body, but ceases when
an animal reaches adulthood. As adults, animals are thus fixed in shape and size, unlike plants, which often continue to grow and change shape throughout their entire life.

All living things require materials and energy to continuously renew their cells, and to grow. Living things obtain these materials and energy from their food.

All foods are chemical compounds which contain the elements carbon, oxygen and hydrogen. Some foods also contain other elements, such as nitrogen, sulphur and potassium.

Plants take up these elements from the air and soil, and using the radiant energy of the sun’s light in a process called photosynthesis, combine the elements to form foods such as sugars, proteins and fats. That is, plants manufacture their food.

Animals obtain their food by eating plants, or preying on other animals which have eaten plants. Animals are thus dependent upon other living things or on their dead remains for their food supply.

Most animals are capable of locomotion, that is, movement of their whole body from one area of their environment to another. However, there are some exceptions. For example, most anemones and sponges, which are animals, are stationary. But such animals usually begin life as free swimming young which later attach themselves to a site.

This capacity of most animals to move around is important, because it allows them to search for and obtain food. Because animals can move around, their bodies are necessarily compact, whereas plants usually have a branching shape for maximum exposure to light, air and soil.

Animals are further characterised according to their type of body symmetry. There are two kinds of body symmetry: radial and bilateral. Radial symmetry is the arrangement of the parts of an animal’s body like the spokes of a wheel about a central axis. Jellyfish, anemones and corals have this type of symmetry.

Bilateral symmetry is the arrangement of body parts about a central longitudinal axis. That is, if an animal has bilateral symmetry, it has right and left halves which are largely mirror images of each other. For example, spiders have bilateral symmetry.
Most animals capable of locomotion are bilaterally symmetrical and elongated in the direction of their locomotion. Bilateral symmetrical animals generally have a head at the leading end of their body, in which is located a brain or a brain-like organ and sensory organs. This concentration of a brain and sensory organs in a head is called cephalisation.

The possession of sensory organs allows animals to sense many stimuli, for example, light and sound, as well as chemicals, which often indicate food, while having a brain enables them to coordinate their movements. Food particles or solid pieces of food are taken in through an opening in the head, the mouth, and digested or broken down in a body cavity called the alimentary tract. Waste products are eliminated at the other end of the animal.
Appendix C

This is a survey designed to explore your ideas on a scientific topic.

1. Please describe below what you think an animal is.

2. Please give what you think are two (2) examples of an animal, and explain why you think these two examples are animals.
Please describe below what you think living is, as in the sentence 'A plant is a living thing':

Please describe below what you think a cell is, as in the sentence 'Living things are composed of cells':
Please describe below what you think growth is:

Please describe below what you think a body is:
Please describe below what you think adulthood is:

Please describe below what you think food is:
Please describe below what you think **locomotion** is:

Please describe below what you think **symmetry** is:
Please describe below what you think a **brain** is:

Please describe below what you think a **sensory organ** is:
Appendix D

Animal
An animal is a living thing which has cells with no cell wall. Its growth generally occurs simultaneously in all parts of its body but ceases when it reaches adulthood. An animal depends for its food supply upon plants and other animals. Almost all animals are capable of locomotion and are either bilaterally or radially symmetrical. Most bilaterally symmetrical animals have a head at the leading end of their body in which is located a brain and sensory organs. A brain coordinates an animal’s movements while its sensory organs allow it to sense its environment.

Living
Living is actively performing functions which sustain life.

Cell
A cell is a microscopic living unit which combines with other cells to form living tissue.

Growth
Growth is the gradual expansion of a living thing through cell division and reproduction.

Body
A body is a complete living whole, which in animals is usually compact.

Adulthood
Adulthood is the final stage of growth in an animal’s life.

Food
Food is a substance from which a living thing can obtain materials and energy to renew its cells and grow.
**Locomotion**

Locomotion is the movement of an animal’s body from one area of its environment to another.

**Symmetry**

Symmetry is the equivalence of proportion in a body.

**Brain**

A brain is nervous tissue which controls the functions and movements of an animal’s body.

**Sensory organ**

A sensory organ is a collection of nerve cells which are specialised to react to specific stimuli.
Appendix E

This is a survey designed to explore your ideas on a scientific topic.

Each question consists of two (2) parts, (a) and (b).

In part (a) you are asked to answer whether a particular example is an animal or not.

In part (b) you are asked to choose four (4) reasons for your answer to (a) from a list of 26. This list of reasons is on the separate 'List of Reasons' sheet.
1. (a) Is a spider an animal?

Yes          No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them.

These should be the ones you think are the best.

Please circle the letters of your choice.

A   H   O   V
B   I   P   W
C   J   Q   X
D   K   R   Y
E   L   S   Z
F   M   T
G   N   U
2. (a) Is a grass plant an animal?
   Yes    No
   (Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them.
   These should be the ones you think are the best.
   Please circle the letters of your choice.

   A  H  O  V
   B  I  P  W
   C  J  Q  X
   D  K  R  Y
   E  L  S  Z
   F  M  T
   G  N  U
3. (a) Is a cow an animal?

Yes

No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them. These should be the ones you think are the best.

Please circle the letters of your choice.

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4. (a) Is a **worm** an animal?

Yes       No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose **four** of them.

These should be the ones you think are the **best**.

Please circle the letters of your choice.

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5. (a) Is a person an animal?

Yes  No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them.

These should be the ones you think are the best.

Please circle the letters of your choice.

A  H  O  V
B  I  P  W
C  J  Q  X
D  K  R  Y
E  L  S  Z
F  M  T
G  N  U
6. (a) Is a whale an animal?

Yes  No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them.

These should be the ones you think are the best.

Please circle the letters of your choice.

A  H  O  V
B  I  P  W
C  J  Q  X
D  K  R  Y
E  L  S  Z
F  M  T
G  N  U
7. (a) Is a **lizard** an animal?  
Yes  
No  
(Please **circle**)
(b) Look at the list of reasons on the separate sheet and choose **four** of them. These should be the ones you think are the **best**.  
Please **circle** the letters of your choice.

| A | H | O | V |
| B | I | P | W |
| C | J | Q | X |
| D | K | R | Y |
| E | L | S | Z |
| F | M | T |   |
| G | N | U |   |
8. (a) Is a crab an animal?

Yes  No

(Please circle)

(b) Look at the list of reasons on the separate sheet and choose four of them.

These should be the ones you think are the best.

Please circle the letters of your choice.

A  H  O  V
B  I  P  W
C  J  Q  X
D  K  R  Y
E  L  S  Z
F  M  T
G  N  U
Appendix F

A. It moves
B. It does not move
C. It is large
D. It is small
E. It makes a noise
F. It does not make a noise
G. It eats other living things
H. It does not eat other living things
I. It has fur
J. It does not have fur
K. It has cells with a cell wall
L. It has cells with no cell wall
M. It is an insect
N. It is a mammal
O. It is a fish
P. It is a human
Q. It breathes
R. It does not breathe
S. It has a brain
T. It does not have a brain
U. It has many legs
V. It has no legs
W. It has two legs
X. It has four legs
Y. It lives in the sea
Z. It lives on the land
Appendix G

This is a short questionnaire to find out how you felt as you read the text.

Please look at the alternatives below, and draw a circle around the letter of the alternative which best represents how you felt.

The text made me feel:

A. Curious  
B. Mildly interested  
C. Indifferent  
D. Bored  
E. Mildly anxious  
F. Anxious  
G. Confused  
H. Frustrated  
I. Irritated

Please explain why you think you felt this way:
Appendix H

This is a survey designed to explore your ideas on a scientific topic.

1. Please describe below what you think an animal is.

2. Please give what you think are two (2) examples of an animal, and explain why you think these two examples are animals.
Appendix I

Neuroglial cells are "collectively known as neuroglia, or simply as glia" (Barr & Kiernan, 1983, p. 13). (‘Glia’ comes from the late Greek, meaning ‘glue’, OED.) In the brain, neuroglial cells are divided into astrocytes, oligodendrocytes and microglia (Bray, Cragg, Macknight, Mills & Taylor, 1986).

Astrocytes are linked by gap junctions, which are "regions of low resistance to ion flow" (Mountcastle & Sastre, 1980, p. 217) (an ion is a positively or negatively charged atom or molecule).

Evidence from laboratory studies of animals indicates that one function of astrocytes is to regulate the concentration of positive potassium ions (K+) in the interstitial space (Abbott, 1986; Mountcastle & Sastre, 1980; Somjen, 1983, 1987). An accumulation of K+ in the latter can "interfere with the normal functioning of neurons and synapses" (Somjen, 1987, p. 465-466). During the generation of nerve impulses in neurons, the concentration of K+ in the interstitial space increases (Mountcastle & Sastre, 1980; Somjen, 1983, 1987). K+ is taken up by astrocytes and redistributed, via the gap junctions, to regions of low K+ concentration, thus maintaining the stability of neuronal function (Somjen, 1983).

In this capacity, glia are said to function as a ‘spatial buffer’ (Mountcastle & Sastre, 1980). The redistribution of K+ to regions of low K+ concentration “can occur very rapidly, because ion currents flow with a speed approaching that of light” (Somjen, 1983, p. 167).

Oligodendrocytes form a fatty sheath, called myelin, around the axons of some neurons. Myelin increases the velocity of impulses (Davis, et al. 1985; Kandel 1981a). In myelinated axons, the action potential is regenerated at regular gaps in the myelin sheath.
called *nodes of Ranvier* (Brinley, 1980). The propagation of the nerve impulse in myelinated fibres is called saltatory conduction. (In general usage, the term ‘saltatory’, from the Latin saltatorius, is defined as “pertaining to, characterised by, or adapted for leaping”, OED, i.e., the nerve impulse ‘leaps’ or ‘jumps’ from node to node.)

For detailed reviews of the proposed functions of neuroglial cells, see Kuffler, Nicolls and Martin (1984) and Somjen (1987).
TRANSCRIPTS OF INTERVIEW

Student 1

I. Um did you do Biology at school
S. No
I. O.K. um where where actually like you know can't help noticing your accent did you go to school here or
S. In Scotland
I. In Scotland
S. I've only been here six months
I. Six months um well what do they do in Scotland did you have a like a general science course in say when you were about sixteen or
S. No when you're eleven and you first go up to secondary school and for the first two years you have a general curriculum course where you can do everything and then when you go into third year you select your subjects and I dropped maths and science and did languages
I. Right
S. So I mean if if you don't want to do science or maths you don't have to
I. So from year from three in secondary you didn't do any science at all
S. Naturally ( ) when I was fourteen I dropped it and I just went on to do languages
I. Did you do any before that at all or
S. Not a lot um the science we did was more um Physics and Chemistry from what I can remember which isn't much
I. Um do you well do you know a little bit about Biology now or you know of it obviously
S. Yeah I'd like to think that from the questionnaires we've been doing that I've learned something
I. Do do you think that Biology as a subject is relevant?
S. I don't think it's for primary schools that's ( ) but um I don't know if your interested in science then (would it give?) you a good grounding because you could understand how things work a bit better

I. So you don't think it's relevant to the BEd primary course

S. No I think it's too complex for younger children to understand

I. Um what do you think an animal is?

S. ( ) it's something that um its something that's got a brain to it can it can decide on where it moves um its I can't remember what the cells are if they've got walls or what now I always get them mixed up I think that they don't have in animals 'cause plants have to 'cause they're thicker um they can think ( ) usually they've got a line of symmetry at some point it usually faces in the direction that they're going like they've got a head at one end um and that that can be sort of the symmetry can be longitudinal um sort of got a right and a left side that's more or less the same or it can is it radial? like in jellyfish

I. Yes like um like what your thinking of a circle

S. Sort of like wheel things yeah

I. Hmm yeah that's right

S. That type huh um like they find food to give them energy to move um and then sort of ( ) they can use their senses to actually find their food and what's right for them I think that's about it

I. What do you think or what do you think the main difference is then between a plant and an animal

S. That they can move

I. Anything else?

S. Um they can well I 'spose plants find their own food as well in a way um they can move and they can think ...

I. O.K. do you remember the passage from last week

S. Vaguely, yes I'm trying to remember it now

I. Um can you remember what you did as you read it, how you read it
Mmm well I just read it through a quick once over to get the idea of it and then I read it through slowly trying to understand each new word or new ( ) that I hadn’t come across and then just before I handed it in I skimmed through it again just trying to remember the main points

O.K. um what you knew exactly which parts that you had to go back and read or or you weren’t sure or

Well no ’cause when I read it through slowly um if I come to a bit I don’t understand I spend longer until I can figure it out and then I’ll move on so I was just and I read through quickly at the end its just to refresh myself get an overall picture again

When you read when you say you read it through slowly till you understood it or figured it out what what did you try to do how did you do that can you remember? Can you remember what you were sort of thinking about or as you when you say figure it out um

Oh um well just I was following the sense of what was written when I came to big words sort of ar ... can’t think of the word ( ) at the moment um just did it mention photosynthesis

Yes, yes

Right when I came to that I had to stop and think about the word so then I would read round it to see what it meant then I’d try and remember the word obviously I’ve not done too bad a job but ( ) so long as I can understand it and I know that word means then I can understand the idea that’s there and then just go on to the next one until I get stuck again

O.K. um ... can you remember what the instructions said? at the top of the page

Of the page? oh

The page was printed on both sides

Yeah um just to read it through and then I can’t remember whether it said anything about trying to understand it or when you understand it to hand the sheet back
I. Um the reason I asked was I wanted to ask you if the instructions had had any effect on the way you read the passage, like having read the instructions did you approach you know a special way or you just did it the way you normally do?

S. No I think when you'd written on the board to put your hand up if you didn't understand anything that's when I thought oh well we have to remember this so otherwise you wouldn't tell us to if you don't understand anything to ask I remember that but not really what was on the page.

I. O.K. um if you'd been given that passage ar say for a course that you were doing and say as well as that a list of references and the lecturer said to you take this away but next week there be a test on it um and it was worth say 20 per cent um how do you think you would have approached it then, what would you have done?

S. Oh I would sort of read it through a lot more and if I had a list of references I would have gone read more about it just to try and get a better understanding sort of try and learn it long-term instead of short-term.

I. Right well what do you think like when you say long-term and short-term what do you think the difference is between those two?

S. I think um going back to when I was at school the teacher said gave us something and she says well your gonna have a test on this next week then you you'd keep reading it over until you could say it back almost parrot fashion but then after the exam you'd forget all about it and you wouldn't bother about it again whereas I think long-term well certainly here everything that we get um we don't we're not to learn it just for the exam we've got to try and keep it so that it can change our beliefs or build up our own theories even when we leave here so you try to remember it so its always there even if if you can't um sort of recall it right away you might see or read something and you think oh yeah I remember doing that.

I. Hmm um why why are you doing the BEd?

S. Oh why well basically I was in computing when I left school like I'd had four years working in a big computer centre and I really wanted a change because I
was just getting so sick of it and coming out here was a ( ) chance and I was thinking ‘what will I do’ and I also like working with younger children um when I was in Britain I used to do nannying in the school holidays for the diplomatic service so I just thought oh why not go into teaching and then my family out here telling me about university and how to ( ) I thought I’d give it a shot

I. Good. What do you think teaching is?
S. Oh ... um

I. Like what do you think it is um your ideas on it at this stage
S. At this stage I would say just um showing children not just teaching them what they need to know through life but showing them how to find out something that they want to know about so ( ) to my teachers when I was younger there were some that would sit you down give your tables you had to learn them off by heart and all they did was threw information at you ( ) that was their teaching but one the teacher I had in my last year at primary school she never did that she’d would say like this week um she had a big book that we could choose a topic out of and she say like go and find out about it and you go and you’d read or ask your parents you would ( ) find out all you could and then she’d just ask what you’d learned I think that was more constructive so I’d say teaching is not just filling a child up with information but certainly showing them and guiding them to find it out for themselves

I. Um ... more or less related to what you’ve already said what do you think learning is? Like I mean we’ve already talked about before about short-term and long-term um if you could tell me again more or less in a general way what do you think learning is?
S. Ar I think if like say if you wanted to find out when something’s caught your interest um then you’ll want to know more about so you read up all you can and you you sort of find out information because your interested and you remember it so you learn about it but um there’s times when your told what to learn and you’ve got to well learning then I think is more memorising ... because if your
not really interested um you can take it in but your not worried about remembering it you know

I. How like when are ... have you have you like had to do that um remembering things like that memorising things can you can you sort of recall how you feel when you do that is there a feeling attached to it at all or you just do it?

S. Just very um I remember in my Latin classes

I. Latin

S. Yeah I did higher level Latin in Scotland and we would work on a piece, we'd translate it but then you had to remember the translation and background theory and notes for it and the only way you do it was to keep on going over it and over it until you'd memorised it rather than learned it and it was just so sort of frustrating and boring because you knew that you had to do it um there isn't any other way round it because its something you've got to do

I. Whereas like that um I think you mentioned in um the comments you made on the questionnaire you filled in after you read the passage you you I think you enjoyed it didn’t you?

S. Yeah I did

I. You found it interesting

S. Ahum

I. You would did you you wouldn’t have been memorising it then

S. No

I. Or not as much say as in as in Latin

S. No I think I would remember a lot more of it if I had tried to memorise it but um because I was just found it interesting so um the things that were new to me that I hadn’t thought of like animals being symmetrical that was a new idea I thought ‘oh yeah hey are I remember that bit about it’

I. Hmm that’s good fine
Student 2

I. Did you do Biology at school?
S. Yes I did yep
I. Right ar
S. Year 11 and 12
I. Both years right did you do any other science?
S. No that was the only subject I did in science I did Biology at year 11 and 12 and just in junior school you know you just do a little bit of Biology and the other little things bit and pieces
I. Right did um why did you choose to do Biology rather than?
S. Well 'cause I'm more interested I was more interested in that I don't know its more I was interested in um I think its I can't really find the words um
I. Well you more interested in it
S. Yeah because it seems
I. Compared with Physics and Chemistry
S. Yeah because it seems more its more handier oh it sounds stupid but its if you relate to ( )
I. Has more potential
S. Yeah just knowing about you know functions of the body and other things which are more useful to you that's what I think anyway
I. Right
S. It was easier too I heard that it was an easy subject
I. What did you think of it?
S. Biology?
I. Yeah
S. I liked it it was one of my favourite subjects ... I really liked it yeah
I. Um do you think it do you think its relevant well like what you said before
S. Yeah yeah just its I think everyone should know a bit about you know bit about Biology ( ) functions not right in depth about ( ) genetics and all but just ( ) but just the basic um functions of the body and that ( ) I don’t know if that answers the question

I. Well its what its basically what you think um you know ar whatever you think um really do you think it relevant to to this course to the BEd?

S. Um ... yeah because you have to for the children to teach the children you have to teach them a little bit about yeah I do think it is you have to teach them a little bit about um like I was saying 'cause its useful they’ve got to know a little bit about it its interesting they want to find out you know different parts of an organ I mean not right in depth as I was saying they probably wouldn’t understand it but I think its fairly important in this course like like all other subjects

I. Yeah can you teU me what you think an animal is?

S. Um an animal um

I. Just what anything you can remember

S. Anything I can remember um animal is made up of ceUs made up of units and um what else um ... wasting tape

I. That’s alright they’re free

S. Oh are they

S. Um animal oh yeah animal what ... well it functions its its it needs needs energy to um ... (of food?) to function it is ( ) it can move around it can not like a plant when its ... its like its not like I don’t know if this makes sense this is what I think and made up of cells that’s about

I. Well like what is the main what do you think the main difference is between a plant and an animal

S. Um the way it obtains its food like photosynthesis um you get like an animal gets its food from other things and um trying to think back at my old Biology lesson and um a plant it makes its own makes it own food through the sun energy I’m trying to think of the two words that describe these two things and also um
I. The two names that are different
S. Yeah one's you know how
I. They're classified as something and a plant is something else yeah I can't think of them either
S. And
I. It's like herbivore or something
S. Yeah that's it yeah something like that and um what else the difference between um one can move like is more oh I'm trying to think of some words um...
I. I think it's heliotropic isn't it something like that?
S. Heterotropic
I. Hetero
S. Yeah that's right yeah yeah yeah that's it they're the words
I. Which is which though?
S. Hetero is um ... I did all this last year
I. See animals can be herbivores, this is just last year when you did your H.S.C.
S. Oh yeah two years I learned all these things we got into depth about the difference between a plant and an animal um ... the way it generates its food and they way a plant is can't move I don't know what word to describe that locomotion I s'pose and um
I. O.K. can you remember the passage from last week um when I gave it to you can you remember how you read it what you did?
S. How I read it what I did like from I just well first I read through it ( ) from paragraph to paragraph just like nor-normal reading but terms that I didn't quite didn't quite sink or I didn't really know about I had to read again or things that didn't make sense I went over but it fairly was it was fairly familiar I was familiar with it because of year 11 and 12 and it was alright do you want me to say what it was about
I. Um not necessarily
S. It was just about the animal and plants the difference between them and you know explaining each one whatever

I. Alright so you read through it just

S. Yeah I just read I just read straight through it and there was something about was it about um trying to think now it was something about it in there that um I hadn’t come across and I just read over that once or twice I just wanted to make it sink in I can’t remember what it was now um ... if I saw the passage I’d tell you but um ...

I. Gone

S. Its gone no yeah

I. You had to read over it go back and read it again

S. Yeah but see look I’ve forgotten about it so it didn’t help ... oh bilateral and all that radial and ( ) is it that the bilateral um yeah that sort of thing I we sort of did do a bit of that though but

I. That was the um something you hadn’t

S. Oh yeah we did but it was something that I sort of had forgotten about and didn’t really the other things sort of

I. Can you remember now like um

S. Bi - it was bilateral and radial was it?

I. Yeah that’s right

S. The structure of an animal was it?

I. Yep

S. Yeah we did that um cutting something we cut yeah we did a couple of experiments when oh its coming back to me now isn’t that when you cut bilateral isn’t that you cut it in half and their are they equal on each side

I. Yeah yeah

S. Yeah

I. And you did you did experiments at school

S. Yeah but I wouldn’t be able to
I. To prove that
S. Yeah just oh well just looking at different um animal - oh like things from the s-
the ocean like let me think different types of um crustaceans just different I don’t
know we thought yeah we actually they actually brought in samples and that and
looked at it and we had this like key and you had to tick off ( ) you had to tick off
which ones like look at it and tick each one which
I. That’s all coming back now
S. Yeah sort of comes back yeah can I just once I’d finished I just through all my
notes away
I. Did you
S. Yep because I was sick of school but now I thinking and I sold by books and
everything and now I’m thinking I should have kept it just to look over
[ ]
I. O.K. um do do you remember what the instructions were there were a set of
instructions at the top of the page
S. Yeah
I. Um
S. My mind it was two weeks ago I think wasn’t it no it was last week that’s right
yeah that’s right we read the passage ar what the instructions were to read the
passage wasn’t it just stating that um that there’ll be a test or there’ll be is that
right there’ll be a test or some sort of
I. I’m not sure
S. You’ve forgotten yourself
I. No I’ve forgotten what passage you actually read because there was two different
ones
S. Oh right was there yeah read through it and um and there was something about
which ’cause of the way I felt really frustrated not about you I felt anxiety cause it
said something like ... you’ll be tested on this next week or something on the
passage that you read it was something like that and I thought how am I going to
remember this like and I kept I was reading it slowly so I thought it might stick there so I could regurgitate it all and that’s all I can remember and then wasn’t it we had to write what we felt after I don’t know if they stated it in the beginning in the instructions

I. No
S. Which was anxiety for me
I. Hmm and that and that was because you you’d been told you would be tested
S. Because I read that but mainly because I yeah and I thought oh no is this going to count all these things are going through my mind and I thought oh no am I going to is this going to count for anything or is it some stupid thing that’s just me
I. Well I can tell you now it doesn’t count for anything in the course no way
S. No its just yeah
I. Its just between you and me um but as as it happens I haven’t given you a test like that um but I wanted to see how you would approach it if you thought you that were going to have a test um you said before about regurgitating what do you mean by that you read it slowly?
S. No no I find like if I read something slowly it sort of sticks more but it hasn’t so (laughs)
I. Alright well imagine if I had been a lecturer and I’d given you that passage plus a list of references tacked on with it and I’d said to you um I’d like you to have a look at this and next week we’ll be having a test on it and it will be worth 20 per cent what would you have done and you can take it away with you
S. Oh you can take it away
I. Yeah I’d give it to you
S. Just on the pa- on the
I. And I just said that we’d be having a test on the topic
S. On the topic
I. Yeah and give you the list of references
S. Well what I'd do I'd read read over it and probably come back to it keep coming back to high school but it would keep coming back from that that would be handy in that way and I'd maybe look up some of the terms if I didn't understand them in some Biology dictionary or something I've got one at home so I'd probably do that and just to learn I find that I write things down and it helps me if I actually write things down I'd probably just really learn some of it off by heart and then if you underst- I find if you understand something then it you can express it like I don't know if this makes sense you can exp- I can express it the way I feel about it like its easier to sort of ... answer I don't know

I. Its easier

S. If if you really understand something then you can put it you don’t have to learn it off by heart you can put it in your own words because that's what I'd probably do just read it over

I. What how do you when you decide your going try understand really understand something you just said how do you what do you do?

S. Try to understand it?

I. How do you go about that yeah

S. Well probably what I'd do is probably read up on it like just ( ) well it was about animals and plants I'd probably things before it I don’t know things before ... before it oh I don’t know if that makes sense um I trying to think I’m tired its an excuse yeah I’d I’d look up different things about the animal and the plants or whatever the passage was on and the functions and I'd probably read it over and over and and if maybe talk to somebody about it who’s like my brother 'cause he’s doing science I’d probably talk to him about it

I. Mmm even though you might not want to

S. Oh he’s alright or my dad 'cause he’s worse fields I always seem to be going to dad

I. Right that’s good um why why are you doing the BEd?
Because I thought well because I want to be a teacher 'cause I love little children and I just and um also ... not because the course sounded really a lot of fun it sounded good I sort of know people who have done it and they said it was good that I'd enjoy with the arts and not just not just learning about maths and but your learning about everything and yeah ( ) I want to teach children

Well what do you think teaching is?

Teaching is um ... is that I've just got to think how to put it in words um ... its helping helping children well or not children anybody really, understand not just understand but um give give knowledge to I don't how to put it um teach no 'cause your not really commenting see your just really quiet and I'm sitting here waiting for you to go yes agree you know in other words I've never really thought about it before um helps develop I s'pose it helps develop children or anybody ... just their knowledge and about things you know in order to not survive I was going to say survive but you don't need um and what else develop personality um just there to help not just to um teach not just that's just the question isn't it teach not just to

Well you say not just to teach um

Because you want to know what teaching is and I keep saying teach so what is this word ... like teach

Like is that is that you think that teaching is one thing but then you think teaching should be as well all these other things

Yeah teaching

Well what do you think teaching is say one thing or what most people think it is

Most people think it is for you to just what I was saying about knowledge um generated or not just make it oh its I can't my words I swear your going to be going your going to be going like what is she going on about

Don't worry 'cause its its when when somebody asks you a question about something something that you've never thought of thought about before and you were actually doing in the process now of actually probably building up a theory
of what you think it is and I mean it might take you three, four, five weeks to do that but you’ve got five minutes alright well we’ll leave it at that I think you’ve said enough

S. Oh have I oh but the teacher’s not there teaching your not just there to you know teach knowledge here it comes again to generate this knowledge and to help develop an understanding of things and personality but um also is there to be a friend or someone to talk to or something you know

I. Yeah yeah

S. I don’t know

I. What about learning that’s the other side of the coin

S. Learning?

I. What do you think learning is?

S. Well its connected to teaching

I. Everybody assumes so

S. Yeah um learning ... to trying to think of the word to to um ... oh gosh ( )

I. Well just tell me what you think learning is quickly that’s it then

S. O.K. learning is um ... well its connected to teaching as everyone says but its taking these different things which ( ) like about the environment or issues I don’t know how to put it and um ... ( ) the same word about them

I. Yeah well what’s

S. I don’t know I have to think about it

I. Well if somebody said if somebody from another planet came and said to you you know what do you do on this planet when you learn something what would you say to them in other other words

S. When you learn

I. Like they’d say you know what’s the use of learn what what do you mean by this

S. Learning I’d say

I. You just learn
S. Yeah you just do it no I'd say what about reading and writing that would come into to it too um I'd tell them that there is different ways I'm still going around the question I'm not answering it I don't know truly I can't I can't answer that

I. O.K.
Transcripts of Interview: Student 3

I. Um did you do Biology at school?
S. Yep yeah
I. Right ar right to year 12 or?
S. Um just to year 11 or 12 yep
I. O.K. did you do any other science?
S. No na no others
I. Why did you um choose Biology?
S. Why did I choose Biology um ... well I wasn’t going to do it all at first and then in year 11 I only had ten Board courses, ten units and everyone told me its best to have twelve and so there was nothing better to do so I just did
I. Safer
S. Yeah so I did Biology and that was it but I didn’t it wasn’t any of my first choice I didn’t really want to do a science at all I wanted to keep away from that sort of area
I. So how did you go with it did you
S. Um
I. Did you like it?
S. Yeah it was interesting it was interesting I didn’t really like the teacher but it was alright it was alright
I. And do you think its relevant like as a general topic?
S. Yeah I do I do actually I think its important especially Biology ’cause you need to know there’s basic stuff that you should know
I. What about for this course
S. For this course?
I. For the BEd is it relevant to you for the BEd?
S. Um some of it is I mean the more basic stuff when you start getting into heavier sort of areas of Biology its not really relevant but like do we do a science like I don’t know do we do science (or something here?) or?

I. Um I know that you do or you do a course with ar Barry Harper where you do um animal and plant studies and do do different assignments and you may collect things from a rock platform

S. Oh yeah yeah

I. Things like that that’s one example, um ... right, so when you say the basics like what do you sort like in general like what?

S. Just living, our bodies and living and stuff like that just

I. O.K. um what do you think an animal is?

S. An animal ... how many times um I don’t know something about that lives and feeds off other things that’s all really

I. Anything else you can think of?

S. Oh ... doesn’t really necessarily have to move um ... I don’t know this is a hard question

I. It doesn’t have it doesn’t necessarily have to move

S. Oh plants are living they don’t move they sort of move internally

I. So an animal is something that doesn’t necessarily have to move?

S. Yeah

I. O.K. can you give me an example or?

S. Oh no wait I did a mistake there a plant’s not an animal

I. No

S. No I just did something really stupid there its this (the tape recorder) get it away no no an animal is something that moves yes yes right

I. Um what do you think the main difference is between an animal or plant and an animal?

S. The main differences?

I. Or difference yeah differences if you can think of ( )
S. Um they photosynthesise plants animals don’t

I. What’s that do you know?

S. Photosynthesis?

I. Yeah what do you think that is?

S. Isn’t that taking in of ... oh hang on I get confused with these (things?) I remember from Biology one’s taking in the oxygen isn’t it? and letting out ... the I mean the carbon dioxide or whatever one’s

I. Its what you its what you think see its not really what what what you like whatever its just what you think

S. Can’t remember (moved close to microphone) I just know the difference I can’t remember what actually it is

I. Um can you remember back to to when you read the passage last week on Wednesday morning its a long time ago ... um you know I handed it out to you can you remember what you did as you read the passage, how you read it?

S. How did I read it ... um I don’t know oh I read it like I couldn’t things came back to me that I had done before well I don’t know

I. Did you read it

S. I read it all

I. How how many times did you read it through?

S. Um well I read it and sometimes when I thought that was an important point I just went back and read that sentence again but that’s about it but I didn’t go back and read it twice or anything but every time I found something I’d went back and read that sentence again

I. Right so you’d sort of you’d be reading it and you’d think oh yeah that’s important stop and read it again

S. Yeah just to highlight it sort of

I. Um can you remember what the instructions said to do?

S. No

I. Or what they they told informed you?
S. To read the passage and that's about it

I. Um ... well imagine if you'd read if I'd given you that passage ar somebody had given you that passage um in a lecture and say a list of references with it and they'd said to you you know take that away and you can read it but there'll be a test on it next week and its worth 20 to 20 per cent how would you have approached it then do you think?

S. Um and we had that sheet I'd probably go and check out the references just to have a look I probably wouldn't look at all of them just a couple and just that's about it and just refer to those who

I. And what would you do do you think at home or whenever just look at the sheet would you or

S. At home?

I. You read it through

S. Yeah yeah ... yeah

I. Like like what you did did

S. Yeah yeah

I. Before for me or in a diff- different way?

S. No ( )

I. O.K. um

S. I'd probably read it more I would have read it over and over again I s'pose

I. Um why are you doing the BEd?

S. Why? um ... I don't know I've always had this thing that I wanted to teach ever since I was a kid so I thought I'll stick to it but now I'm sort of having second thoughts I don't know if I want to do it

I. Why is that?

S. I don't know I just sometimes wonder if this is all going to be worth it I don't know sometimes like you do a subject and I just think you sort of think is it really worth it you know why can't I just go straight out and teach you know sometimes
you think you don’t you don’t need the stuff that they teaching ya like we do arts and all that I know its important to do arts and all that but

I. What what would you what do you want to teach the most like what what do you find that you feel really confident with music or?

S. Um yeah a bit of music I don’t know more worldly stuff for today I don’t know

I. Hmm ( ) social studies

S. Yeah yeah social studies stuff like that I think that’s important oh I’m not saying that you shouldn’t do arts and all that you should there’s a lot of we don’t do a lot of lectures and stuff on it like six hours of art and music and dance not much of the other stuff but I suppose this is only the beginning

I. Hmm first session first year

S. Yeah so I can’t really say much

I. What do you think teaching is?

S. Um passing knowledge onto young children and just enhancing their knowledge so they have a better understanding of things

I. Um what what

S. And you can also be their friend you not not really a teacher your more or less a friend

I. Yeah what are the what do you think the main ways are of passing knowledge on main ways

S. Main ways? what do you mean like sort of like activities and stuff like

I. Well yeah if that’s what you think I don’t really know through activities you said is there any other ways?

S. Research just like getting them involved in like basic research not hard stuff stuff that they can handle

I. What about learning what do you think learning is?

S. I prefer the animal question

I. Alright well we’ll go back to that
S. No no don't go back to that learning what's learning enhancing your knowledge and learning knowing more getting information about more and more things and widening our capacity our knowledge capacity and stuff like that

I. O.K. well that's it

S. Oh good

I. But I did think you might be able to tell me a bit more about animals

S. An animal

I. You said that it moves

S. Yeah

I. Um

S. Breathes it lives it feeds

I. Can you remember anything anything from what you wrote in your answer

S. From what I wrote

I. After you read the passage

S. An animal

I. Remember when you filled out

S. Yeah I didn't write much ... um ... I don't think I wrote any at all ( ) I can't remember its too long

I. Too long ago

S. You should of put more in the week all of it
Student 4

I. O.K. um did you do Biology at school?
S. No
I. Um
S. We I had a choice to but I didn’t
I. Um can you remember though did you do it in year ten?
S. We had a common like a common core subject for nine and ten where we did everything together and you could choose to elect in year 11 and 12 what ( ) and I chose Physics big mistake I chose Physics and then because of the timetable you couldn’t do Physics and Biology together so it was either or one or the other
I. Uh huh um well what made you choose Physics?
S. Ar we did um we did a a unit of astronomy where we just liked looked at the stars and stuff and I though that was pretty interesting um we just mapped out um pla-the planets how they moved in accordance to the stars and that was really interesting and I thought that was what we’d be basically doing in Physics but once we started the next in the next year we only did like about two months of that and then we changed completely to just you basic Physics and I didn’t like it that much but I couldn’t opt out of it because it was too late
I. O.K. what what can you remember anything from those that year 9 and 10 um from that general
S. Bits and pieces yeah
I. Can you remember what you thought of it then
S. Um
I. Like do you remember did you think it was interesting or?
S. Yeah I didn’t mind it I mean I would of if I had the opportunity I would have done it but as you know the school is so small that the timetables are pretty you can either
do one thing or the other and I was told by people before me that there was a lot of work to do and I thought ‘I’ve got to get out of some work’

I. Right

S. So

I. Yep O.K. Do you think it is relevant as a subject?

S. Biology?

I. Mmm

S. More so now that it was before I think because before it was just like study of animals and how its more sort of relevant to what what relevance it has to us we’re getting more um conscious of our own um environment and stuff especially like with things like ozone layer all even things like smoking we’re more aware of what smoking does to you and stuff that’s through Physics I guess so as we’re more we get more conscious of the dangers to ourselves even like things like skin cancer and going out in the sun and stuff even ten years ago we didn’t have things like lotions and stuff to put on but now everybody’s a bit more aware sort of

I. Um do you think its relevant to this course? Do you think its relevant to the course that your doing now?

S. Um in a way it is in a way because um you’ve got to um you’ve got to be aware like if your teaching what stages the children are at I guess if you ... if your aware of you know wha’s what’s happening to them physically you can sort of understand what they’re going through and stuff how to approach it like I guess it would be hard to approach an adolescent or something ’cause lot of changes going through and stuff

I. O.K. um can you tell me what you think an animal is?

S. An animal now I’m trying trying to remember what I wrote down ar I put I think I put it was something that breathes um feeds reproduces itself so I guess you could put plant under that category so its a bit bit general um and moves
Transcripts of Interview: Student 4

I. Well that's actually the next question what what do you think the main difference is between a plant and an animal?

S. Yeah um a plant moves in way I guess over a long period of time in its reproduction like I mean it can move down a mountainside um when I mean move that prov- I guess that shows that its alive it doesn't show that its an animal um animals sort of has can make its decision making it can decide I'm going to go down here or I'm going to go do that and its adaptable to its environment in terms of just keeping itself alive like a tiger or something learn as a youth you know as a young tiger to chase a gazelle or something to kill it to eat it so

I. Right. Did where um the example that you give the gazelle and the tiger have you seen that somewhere or read that recently or?

S. Um we well my Dad used to collect National Geographic and they used to have lots of things about and I was just pretty interested in that as a kid you know just especially wild creatures that really um like things like lions and tigers and dol- things that we don't see much of everyday like we see dogs and cats they're as much living as tigers and lions are I just used those examples again

I. Um ... if you think back to the passage from last week um can you tell me what you actually ar did as you read it?

S. The passage ar which one was that that was the um

I. Um if you remember from last Wednesday I gave you a a sheet and it had um like a little introduction, a set of instructions and then and then then something about animals it was on both sides

S. Oh right yeah I can remember

I. Can you remember back then to actually when you read that how you read it, what did you do?

S. Um ... there was like actually I read it I just read it straight and then there was a few things I went back for just to make sure 'cause I thought that the well I thought the
given us that the question said that you'd be giving us next would be questioning like the comprehension of what we'd read so I tried to take in as much as I could you know so especially things that I'd never seen before I thought 'I've got to remember that' because there's probably going to be a question about it but it was completely different you didn't ask us specific questions about the text like I thought it would be that's why I thought you said you know go read this carefully so I thought oh he said carefully so I'm going to read it 'cause there's going to be a lot of questions on it but it wasn't it was more just personal opinion

I.  Did I say carefully did I?

S.  Yeah you said I think I'm pretty sure you said to read this carefully

I.  Right

S.  I think

I.  Can you actually remember what the instructions were then?

S.  Yeah on top it just said to read it didn't it didn't even say at all that it would be a comprehension that was just my assumption I just thought that you were going to throw lots of questions about what we read to see what our I don't know our memory recall or something was but instead it was more about the our opinion of it rather than what we could remember that's what I thought the task was going to be what we could remember

I.  Right and you said that you read it through once and then you went back

S.  I went back to the things that I hadn't se- read come across before

I.  O.K. um can remember what those things were? some of them?

S.  Um ... photosynthesis I'd never see- come across that before I didn't know much about that I remember that word because I wrote it down on my wrist

I.  Right what did you do

S.  That's what I normally do if ( ) forget something I write on me because its there ( ) I remember it
I. Right did you go and look it up at all or?

S. Um it explained it in a way in the passage and I asked my Mum when I went home about it and um it explained it sort of explained it

I. O.K. um ... if if I’d given you that passage last week and it say had a a list of references tacked on the end of it and I said ar you know you can keep this take it away but next week there’ll be a test on it on what’s in the passage and it was say worth 20 percent 10 or 20 per cent of the total mark for the subject how how do you think you would have approached that particular

S. Well I’d read it over again a couple of times um and then I’d pick out what I thought was important or interesting and or what I thought was interesting ’cause its no good ’cause it makes me study easier so and then I’d see the reference for that particular like for example photosynthesis if you had a reference for photosynthesis I’d go right O.K. try and get look it up read more about and then see if what the passage was written about was right and then make my own assumptions from there

I. O.K. um

S. But it helps if you’ve got a reference

I. Mmm you can why why do you say that it helps

S. Because you get other people’s opinions of the same thing in terms of scientific things I guess that wouldn’t change much like you can’t say that photosynthesis is different really because its pretty much the same process but you can get different authors opinions and how they try to get their point across and you learn from that and you sort of go along with the one that’s easier to get the point across

I. With with photosynthesis the example that you gave um when you went back to re-read that part you just what read it through again or or did you do something else?

S. I read it through again and um tried to understand it ’cause when I first read it I thought ‘right that’s cool’ and didn’t quite understand it the concept of it
I. When you say tried to understand it what

S. Um

I. What did you try and do you just tried understand just look at what the words were or

S. Yeah and just tried to see exactly what they meant I didn’t really know I remember that distinctly because I didn’t know anything about it never heard of it before I didn’t know that it was as important I knew that like if you don’t keep plants in the sunlight that they slowly wither away but I didn’t know what you know how how they get the energy from the sun I didn’t know any of the process so that sort of explained it

I. Well what’s your idea about it now?

S. Well now because I’ve gone ( ) because it was something that I remember and everyone likes to think that they know everything about everything right you know I’d come across something that shit I don’t know anything about this so I went back and tried to find out a bit more about it and asked questions at home and um I didn’t look up a book about it or anything but asking questions and stuff I found out a bit more

I. Hmm well can you tell me now what you think it is or?

S. Photosynthesis?

I. Yeah what you think it is

S. Yeah um I don’t know if I’ll use the right scientific terms or anything but um without the sun I mean the plants use the sun in conjunction with um the the proteins and stuff they get from the soil you know like a chemical reaction and the sun and the what its already got what the plant’s already got puts it out on its leaves and the reaction of the sun on it or what is it um the sun’s rays I guess you could call it I don’t know if photosynthesis works through windows either that’s one a thing I was interested about whether it works through windows ’cause I don’t
know if the energy you have to get is immediate or whatever see 'cause that's another thing I asked too would photosynthesis work off mirrors and stuff I don't if it would and um well I guess it wouldn't because then its not directly the sun I took photosynthesis to be um the plant using what its got um as chemical reaction to create an energy an energy or a like a fuel

I. Right, and what does it
S. Its like a combustion I guess in a way
I. Yeah and that
S. That's how I interpreted after I'd asked questions and sort of thought about it
I. In order to do what combustion for what purpose do you think?
S. For its regeneration to keep itself alive or to keep ( ) for itself to grow
I. Right O.K so so its like a a photosynthesis is like ar ... an energy producing process?
S. Yeah like eating I guess energy oh energy um be more like it seems it seems as if it was essential anyway
I. O.K. good um why why you why you doing the BEd?
S. BEd um well I started when I left school I did an educa- I did an Arts course doing craft glass blowing I was doing glass blowing and ceramics and I had an Art History component and um I did that for a year and deferred it and went out int- and worked I just thought this working game's not for me you know I want to get myself a bit of paper and um I'd taken kids to camps and stuff and I worked over the summer break at you know those camps that parents send their kids to over the summer holidays when they don't like when they go on holidays and stuff um they’re run by the government and I worked there for a while I really enjoyed myself I thought well make a career of teaching I thought primary school teaching would suit me more because I’m pretty impatient I get bored easy and in terms of primary school your teaching the kids all these different things so well because if
your a high school teacher you just English or you just teach History but if your a primary you have to go across the whole curriculum and since ( ) I I get bored pretty easy so if ( ) changing my subjects and stuff I guess (it will?) keep me interested

I. Right O.K. um ... what why do you think you bored easy or?

S. Oh I guess its my nature I don’t know I’ve just got a low attention span perhaps I don’t know

I. O.K. um not necessarily um what what do you think teaching is?

S. Um ... oh its (a big?) question isn’t? teaching um I think ... well its its preparing ( ) for growth its just the st- its preparing children to be able to (cooperate?) between each other ar between the society I guess when they’re older people if you if their not taught how to speak and write how the hell are they going to communicate ... I guess our society has put us in a spot where we have to teach them these things ... um I don’t know what they did before we had teaching I don’t know well I’m sure they had teachers long long like even in the neolithic whatever ages they had some form of teaching whether it doesn’t have to be like a teacher figure a father figure could be a teacher its like a transfer like transferring culture across like the aborigines they didn’t write anything down ( ) but they still transferred their culture different generation to generation I guess that’s a form of teaching doesn’t have to be written.

I. What about learning, what do you think learning is?

S. Learning is different from teaching ’cause teaching is more trying to get a specific point across whereas learning is the person that’s being taught an individual taking that idea and using it for his own purpose tha- I see learning as um not you can’t learn somebody something you’ve learned it off them like teaching is I’m going to teach you how to ride a bike and learning is the person that’s being taught how to ride a bike saying ‘oh this is how you ride a bike’ and learning like thr-making
mistakes and stuff saying well it doesn’t work if I do that doesn’t work if I do that so I learn through experience that this is the way it works

I. O.K. that’s it
Student 5

(there was some construction noise which intruded during the early part of the interview and rendered some parts of the recording indecipherable).

I. Um did you do Biology at school?
S. No, had nothing to do with the sciences
I. Didn’t do any science at all at school
S. No ( )
I. O.K. you went right right to year 12 did you
S. Yeah
I. Um O.K. so I can’t ask you what you thought of it then ... Do you think Biology is relevant though?
S. Oh yeah, many times I regret not doing it but I had my other interests that to me were a priority before Biology but I think the basics should be compulsory, its very relevant
I. Why do you think its relevant?
S. Oh well its just for your own general knowledge more than anything else ... (there’s) so much around you that if you don’t understand I mean I feel very ignorant about what life around (me?) to me its just the fundamentals ( ) there are times I’d like (to get?) more about it
I. Yeah O.K. do you think its relevant to the course your doing now?
S. No
I. Why is that?
S. Um the general science is yes but Biology in particular no because I’m doing a bachelor of education primary and you can only explain so much to a child they can take in like I said the basics are necessary but not in an intense
I. O.K. can you tell me what an what you think an animal is?
I knew you would ( ) ask me this, I knew it I was telling (my friend?) I said that’s got to be a question um ... let me say one thing before I read that piece of paper I couldn’t really give you biological definition to mean animal was something that had no intelligence it didn’t have to just be furry or anything like that it just didn’t have intelligence but if you want me to talk in a biological sense its all these cells and membranes and whatever you want to call (it) ( ) human life would be categorised under animal ( ) and the other differences a plant had as opposed to animal life

Well what are some what do you think the main differences between a plant and an animal?

Well the structure, the the way it takes in energy or fuel or whatever you want to call it the way it keeps itself going

Like how how

Oh well we consume things as through an opening like the mouth (or what have you?) whereas plants take photosynthesis and all that sort of stuff from the surrounding environment they don’t actually consume it through

Do you know how that works?

Oh not really no, when you hear about it ( )

Sort of familiar with it

Yeah when someone mentioned it to me I’d understand what they were talking about but (give detailed no way?)

O.K. um well what would you say for example to a an eight year-old who asked you um its probably unlikely but just say they did ask you to explain to them what an animal was and how its different to say ... Like do you think you might say to an eight year-old.

What the difference between an animal and a plant is?

Have you taught any done any microteaching yet?

Yeah we have

Well what age-group did you do
S. Year 2 ... one day she did a science subject with them they're more interested but I couldn't honestly say that they'd ask questions like they came up and asked me something like that

I. Well what say what say you were doing a unit on um on our environment and you were talking about animals and the importance of say ar ( ) some species um like that you might be doing a unit on ar the fact that some animals there’s not many of them left how would go about first of all you know saying what’s how animals live or what’s important.

S. Probably explain to them that an animal just doesn’t just take on the form of one structure (um?) you could have the human you could have the everyday recognised ones cow and sheep, cats, dogs and they you go into other things that a child might not have ever seen besides in books and things like that other animals that you wouldn’t know of um ... explain to them that well actually I think the best way would get a plant and then ask a child to compare it to an animal get them to make up ( ) ’cause I couldn’t honestly explain to ’em in a definite manner. Perhaps a child would perceive it differently a child would say oh well an animal has eyes or an animal has um feelers or what ever you want to call it whereas plants oh look this is really hard you picked me got me on the spot straight away

I. Its hard because we're sort of exploring part of your knowledge of something that’s that’s a bit foggy that’s all

S. Very foggy

I. But O.K. that’s fine what you’ve said is fine um if we go back to the passage can you remember when you sat down to read it what you actually did ?

S. What I actually did?

I. Yeah what you did as you read the passage can you remember?

S. Yeah all I kept thinking was ‘I knew you were going to ask and what do you think an animal is now, I knew it’ um I just I think I found it more humorous oh and very educational but but I knew just kept running through my mind I thought
'how is this relevant?' that's all I kept asking myself why is this why is he asking me these questions it wasn't the actual information that went in because like I said my mind isn't adapted to Biology and things like that you know it was a passage about maths or something like that it would sink in but something like that it just doesn't appeal to me and therefore it just goes gets sifted put it that way in the brain

I. Alright did you read the whole passage?

S. Mmm yeah I read it two or three times actually and if I ever read something I didn't understand I went back and read it again and at the time I did I did understand it but to give you an explanation now you know I can give you a general one but

I. So can you remember what the instructions actually said

S. Um yeah um you had to read it and then get questioned about it the week after

I. Right and did that have did those instructions have an effect on you?

S. Yeah but um

I. On the way you read it or?

S. Yeah 'cause I wanted to take in every detail 'cause I didn't expect it to be this sort of questioning I thought oh here we go he's gonna give me some test and

I. Like multiple-choice or something

S. Yeah something like in that sense ... so I did read it bit by bit and tried to take in all of it and then I thought 'well I can only take in so much when it comes to science and that'

I. O.K. um imagine if you had to read if this particular passage was part of a subject in the the BEd say you were doing something to do with animal and plant studies ( ) its important that well you had to read this and you knew you were going to be tested on the things in the passage the next week say its worth 10 per cent of your overall

S. And I only had that time to read it?
I. Ar yeah just say you did yeah how what do you think how would you approach it?

S. Um would of sat there and read it and read it and read it and read it knowing that I was going to have a mark next to my name would have made it different but this was a number and I though well people can’t associate that with me you know they can’t say oh well she was one that didn’t understand that or what have you so I took it for I do the best I could, whereas as an exam you know to compare it with an exam academically everyone would of probably just sat there for the next half hour and read it again and again but for something

I. And what would you what you would just keep reading and reading it in order for something

S. To take it all in. That’s my means of study oh a lot of people you know will go and read other books but a lot of people only need to read it once or twice and if they’ve got that sort of structure up in their mind then they’ll take it in straight away but I tend to read it again and again and then I’ll explain it to somebody else until I find that I know that I either do know it or don’t know what I’ve learned

I. O.K. um ... well why why are you doing the BEd?

S. Why?

I. Hmm

S. I’ve always wanted to teach. I’ve had a lot to do with kids through primary schools and that um I think its a satisfying job I honestly think its got to be one of the most satisfying most responsible jobs a person in the community could have um kids they just they get you on a low one minute and all they have to do is say one word and your back up again so its a non-repetitive job its a ... I don’t know I ’spose I’ll have to wait till I actually get into it a classroom situation to give you any other details but I’m really looking forward to teaching I do enjoy being among kids

I. Well like what do you think teaching is?

S. What do I think teaching is?
Transcripts of Interview: Student 5

I. Hmm

S. Um ... how would you say um a projection on a person's knowledge onto to someone who's not as knowledgeable or someone who needs more ... help (in areas?) of study

I. When you say help

S. Oh well peop- well if you look at it in primary stages a child comes to school not knowing how to read and write you've got to explain to them you've got to show them how to read and write adapt them to what's ahead of them things like that I mean there's a lot to it its not as basic as just what is teaching or why teaching every little area has its own specifications so

I. What about learning, what do you think learning is?

S. Learning? I think its a progression from one stage to another you go from not an ignorant stage but a a not a knowledgeable stage to knowledgeable I 'spose so its going from a stage where you don't know about something or you know little of but progressing to knowing more or all about it ... its (hard?)

I. How like like I mean take a bit of a risk how do you think that happens how do you think people, children, adults progress from not knowing to knowing how do you think it happens?

S. Well ... probably just I think the brain just gets either conditioned or it gets formatted in a certain to to understand concepts I mean the same with this Biology if a child is continually given biological terms biological concepts his brain will begin adapt to that sort of information and that whereas another child wouldn't so I'd just say its a a adaptation of the brain

I. When you say biological concepts, where do you get those from?

S. From a person who's more informed, a person who's learned previously to that child that's learning now but I mean a person never stops learning it just means like I said its a progression ... from one stage to another

I. Right perhaps you don't have to motivate people to learn because their learning all the time anyway
S. Yeah its in the environment

I. Its just ar just when you want them to learn something particular that its becomes difficult or a problem ( )

S. Yeah

I. Um right if we go back to a question a I asked you earlier about um ... reading the passage and you imagined you imagined that it might have been worth 10 per cent, if you if that was resource material something you could take away with you in your hand you had some references perhaps even to go to um what how would you approach the task then knowing that its was say worth 10 per cent just like a little test you would be having the next week

S. Can you repeat that again what do you mean by

I. If you'd been handed the passage say with a list of references tacked on the end of it to go and have a look at as a starter and then you were told that there would be a test on the topic next week and it was worth say 10 or 20 per cent would you have approached it any differently or in the same way or?

S. Um I'd probably taken it home and read other articles because you only limited on that page I mean I'd go into it a bit further with books and things I'd take down my own notes and not just study it through the sheet of paper but study it through what I'm learning as I'm going along what are the sort of things I can relate to to things around me and that. Oh yeah you'd approach it much much differently than just being told well this is a questionnaire you got a big question next week yeah question wasn't that was the word? Tested or questioned?

S. Um when you say questions are they multiple-choice? 'cause that makes a lot of difference, a lot of people's approaches change to that

I. Well how does your approach change when its multiple-choice?

S. Oh I've I've got this memory thing that I'll read something and once I see it again on paper it automatically know what it is do you know

I. So you find things that once you've read something um you find it easy to recognise
S. Yeah that's it to recognise it exactly

I. Even though you might not be able to actually remember it word for word

S. The second time I put it in a more scientific sense and that was after reading the passage, so I went over and said that an animal had a form consumed animals it um ... just took down facts from the sheet of paper so now it was no longer my concept oh it was my concept after being informed through that piece of paper

I. But you can't remember what

S. Not word for word no ... the one I wrote for 'what is an animal' the second time around was straight after reading the passage

I. Yeah

S. It wasn't whereas the first time it was my interpretation, fresh, no influences or anything I can't remember off hand or what was said mine was

I. When you when you sort of actually finished on that Wednesday did you have a lecture after it didn't you

S. Yeah

I. And did you remember any of it during the day or did you just sort of say well that's it I don't need to

S. ( ) next lecture I mean its bad enough trying to ( ) what's being said there but a friend and I did sit down and talk about it and it again it wasn't what was in the paper it was why you were asking me these questions

I. Oh you were talking about the purpose of the study

S. Yeah we couldn't understand what why we ask- kept getting asked about animals and things like that

I. Hmm

S. So it wasn't the actual information because for some reason my automatic um

I. Response

S. Yeah was to that this was a survey it wasn't it was what we understood of it not factually or anything like that but just our perception of it do you follow what I'm saying?
Hmm ... so what you're saying is that the survey that you perceived to be a survey that I would be giving you the next week that's different to say a test that you would have in a real subject.

Yes it is, exactly.

It's different in what way, it just means, do you think?

I don't know I mean whether it's just human nature or you know as soon as somebody says to you that this is a test that's going to get marked against your name you automatically freeze up and you want to take everything in but when you get told that this is a survey to see how much you learned from it now whether you get it right or wrong it's what you've learned it it's what you've consumed at that moment it's not something you've forced yourself into learning whereas tests half the time you do do do you follow what I mean?

Yep.

Yes?

Very good um the other thing do want um tell me a bit more about tell me a bit about your idea then about this intelligence and like if I get it right like you think that us um humans are intelligent but other animals are what? Their their also intelligent.

Yeah I mean there's so much that we still haven't learned about animal intelligence that some day will perhaps show us that their not as docile as what people think they are.

Hrm so what is is intelligence then? what does it, how do you describe it?

Um doesn't have to be some sort of writing or reading ... you know acceleration in one of those or anything like that but it's just being able to perceive what's around you, make judgements that will be of benefit to you things like that I mean people assume that intelligence if you intelligent then your going to get an A 1 in all your exams or whatever but that's that's a pretty superficial definition intelligence goes way deeper well that's what I believe I mean a person could be intelligent in other ways besides just reading and writing and academically.
So they respond to what's

So an animal is intelligent if they if they um you know are able to control themselves or move or behave in a way which is beneficial to to obviously their own self and perhaps even say cubs or whatever

Exactly. Families or whatever. That's true I mean if you saw you were driving along the road and a bird's in front of you now that bird might not be able to speak or anything but ( ) senses something coming at it flies away I mean that's intelligent to me do you know? its just an automatic response that has been of benefit to them

So say say ( ) take an example (perhaps not for me to?) say an eight year-old child as compared with that bird on intelligence how would you, would you differentiate the two or?

Oh ... Oh ... I find it hard to compare the like different forms its diff- seems a bit different there I mean humans are distinctly different, you but ... how can I say it I wrote in an essay once that an animal they perceive that animals are docile and that but that's only a human's perception and what an animal perceives of just as human no one ever knows I mean whether they do perceive anything of us or not so whether a child is more intelligent probably yes I won't say that their not I can't honestly say that a bird is more intelligent than a child but um the process

But that's human intelligence ( ) on the basis of human characteristics

That's yeah in comparison to hum- yeah so the process of intelligence I think would be the same I mean a child would jump out of

Its very similar you know what your id- concept is I don't know if you've read any Piaget?
Student 6

(the record and play buttons of the tape player had been pressed down at the beginning of
the interview, but the player had not been plugged in. This was not discovered until about
three quarters of the way through. Thus references made by the interviewer to 'what you
said before', etc., are references to what was said but not recorded).

I. What did you say you didn't do Biology at school did you
S. No I didn't do Biology at school I did science up to year 10 but nothing in years
11 and 12
I. Um ... ar and what did you think remember what you said before about what you
thought of it of some of the Biology that you did do
S. Yeah well you mean the topics we did?
I. Yeah
S. Right we did ar bit of ar we dissected a rat in year 10 I remember that was an
experiment we ar did a bit on plants and animals can't really remember ( ) we ar
did a bit on the environment and ar I think the natural processes which make it up
landscape and all that mountains um insects ( ) yeah basically that's it
I. Can you tell tell me what you said before about um like you thought what is
relevant? Is it relevant?
S. Is it relevant to what I ( ) well I think um I think it is to certain degree yeah I
thought that are its good that I know that stuff that I learned in years 10 in year 10
and before like you'd are it help me I 'spose everyday life its good to know what
animals do what and how they do it and what their functions are and everything
so you know just for general use like (if you own?) plants its good to know like
ar what to feed them and how to care form them and how to treat 'em so its good
in that way and also good for interest like going to the zoo and showing your
friends what animals do oh yeah its alright.
I. And do you think its relevant to the course that your doing?
Transcripts of Interview: Student 6

S. Um ... I think it will be because that's what I'll be teaching at the kids when I get out into the real situation to a certain degree like I'll be telling 'em, teaching them like at what certain animals do and that and if I know what they do what their functions are well then its not much point me um you know I won't teach them much will I? so definitely, but we haven't done much yet in Biology (unless?) I do stuff

I. Right and tell me again what you think an animal is?

S. An animal right its ar its similar to a human being it breathes its ar got similar features like legs, eyes, noses, ears, etcetera it um fur it eats and drinks (and lives?) reproduce like humans um moves around its made up of various cells which ... heaps of cells actually a lot of cells um

I. You made that distinction before didn't you between that you thought and and and a scientific view

S. Yeah well that's what that's my opinion that might not be right

I. Oh. Can you say can you tell me the difference again between what you think and what you said before about a good definition

S. Oh well that's what I think but it might'n be um a good definition

I. O.K. and what was that again?

S. A good definition?

I. Yeah, yeah

S. I don't know what is a good definition you can tell me

I. Um didn't you say before it was like um a scientific definition

S. Yeah well its not it might'n be a scientific definition but its mine

I. O.K. um and the main difference between a plant and an animal

S. Between a plant and an animal plants um ... plants can ar they they don't move around at all they're just stationary, animals can ar plants ... ar I think some plants anyway grow a lot more than animals like animals can only grow up to a certain limit but plants can grow like for example trees they they can grow up to several ar maybe hundreds of metres um animals are more interesting to look at I reckon
than plants I like animals better than plants (that’s my view?) um animals ar
they’re more similar they they’re more similar to human beings they look more
like they look like human beings more than plants plants look like plants

I. And when you read the passage what did you do again?
S. Oh just um

I. You thought the second page was (previously he had said that he thought the
second page was much harder to understand)
S. Oh yeah the second page was ( ) in my own opinion was very detaUed like it
didn’t it had a lot of information that I it didn’t go into my head I couldn’t
understand if I read maybe it a bit more better or if I had more time I probably
would of um

I. You said you ( ) treat it seriously you would have treated it more seriously if
S. Well that’s right if was for assessment or if was for a test something very
important to the course I would have um taken it more seriously and looked at
more closely but because it was only for this well you know I didn’t treat it as a
joke or anything um I treated it less seriously

I. Well just say it had been it had been something you’d been given by the lecturer
and then he said oh you know you’ll be tested on it next week its worth 10 per
cent what would you have done?
S. Oh probably would have taken it home and looked at it very closely and maybe ar
revised it in my own study technique like took take notes on it and ar read it over
and over until you know it went in or until I understood it clearly and then um
yeah that’s what I would have done actually looked at it closely

I. Um ... well what can you tell me why why you decided to do the BEd?
S. The BEd, the course? Basically because um my father was a teacher he’s a teacher
himself so that influenced me to a certain degree but that wasn’t the only reason
um I had other options but like the police force and um the air force too and also
something else but I chose this because I though well um its a good career um the
money’s good its ar yeah and think Uni would be good like I think I’d learn a lot
like a teacher’s a very respectable job um I think I’d enjoy it I enjoyed school to a
certain degree so that was good ar plus like the Uni is pretty good so far I’ve
enjoyed it yeah plus like yeah even though I knew that I wouldn’t be getting paid
for the next four years after that I’d be getting paid you know a pretty good a lot
of money so make up for the four years that I missed out with no pay at all

I. And what about what do you think um teaching is?
S. Teaching? its ar explaining and demonstrating and showing and all the things like
that to the kids like telling them what’s right what’s wrong demonstrating how to
do things and why do to it and what do you do and generally um explaining and
teaching just explaining to the kids to children to anyone really ( ) what are like
getting them to know things expanding their knowledge in different areas of life

I. What about learning, what do you think learning is?
S. Learning um ... its the process whereby someone um takes in new information or
expands the ar brain like if someone if someone learns or knows more about
animals that means he or she has learned more because ar they’ve ar they’ve taken
in more information to their mind which hopefully stays there

I. Hmm can we just go back again to that that question I asked you earlier about can
you remember when you read the passage what you actually did um can
remember again when you started you know what (Ud what sort of thing did you
do as you read it?

S. I just um I had the view that what I read or what I would read would ar it
wouldn’t do me any harm at all like what ever I did whatever I read ar probably
learn from it and I did I learned a few facts from it which I didn’t know before
also I took the view that well ar its for a good ( ) its something good

I. What about how (Ud you read how many times did you read it, did you read it
once?

S. I read it at least once probably twice then in certain sections I read it you know
three or four times just to a get the message to sink which in some cases was
pretty hard because information was pretty ar hard but yeah ( )
I. What how what made you pick out those sections?

S. Um well I read a paragraph say and by the time I got to next paragraph if I if I knew in my own mind I didn't understand it again I probably do it again but if I didn't understand it after four times I think I knew when I didn't understand something and if that was the case I just read it over again

I. Um... when you said before that ar... Biology did you think do you think it was relevant in general in general to you know yourself or?

S. Biology? you mean this course or my studies in general

I. No

S. Just general Biology, oh yeah as I said before I think its are good for interests sake um and for your for your own ( ) its just good to know about certain things in life its good to know how um animals and plants function and what they're made up of and what they're uses are for ... and how they do certain things and survive generally its its good to know that way its good to know in my course or in my own mind to ar teach people because that's what I'm going to be doing in a few years teaching people about not only Biology but other subjects to

I. ( ) um O.K... so what you said before was huh you know you were going along really well it was interesting what you had to say and the fact that we didn't have the bloody tape running um

S. Yeah

I. Um... ( ) like when things are um when you've got to do something that is worth say 20 or 30 per cent of the marks for the subject how do you treat it generally?

S. Oh generally

I. Can you give me an example

S. Oh just give you an example of language we've got a language essay due next Monday which is worth I think 30 per cent so um I haven't started it yet we had a few weeks to do it but in the next few days I'll be getting down to study like I'll be treating that very seriously 'cause it is for assessment but not only because of
that its for um its just food to know about things like language you know not because its for assessment because ar you’ve gotta language is a very a fundamental part of the course but I’ll be you know getting down studying looking over it reviewing the passages that I’m going to read ( ) I do various rough copies of the essay until I come up with the right formula then I’ll write it out but definitely it take up a bit of time but that’s what that’s what’s needed to um you know to succeed in the course you’ve got to have time for sure if you don’t have time I think generally people fail
**Student 7**

I. O.K. um I think you did Biology at school?

S. Yeah

I. Didn’t you? you did what um when did you do it at school?

S. Um year 11 and 12

I. Right did you do any other sciences?

S. Um (we?) did no not in year 11 and 12 that was all we only had to do one science

I. Right you only had to do one and you chose you chose

S. Yeah I did science in years seven, eig- 7, 9 and 10 and then Biology in 11 and 12

I. What made you pick Biology?

S. Oh well I didn’t really I wasn’t I was more interested in Biology I didn’t really like Physics or Chemistry um I don’t know like animals and the sort of things that they read like we got an outline of what was going to be in it the course and I thought ‘oh that sounded more interesting than the other ones’ so I did ( )

I. O.K. so um did so did you like Biology when you actually got to do it did you like it?

S. Yeah its a lot of practical as well and theory so we did a bit of everything so it was good

I. What what did did anything in particular you liked about it?

S. Ar ... I liked learning about um ... the parts of us and what what the functions (were of?) everything inside does and stuff like that um

I. Did you think do you think its relevant? Biology?

S. Yeah

I. Why do you think its relevant?

S. Why um ... well its about all living things (and?) that is relevant um its um ... I don’t know if more people knew about it or had the chance to do it probably realise that it is very relevant like um with learning about the body and that inside
you like maybe more people would um not smoke and do bad things to them ar I
don’t know its just interesting um

I. What ar what do think an animal is?
S. ... ( ) what do I have to go through it all?
I. Um well
S. I’ll just read it

I. I can see from from from the survey that you gave me this morning that you’ve
that you’ve written quite a bit so perhaps if you could summarise the main things
that you think are important in in describing what an animal is

S. Ar um its living its made of cells and that’s important in growth um reproduces
um its either bilateral or radial symmetry um its got a nervous system digestive
cavity um circulation and respiratory and all that stuff um ... it its able to move
around not like plants they’re immobile um ... what else

I. Well the other question I’ve been asking is um what do you think the main
difference is between a plant and an animal

S. Mmm well a plant’s immobile and animals aren’t um ... animals are able to eat
plants or animals but plants don’t really eat animals um
I. Can you remember ar how plants get their food?
S. Oh right yeah um they can um from the roots and the soil get nitrates and um they
can trying to remember my Biology um
I. Your recalling this from school now
S. Oh and what we read last week its hard to remember what we read um they get
um moisture they get it from they get oxygen and um they get carbohydrates um I
can’t remember carbon dioxide um hydrogen, oxygen, nitrogen from the air and
the soil ar I don’t really remember that’s about all
I. Um well what about if I said to you photosynthesis do you know can you
remember what that is?
S. Oh right yeah its the manufacture of um sugars and um ... I don’t know
I. O.K.
S. Um its through ... um ... I'm trying to remember I can't remember

I. O.K. well what you've remembered that's fine ( )

S. ( )

I. O.K. um now if you think back to the passage last week can you remember what you did as read it sort of thing what?

S. Um just remembered the main sort of points of what it was trying to say um I tried to take it all in together but it was hard to sort of remember it all parts of it um ( )

I. Did you ho- you read it through once did you?

S. Yeah 'cause I thought that's all you could read it through I didn't know you could read it through a couple of times yeah I just read it once fairly slowly so I could remember it

I. And that was it

S. Yeah so I can't really remember it

I. Right um ... and as you were reading it through did you find it new or familiar?

S. Familiar not really new like a couple of words were new um can't remember what word it was think it was about the digestive cavity or something nervous system it was sephilism or something?

I. Cephalisation

S. Yeah something like that I couldn't I was going to (write it in my?) thing but I couldn't remember what the word was

I. But you think its about what do you think what that word refers to?

S. Um what I was talkin' about the digestive cavity and the nervous system and things like that

I. Right O.K. um do you remember the instructions at all? to ( ) the top of the page what they actually said?

S. No think I was in too much of a rush um

I. Why was that?
'Cause I came in late and there was a lecture on next so um no I don't know if it said just read read the passage and give it back to you and they to answer questions but I thought I can't remember if it said read read it once or twice or

So you sort of the instructions didn't really have an effect on how you read it you just read it through the once because you were you thought that you didn't have enough time or

Yeah but I though that was like the general idea just to read it through once and see how much you could remember

What gave you that impression?

Um I don't know it was like a test

Right um if you imagined just say ar I gave you someone had given you that passage um and say with a list of references tacked on the end of it and they said you take with you um but next week there'll be test on what's in the passage ( ) list of references 10 or 20 per cent of the total mark the subject how would have approached it then do you think?

Um

What would you have done?

Well read the passage as many times as I could um get the main things out of it and then I go to the references and just compare and then if there's new information um or if its a bit different I'd um I don't know to that down as well or learn that as well

O.K. um can you tell why why you are doing the BEd?

Um no yeah um I've just always wanted to be a primary teacher since I was little I s'pose and um I just want to help little kids to learn and see how they learn and what they learn um I don't know I just like little kids

What do you think influenced you that way that you know like liking children

What did I don't know

Mum or Dad or you just

Its just how I felt felt at the time
I. Have you had much to do with kids before you came to uni?
S. Yeah I've got um I haven't really got any little cousins or anything but we've always had little kids in the street or friends with little kids and sort of um baby sat a few times and um I don't know
I. What do you think teaching is?
S. What do I think it is?
I. Teaching yeah
S. Um ... just showing sort of making a model of what can't really describe it
I. Have you ever really thought about it before?
S. Not really
S. Its just showing ... like you could teach them about um ... different rules ( ) at home you can't do this and you can't do that its just really showing them what's what's um the required behaviour what um its hard to describe
I. What about learning, what do you think learning is?
S. I don't like the questions
I. Its the last one so there's one more after this I mean learning with not many people teach but everybody I guess learns at some stage oh you know more or less all the time so perhaps if you think about how you learn or
S. Just by observing and listening um things around you and then just making meaning out of what you are seeing and listening um and then acting on it like you might ... you might think oh that's something good to learn or its not good to learn or you just sort of take responsibility for your learning um just learn what you want to learn um from what you can see and hear
I. When you said go back to a question earlier when you said that um you read the passage and you read it through slowly what do you mean by slowly what does that entail when you read slowly what did you do you just
S. What do you mean?
I. Is that different to how you would have normally read something?
S. Just the normal book or something
I. Yeah say you were reading the paper

S. Oh right yeah

I. Is it different to what you did with the passage?

S. Yeah

I. Well tell me can you tell me how how its different?

S. Well in a paper I always sort of read the ones that look good like if its got a picture to it ( ) um if it interests me from what I can see but with that I had to read it so and I knew that there would probably be questions on it or something so I read it word for word and like with the other one I'd just I'd see few words and go I'll just skip that bit in the paper um I'd sort of take notice of them ( )

I. Did you find any as you know as you read it did find that any any parts of it were difficult

S. Not really no 'cause I'd seen it before but if I hadn't done Biology


Transcripts of Interview: Student 8

Student 8

I. O.K. did you do Biology at school? You didn’t do it in year 11 and 12, what about year 10?

S. Um ... oh bits and pieces, we did bits and pieces during year 11 and 12 I didn’t do the Biology course I did the general science one and we just did ’cause general science was just an amalgamation of them all sort of a basic overview of everything so I only did little tiny bits

I. Right well that from those little bits that you did can you remember whether you liked it or not?

S. Oh ... um I really don’t know ( ) I put it all behind me now ... it wasn’t too bad I remember in more so in year 10 and that where we had to draw the particularly draw the like the cell and colour it in and label it and all that sort of thing so it mustn’t be too bad

I. Did you did you think it was relevant?

S. Oh yeah ’cause you can um ... oh its just shows you processes that plants go through and animals go through to survive and how they work and that sort of thing so it wasn’t too bad pretty relevant

I. Do you think its relevant to the course that your doing now?

S. Oh ... possibly ’cause some of the processes you can sort of make analogies between maybe

I. What analogies?

S. Sort of just like the processes you got to go through to break things down and get it in their simply- like we’ve been given things in the simplest form sort of thing so its been broken down and just easier little bit easier to understand sort of thing just accumulating information through that way sort of like the reversal of some of the processes (they?) go through that’s the way I sort of look at it
I. Um ... when you say you did sporting science did you do any any of the you know did you come across any any biological topic, topics in Biology when you did that course?

S. Um the only things I can think of would have been oh ... in are sort of a subject training fitness where there would have been at the energy systems used just the break down of the energy yeah the energy systems used like ATP and CP and at the break down of glycogen and all that sort of thing that's about the only thing really and the different types of muscles

I. When you said before um put it in a simpler form things that you are learning in the BEd

S. Right

I. Why do think that is?

S. Oh just easier to comprehend especially that's what it seems to be at the start this course anyway

I. Can you give me an example or?

S. ... the easiest one I'd say for me to relate to is at like I'm doing the P.E. ar elective and its just a simple, simple overview of sport science or human movement its just broken down into so its that easy to understand sort of thing you can't really go wrong um and later on we've been told it does progress and get a lot harder and more in depth um that's about the best example that I can think of that I've got anyway

I. O.K. um what do think an animal is?

S. Um ... well its its a living organism ar ... I'm just thinking about how to go about it do we from what we've learned from this

I. Anything that you think if that means what you've what you remember

S. Oh well its just sort of basically what we (gained?) from what we've done with you ar its a living organism it has appendages has ar has a form of symmetry whether its bilateral or sagittal I think um generally has a has a outer covering to
are protect it from whatever ... generally eats food for food for survival and sex for reproduction

I. O.K. um what do think the main difference is between a plant and an animal?

S. Oh well generally plants are are stationary rooted to the ground and go through different process are of oh orgasi- um processes for obtaining food photosynthesis against the are digestion of foods um I think there's a different cell structure are their animals have a more a brain usually involve complex things which is thought and controlling movements that sort of thing that's about it I think

I. Right um ... now remember that passage that you read from last week um can you tell me what did remember what you did as you read the passage? or how did you go about reading it?

S. Just oh just had a glance through it like front back um just read through it and just remembered bits and pieces and that I thought were more relevant than others that's about it

I. Hmm um what did you do read it through once or?

S. Um well I sort of skim read it first and glancing through it and then read through it and then just then ar sort of skim read it again just to sort of reinforce

I. Um can you remember what the instructions were?

S. For the passage or?

I. Yeah like ar if you remember there was

S. On the board, that you wrote on the board or?

I. No the the passage that was printed at the top of the page before you before the actual writing

S. ... No

I. 'cause I was I wanted to ask you if they had any effect on the way you read the passage

S. Oh I can’t remember, no I can’t remember them
I. So when you say you skimmed what you did you read each sentence or you just, what did you actually, what do you mean by skimming?

S. Oh well just going through and sort of picking out points like ar relating to what an animal is such as ar ... oh just going through like appendages and locomotion ar oh the axis of symmetry and just going through and just picking out points that I could sort of relate to and before I read it properly that I could remember and then just read it again

I. Hmm O.K. um ar ... well what what why why did you choose that way is that way you always read something or?

S. Basically yeah I just glance through like its just sort of like when you go to ar for example you go to the library you can’t sit there and read read everything is a book to find something so you just sort of skim through it so that’s what I do first and everything skimmed through first and if I see that its relevant relating to the topic whatever it may be and I just I’ll grab that book go through it later on when I’ve got more time

I. Um O.K. can you if you’d read that if that passage had been if I’d been a lecturer and I’d given you that passage to read and ar take away with you say and perhaps a list of references with it um and you knew that you’d be tested on it ar what was in the passage the next week and say it was worth 10 or 20 per cent of your of your mark total mark how do you think you would’ve approached it?

S. Pretty much the same um if you’d given references and I knew I was going to be tested I probably would have gone and done a little bit more to sort of expand those points that you had given in the passage just from the references and check them out if I’d known I was going was going to be tested on

I. O.K. um can you tell me why why are you doing the BEd?

S. ... um

I. Like you said you did sport science, what what made you decide to to go on and do this course as well?
S. Um well doing the other course that was just I didn’t know what I was I had I really didn’t know what I was going to do when I left school so I did that course and then after finishing that oh we did a for one of the subjects we had to go out and teach or coach kids and play sport once a week for about I think it was about eight or nine weeks at a school up here and ar I really enjoyed that and I thought I could I could get to like this a little bit more and thought oh well teaching’s a pretty secure job once you’ve got a job I get on well with young kids and I thought I could help them somehow ( ) that’s sort of one of the reasons bit of parent pressure to get out and do something ’cause I didn’t do much last year but mainly just to I get on well with kids help them learn because they’re sort of the future that’s about it I suppose

I. Um what about teaching, what do you think teaching is?

S. Oh transference of knowledge building up social attitudes that are relevant ... and ar helping them cope with the demands they’re going to face later on especially once they primary going onto to high school tertiary and just life generally

I. When you said um like to help kids or um building up certain attitudes how how do you how do you think teachers go about doing that? well its pretty general I guess but if you can think of an example how would you go about doing that? Have you done any um microteaching? um what was the unit did you do a particular unit or?

S. Oh well we were just sort of given a topic farm animals I got kindergarten so it was just basically ... just transferring or getting them involved that’s the only we had to do

I. In in what?

S. Kindergarten I was I did well I was getting them I did sort of broke away a bit I did farm animals and alphabet letters that were associated with farm beginnings of words such as d for dog and c for a cow and just the farm animals that sort of thing we’ve got another one coming up questioning so just sort of getting their
beliefs and question- questioning them on what they believe and that sort of thing
I really don’t know

I. Um O.K. what do you think learning is?
S. Oh well the acquiring of knowledge, social skills, social attitudes

I. Like with the kindergarten kids that you
S. Oh with everything um like for everyone really
I. How do you think the kindergarten kids approached your unit how do you think they they learned it
S. Um ... oh kindergarten you had to make it fun and interesting in a short time because they have only got a short attention span so if you can do that with them I suppose that sort of might just trigger something off and they just sort of remember it and learn the alphabet and that sort of thing if it is fun and interesting in that short time that we have got if its dull and boring I don’t think they’re going to take much interest and participate in the class as much so there not going to learn as much I’d say

I. Before you said acquiring knowledge how do you how do you think we acquire knowledge?
S. Um repetition just through experiences everyday experiences ar ... just modelling off other people that’s what that’s what they’re doing I’d say um ... yeah modelling repetition, just general experiences picking up just things like that information

I. Um can remember actually what you actually wrote on that ar second survey that we did last week?
S. Which one was that?
I. The one we did last week when you read the passage um I was just wondering that’s all if you can remember it um you read you said then there was a questionnaire about how you felt and then and then you had to write down your thoughts about animal
S. On what it was again?
I. Yeah do you remember?
S. After we handed the sheet back?
I. Hmm
S. Oh well its pretty oh
I. Does anything come back other than what you’ve already said
S. No basically ... what I said before
Student 9

I. Did you do Biology at school?
S. No nup didn't
I. What did you do any
S. Physics and Chemistry
I. In year
S. 11 and 12
I. Right
S. I did them for the H.S.C.
I. O.K. um in year 10 did you you would have done some
S. It was yeah general topic general science that sort of thing and that was a bit of everything really had Biology in it bit of Biology bit of Physics bit of Chemistry just a general strand
I. Can you remember anything you did back in year 10
S. Oh um um one thing we did we did um for we were doing back in time like dinosaur age and stuff we were doing why things become extinct and we did this like a big flowchart from one animal how it adapts to different environments it was like a big flowchart that's that's always stuck in my mind since then 'cause we did it in a group and we always when something became extinct we did like a little grave and nobody else did that so sort of stuck in my mind
I. That was a good idea
S. Yeah
I. Did you from what you remember ar from year 10 did you find it interesting at all Biology -logical topics?
S. Yeah 'cause it was a general strand it was sort of in bits of everything we were always sort of chopping and changing around the place and so your mind kept ticking over what are we going to do next was interesting yeah
I. What made you choose um Physics and Chemistry? say rather rather than do Biology?

S. I don’t know um well um when I started oh before year 11 I had being a pilot in mind so I took Physics and Chemistry ’cause I know that they were essential for a pilot if I was going to follow that through later on and Biology didn’t really come into like I had teaching as well in mind and Biology didn’t come into any of the as as a job motivator you could say it wasn’t one that I wanted to follow up

I. Um do you think ar that Biology as a subject as a topic of study is relevant?

S. Yeah um I s’pose it depends want you want to do as as your career what career you want to find like a lot of my friends one of my friends did Biology she’s up in Sydney doing medicine doing radiography or something like that so I s’pose that’s going to help her later on in medical field just depending on what you want to do

I. Um do you think its relevant to this course?

S. As in teaching this course I’m doing now Bachelor of Education um not particularly I don’t think so no ar only in maybe the strand of P.E. like the elective that I’m doing it might come in it a little bit there with some of the stuff we’re doing but otherwise I don’t think no its not that relevant to other course to other bits of the course

I. Um if if somebody asked you um for some reason they they didn’t have a clue ar what Biology was about what would you say?

S. Um I’d tell em its the science of living things living things ar plants and animals and ... exploring living things and how they survive

I. O.K.

S. What happens to them after they die and stuff

I. Um what is what do you think an animal is?

S. Um just think back ar no well an animal I think is a living thing well obviously but um can move about as opposed to a plant which is sort of fixed animal is
pretty free to move where it wants um depends on food for survival and it has a heartbeat ( ) like that

I. What does a what do you think a plant depends upon for survival?

S. ( ) plant ar requires the sun sun and water and something to be fixed to like soil or the ground or something it just needs the sunlight and the water to survive

I. How does the sunlight and the water come into it?

S. Oh well oh sunlight um strikes the leaves or something and photosynthesis occurs and the water goes in through the roots and the food goes up to the leaves and then its photosynthesis is occurs and changes it into starch I think I can’t think of remembering back a long time that yeah like you couldn’t put it in a box and expect it to survive a darkened box it just wouldn’t it would die

I. Is there any other um differences between a plant and an animal?

S. Um ... um well most most animals almost all animals I s’pose take in food through a mouth or some other inward thing rather than as a plant soaks it in through the roots and through the leaves and it defecates if that’s the word it has to go to the toilet I s’pose

I. Um can ... you remember the passage that you read for me last week um can remember what you actually did as you read the passage how you approached it?

S. Um well I sort was reading through it and sort of tried to assimilate it to the things that I already know like ( ) animal ar thinking of horse or a cow or something bit of about the plant um you know thinking of a rose bush or a tree or something and I think it mentioned um sponges or coral or something and that picture came up in mind and you know I could see the difference between that and a cow or that and a plant

I. Um did did you how many times did you read it can you remember?

S. I skimmed through it pretty quickly once and had went back and read it through and then as I was sort of answering the questions I sort of came back to look at that particular section of passage and then sort of re-read that section and wrote an answer for it
I. Right um did the instructions for the passage have any effect on the way you read it?

S. Um not really um its that's the way I tend to read is skim then go back and go through it slowly I did read the instructions but I don't think they had any particular bearing on the way I was going to go about and read it

I. So when you actually answered the ar survey the one that I gave ar 'what is an animal?' um what you referred back to the passage to answer that you you?

S. Hmm

I. What did you do then did you read?

S. Yeah um yeah well I read the question and it might say ar does ar can't remember the questions exactly does an animal take food into its mouth or something I'd go back and look at that for that section just to find the a correlation between question and a possible answer in the passage and then reading that possible answer to give me an idea for my answer

I. Um if you'd read this passage for a subject in a course that you were doing and the ar the lecturer had said take this away with you and he'd also given you a list of references say and he'd then said that it was that you'd be tested on it the following week and it was worth 20 per cent what how would have approached it then do you think?

S. Well I'd ar take it away and read it obviously ar take it away and read it and then ... list of references I'd probably look up depending on how many there were if there was ten references I'd probably look up oh five five at the most ar but not just I wouldn't go and get just one reference I'd go and get a few and read up on the relevant bits in those references as well as the passage to study for that 20 per cent test

I. O.K. why are you doing the BEd course?

S. Ar ... I like kids and once I got um like to the beginning of year 12 and I wasn't doing that well in the Physics and Chemistry was fairly going all right but Physics was down a little bit so I realised that maybe the dream of the pilot was going to
I. What do you think teaching is?

S. Ar teaching ... sort of like passing on knowledge not necessarily what you know you know yourself just getting the learn passing on the knowledge to the kids so they can learn and grow up and find their own careers ... um just

I. What about learning, what do you think learning is?

S. Learning ar that's an acquisition of knowledge or either through sitting down at a book and reading it and saying right I've learned that or just through experience like you might be walking along the street and go to cross the road and a car will screech to a halt and you think ar I have to stop and look so you've learned either through experience or just sitting down and straight out of a book

I. When you 'straight out of a book' what happens then?

S. Oh that's just reading and if just reading it through and if you like it you'll go back and probably read it again and it will stick in you mind if its something that you if it was just something that interested you could say that its the same at school where you are required to learn stuff from a book so you'll sit down and read it knowing that you have to know it or that it is a part an essential part of the course or something so you learn learn from the book its just by reading yourself and working out assumptions and stuff from it
I. Um did you do Biology at school?
S. Years and years and years ago but I only went to fourth form and did half of like six months of fifth form so I didn’t do Biology in the what do they call it year 11 and 12 now
I. Right, O.K.
S. I just did the basics in the junior high school
I. O.K. um can you remember back then what what did you think of it?
S. I enjoyed it. I think Biology was my favourite part of the science ’cause it was all lumped in together
I. Right
S. And except for the cutting up of the animals I enjoyed it
I. Um so you what you left school be
S. Halfway through fifth form as it was called then
I. Oh right yeah. What and you didn’t want to go on and do Biol- or
S. Oh yes I wanted to go but because of family reasons I had to leave then
I. O.K. fine
S. That’s why I’m back now
I. Yeah, good. Um do you as a general subject do you think its relevant?
S. Yes yes I do. It helps you understand you know all living things specifically human beings I think you know which is very useful thing to understand
I. Um O.K. and what like do you think its relevant in this particular course or?
S. In the the education course?
I. Yeah, the BEd that your doing now
S. Um ...
I. Or how would you rate it against other things?
S. I don’t I don’t think that its as relevant as you know taken to extremes. Just a basic understanding of Biology which I think I got in the junior high school I
think is useful as a teacher and also being able to teach 'cause its primary that I'm doing, bachelor of education primary and I think yeah just the basics there is relevant and useful

I. Um can you remember ar what an animal is? from what you read?
S. Um from what I read?
I. Or from what what you think an animal is
S. Yes I changed it slightly in my second one (second survey) after having read that paper because I when we did the the second week with the no cell wall and cell walls (multiple-choice survey?) I couldn’t remember which one an animal had and then I read it I remembered oh yes that’s right and you know that sort of thing cause those that didn’t stick from school

I. Right so you recalled when you actually read the passage and that part
S. Yes
I. You recalled that from
S. Yes that’s what I put in my reaction you know when you said that you found this interesting, boring or whatever I put interesting because it brought back all the things I had learned and it wasn’t that well I suppose I had forgotten, but they instantly came back to mind and there they were ‘Oh yes!’ you know

I. Good. Well what would you say if you had to sort of give a quick summary
S. Of an animal?
I. Yeah
S. An animal is a living thing that ingests food that was once living um it has no cell wall and it usually is capable of movement and when it reaches adulthood it stops growing, it doesn’t change its shape any more

I. With the um the cell and the cell wall do you want to describe to me what you think a cell is
S. Um ... a cell is a single a single cell um it has a nucleus and in plants they have cell walls which is ar um it has a nucleus and in plants they have cell walls which is ar um I can see it um ... no I really can’t go much more than that
I. Right that's fine
S. I've got mental images of the two different cells but describing them is difficult
I. Right um you also mentioned um the alimentary tract
S. Yes the digestive system, mmm
I. Is that
S. That's peculiar to animals
I. Right O.K. um and what about radial symmetry
S. Radial symmetry is like the cartwheel symmetry um I'm drawing in the air its not going on the tape
I. That's alright
S. And er things like starfish and sea urchins and those sort of things experience ar have that sort of ar symmetry
I. And what about bilateral
S. Bilateral that's it I knew I got half I couldn't remember it yes that's long one plane of axis in living things usually its in proportion to the way it moves
I. Right. What about sensory organs um ( ) also sensory organs
S. Yes
I. Can you give me an example of a sensory organ
S. Sense of touch, sense of smell, sight, hearing ... taste got 'em all
I. Yeah. Um right, about the passage can you remember it from last week like what you how it was actually set out got a copy of it here um can you remember what you did as you read the passage? Once you'd read the instructions can you remember what you then did?
S. Yes. I read it through slowly in an effort to retain what what it was saying and then when I'd read through once I went back through and read it through again paying particular attention to anything I found that was new um like the radial symmetry although I knew it existed I'd never really given it much consideration are especially pertaining to animals I'd never stopped to think that starfish had lots
of axes of symmetry um so I read that bit again and the um the term about a brain
the word’s gone its starts with c, I tried to remember it

I. Yeah um cephalisation

S. That’s it I tried to remember it because that was a totally new word to me and I
imagined that I wouldn’t remember it but I thought if I saw it written again I’d
know what it meant

I. O.K. um good um what about the instructions can you remember what the
instructions were before you can you remember what they

S. Um the instructions said something along the lines of read it through carefully and
questions will be asked next week. I can’t remember any much more about that ()
the instructions

I. Did can you remember when you read them did that have an effect on how you went

S. Well yes because I thought ‘well they’re going to ask questions about it next
week’ and I knew that I had to hand it back in and I wouldn’t get time to study it
again I tried to remember as much in that short time that I had as I could

I. O.K. um ... and do you think like ar if you if it hadn’t of been kind of like part of
a study but actually part of a subject that you were doing and that the test that you
or or the questions that you were going to be asked the next week were a test

S. More important

I. And and you know say was worth 10 per cent or something, would that of
changed the way you read it do you think?

S. I might have been very reluctant to hand it back. I might have read it through a
few times and really consciously repeated and repeated the bits that I didn’t know
that I wanted to remember like word that’s gone again

I. Cephalisation

S. Cephalisation yeah

I. Um O.K. alright why why are you doing the BEd?
S. Um I've always wanted to be a teacher from the time I started school. That was the one ambition in life and then when I had to leave school early of course I lost the chance I got married young um and then because my husband's got a well paid job there was never any need for me to work and now we're looking at going into farming and teach- my husband's in computers and teachers can go places that computer people can't go and it just seemed a great opportunity to convince the family that I could go out and do what I've always wanted to do

I. Good um so your enjoying the course so far?

S. Yes yes its a lot of work but I'm not finding it difficult which I think adds to the enjoyment oh its just finding the time with three children and a husband and a goat farm but other than that yeah um I'm coping I seem to be doing well with my essays ( ) getting distinctions which is pleasing me no end

I. Um alright well what do you think teaching is if you

S. Hum teaching is imparting knowledge onto other people in my case it will be children and encouraging the people I think to learn for themselves to to want to learn you know I don't think that teaching stops at a person saying this is how its done or this is what it is I think a teacher really needs to encourage children to want to go out and find out things for themselves ... and to also give them the skills to do it

I. Yeah do you think that is difficult like ar do think that the course provides you with strategies for doing that or

S. Yes yes so far and I mean we've only haven't even finished first session I've learned quite a bit about providing children with strategies for learning the essay that I've just completed was on learning disabilities and um I concentrated on cognitive training and behaviour modification for learning disabled students and I found that extremely interesting and I think it will prove useful in an ordinary classroom and I was very impressed with that being one of the questions

I. ... The other side of the coin is learning. What do you think learning is
S. Oh ... well we learned in one of our essays our lectures that behaviourists say that learning is a change in um behaviour through to form a stimulus and reinforcement one or the other being changed I don’t know quite if that’s exactly how it is um learning is taking in information and storing it away for later use um I can’t think of much else of what learning is

I. O.K. that’s fine. Um ... when you say taking in information um what then what do you think then becomes important for a child?

S. I think children basically only learn what they perceive to be important to themselves. I don’t think that um children you can give them facts of something that they find totally irrelevant they may learn it for a test but you ask them in a years time and I don’t think its there so I don’t believe they’ve learned it its only things that are there long term that are actually learned in my opinion.

I. Right so you think there might be a difference between learning something for a test and learning there’s another way of learning or?

S. Yes I I think that children when they learn for a test if they don’t find the subject relevant simply um repeat it over and over themselves and they’ve got it there and soon as they don’t need it any more they don’t practice it any more and because it has no relevance to them it just goes it just disappears whereas if its something that they maybe not even have to learn for test just something they’re told in class or outside the class that they find interesting its in there and it stays there. I know with my own children that’s how it happens my my four year-old son sat in on a a lecture that I had to go to on computers a couple of weeks ago and last Friday he was telling me things that the lecturer had said on care of disks and things like that and he the computer at home and he was saying things like ‘you mustn’t leave magnets near disks you know’ you know no one was aiming the lecture at him and he was sitting there drawing away but he found them interesting mmm yeah what two or three weeks later he still remembers em that’s learning whereas things that she said that he didn’t find relevant he can’t remember her having said so you know
I. If we can go back to um when you read that passage um you said that if it had been part of the course and had been part of assessment you would of been

S. Made a conscious so retain it all

I. So you didn't make that kind of conscious effort because you knew it was or what?

S. Mmm ... I made some effort because I read it twice and I concentrated on the the bits that I didn't already know um but and I relied on that oh that word's gone again

I. Cephalisation

S. Cephalisation I wonder why I can't remember it

I. Well what do think it means, can you remember what that means?

S. Having a brain ... just the physical fact of possessing a brain

S. Yes but other than that as I say I did make a conscious effort to retain some of it because I knew that you were going to be asking questions about it and even though I didn't perceive the exam or what ever you want to call it as vitally important I still wanted to be able to get things right

I. O.K. um you wanted to be able to get things right why is that?

S. I don't know ... I suppose its much more pleasant to be able to sit down and do that um any of your questionnaires and know that what your saying is correct

I. So its important to you

S. Yes yes I noticed that the first lot of questions that you had I didn't find hard 'cause they all said what do you think and I mean you can't get that wrong if its what you think but other students said 'Oh I'm sorry I did this and its too hard' and I don't think they homed in on the 'what do you think something is'

S. ... no I was just surprised at the comments that they did make because it didn't worry me I thought well O.K. you know this is what I think whether its wrong or wrong I'm afraid its what I think whereas they tend to get a bit anxious didn't they and some of them didn't come back