Introduction

Oh why must we endure
All the whims of every boor
That forces us to sow
Every seed we wouldn't grow?

They don't know more than I,
But teach me they will try;
They'll destroy each private thought
That, fleeting, you have caught
To savour in your mind,
Then get discovered to find
Yourself torn apart and shamed
Like a criminal, be blamed,
For the nation's wanton youth
Egocentric and uncouth.

Then you're standing on the rim
Of the homicide of him,
And his petty little ways
That will rob you of your days,
Of youth and love and light,
To be banished from your sight
For numbers, quotes and corn.
I regret that I was born
If I must spend another day
Wasting life this ugly way.

I'll wait till I can be
On my own, at last, and free;
I'll walk down the aisle and frown
In my silly cap and gown
And feel a pang of fleeting years,
Then muffle it with cheers;
For now I'll choose my road,
My food and my abode,
And live a life of my own
When these tortures I've outgrown.

Bonnie Robertson

This contribution to the University of New England (1978) Orientation Handbook highlights many interlinked issues of learning and teaching in higher education. In it the author expresses her perceptions of the tortures of her learning environment, and the discrepancy between her approach to learning and her teacher's approach to teaching. For this student the outcomes of her learning were clearly unsatisfactory.

Much research into learning and teaching in higher education over the past few decades has focused on the interrelationships of these and similar issues. The 3P model of student learning, that has been adopted in some form by many researchers (e.g., Biggs, 1978; Dart & Boulton-Lewis, 1998; Prosser & Trigwell, 1999), captures some of these issues and was adopted as the framework for this thesis. The 3P model highlights the interactions between the characteristics of students and the learning context, students' perceptions of their learning context, the approaches they take to learning and their learning outcomes. This research study focuses on two aspects of the 3P model; student's approaches to learning and students' learning outcomes, as well as the relationship between these two aspects of learning.

The study context is a first–year biology topic that is studied by students either by distance or on–campus at the University of New England (UNE). At UNE, the distance and on–campus modes are known as "external" and "internal" modes, as many "distance" students also have a short on–campus, residential component to their study. The external and internal terminology is adopted in this thesis, to refer to the distance and on–campus modes respectively.

Three research themes were posited at the outset of the study. The first was to identify the approaches to learning adopted by students in a specific topic area. The second theme was to identify the qualitative variation in learning outcomes from that specific topic, using (and testing) recent developments in the SOLO model. The third theme was to investigate the relationship between the learning approach adopted and the variation in learning outcome.

The philosophical framework for this research study is described in Chapter 1, together with a discussion of different paradigms in research into student learning in higher education. The multiple conceptual lineages that have converged in research into learning approaches and outcomes are reviewed as a background to the research study. The chapter ends with discussion of the 3P model and the broad aims of this research.

Chapter 2 reviews the literature relating to student approaches to learning, qualitative variation in learning outcomes, and the relationship between these two factors. Particular emphasis is placed on studies of learning that have been conducted in a first year tertiary science context, and those that have used the SOLO model as a measure of qualitative variation in learning outcome. This chapter concludes with an outline of the three general study themes of approaches, outcomes and their inter-relationship, and a number of more specific lines of inquiry within each of these study themes.

Chapter 3 presents the context and research methodology of this research. Details of the unit context are described, as well as the particular scientific concept for which students' learning outcomes were investigated. The research methodology, which was based on a triangulated design consistent with its underlying philosophical framework, is described, justified and evaluated.

The following three chapters, Chapters 4, 5 and 6, present the results relating to the three study themes. Each of these chapters is organised according to the lines of inquiry guiding the investigation of each of the themes, and a number of more specific research questions within each of the lines of inquiry.

Chapter 4 presents the qualitative and quantitative results pertaining to the first research theme: identifying students' approaches to learning in a specific, naturalistic learning context. Results relating to the second research theme, of identifying qualitative differences in students learning outcomes, are presented in Chapter 5. Chapter 6 presents results concerning the final research theme; identifying the relationship between learning approaches and outcomes, particularly as measured by the SOLO model used in this study.

The results that were presented in Chapters 4, 5 and 6 are discussed in relation to previous salient literature in Chapter 7. This general discussion highlights and considers areas of commonality and dissimilarity between the results of this study and other research.

Finally, Chapter 8 raises potential limitations of this study, and provides a brief synthesis of the major findings of the research in relation to the three guiding study themes. The implications of these findings for theory, practice and future research are then outlined.

Chapter 1

Theoretical background

Introduction

Educational research has historically been conducted within a range of philosophically and methodologically diverse research programs. This broad and disparate research foundation demonstrates several important and far–reaching complementary findings about learning and teaching, as well as cross–fertilisation within and between paradigms.

Several strong and consistent messages about tertiary students' learning have emerged over the past few decades from this research base. One of these is that the way in which students approach their learning matters, and the other is that students can exhibit qualitatively very different learning outcomes. These two aspects of learning are interrelated, and also relate to other aspects of the learning and teaching environment, including perceptions of students and practical aspects of the pedagogy that they experience.

The purpose of this chapter is to analyse the theoretical background to current concepts relating to tertiary students' learning approaches and outcomes. The chapter begins with an explanation of the philosophical underpinnings of the research reported in this thesis, and a discussion of different paradigms in educational research. The second section of this chapter outlines some influential idiographic research into student learning in higher education, and the following section discusses influential research from the nomothetic tradition. A model of teaching and learning in higher education, which has been informed by a combination of the research traditions discussed, is then described. Finally, an overview section draws together the major points of the discussion in the chapter, and introduces the research focus of this thesis.

Philosophical framework and research paradigms

This section outlines the philosophical framework of this research. The first subsection makes explicit the world view of modest realism underpinning the study, and its relation to science education and the postpositivist research paradigm. This starting point provides an essential background for considerations of the discussions that follow in this and subsequent chapters. Different paradigms in educational research are then discussed, highlighting differences and shifts in focus between postpositivist and alternative perspectives. Research into student learning in higher education from different paradigms is outlined, and the convergence between paradigms is highlighted.

Modest realism

The metaphysical foundation of this research is modest realism. This variety of realism is broadly consistent with what has been variously described as referential realism (Harré, 1986; Osborne, 1996) transcendental realism (Miles & Huberman, 1994, p. 4) or contextual realism (Schlagel cited in Good, Wandersee, & Julien, 1993, p. 80). Modest realism accepts that there are real and stable patterns and properties in the arena of human learning, which can be investigated by humans using tools of sensory input and rational enquiry. Modest realism, though, holds that knowledge of reality can only be conjectural (Phillips & Burbules, 2000, p. 26). This form of realism differs from relativism because this conjectural knowledge of reality is based on criteria other than subjectively experienced "realities" (Phillips & Burbules, 2000, p. 37).

The realist underpinning of this thesis is pertinent from at least three perspectives. Realism is consistent with the epistemic position of much current science. It is essential for rational adjudication of conflicting scientific and other ideas (D'Agostino, 1989) and is consistent with a postpositivist paradigm of inquiry (Guba & Lincoln, 1994; Phillips & Burbules, 2000).

A realist view of science is reflected in many recent scientific texts and papers, including the following standard first–year biology text:

> The word science is derived from a Latin verb meaning 'to know'. Science is a way of knowing … At the heart of science are people asking questions

> about nature and believing that those questions are answerable. (Campbell & Reece, 1999, p. 13)

Notwithstanding this predominant view among practising scientists, acrimonious debate still surrounds the nature of scientific knowledge in the "science wars" between realists and relativists.

Philosophers of science such as Kuhn, Popper, Feyerabend and Lakatos raised philosophical questions that transformed the traditional logical positivist view of science into its current postpositivist position, and influenced the development of some constructivisms. Since the 1970s, postmodern sociologists and philosophers of science, such as the Edinburgh "Strong Programme" have advocated a more relativist and irrational view of science (Matthews, 1998, p. 3). However, many scientists, philosophers of science and educationalists (e.g., Harré, 1986; Sokal & Bricmont, 1999; Stove, 1984) have rigorously defended the realist and rationalist position.

This debate about scientific epistemology is central to science education, and therefore to research in science learning. Teaching and learning about the nature of science is a crucial element in science education (Kelly, 1997, p. 364; Osborne, 1996, p. 55), and according to Matthews (1998, p. xi) is its most important component. Many science educationalists question the place of relativist ontology in science teaching, and warn against its potential dangers. It has been claimed (e.g., Gross & Levitt, 1994, p. 244) that tertiary scientific education is being "debased" by relativist influences from the postmodern academic left, which open the door for pseudo- or anti-science in the science curriculum (see also Slezak, 1994).

In addition to being consistent with science as it is practised, realism has been shown by philosophical thought-experiments to be essential to rational adjudication of ideas (D'Agostino, 1989). Without the yardstick of reality (internal validity), and notwithstanding notions of trustworthiness and "viable" knowledge, adjudication between different ideas in relativist paradigms is problematic and "not well resolved" (D'Agostino, 1989, p. 114). The epistemic position of science pedagogy, therefore, has profound implications for how today's science students will meet growing needs for scientifically literate adjudication between the ideas and products of scientific endeavour. In addition, the epistemic basis of research into science learning has implications for the adjudication between relative merits of possible research designs, methods and analytic techniques.

The final consequence of modest realism is that it is consistent with a postpositivist orientation to research. A major implication of its postpositivist framework is that this research is based on hypotheses derived from pre-existing theory. It seeks evidence about these hypotheses to further contribute to underlying theory, using quantitative tools including inferential statistics and qualitative techniques such as interviews.

In summary, the research reported in this thesis has been conducted from an ontological position of modest realism, which relates in a coherent way to the practices and processes of science, science education, and the basis on which different ideas are evaluated. This philosophical basis is reflected in a postpositive orientation to research. This orientation influences the development questions, choice of methods and analytic techniques, as well as the reporting and interpretation of results.

Paradigms in education research

Educational research, like much other social sciences research, has undergone a paradigm shift in the past thirty years. This subsection begins by contrasting postpositivism and other research traditions. It then details the complementarity of research from different paradigms into student learning in higher education.

Postpositivism and "alternate" paradigms

Postpositivist studies have in many cases supplanted the traditional positivist approach to research, which was associated with realist ontology, quantitative methods and focus on explanation and prediction. Postpositive research recognises and takes account of perceived problems with the positivist tradition, such as the interdependence of theory and facts, the value-ladenness of facts and the interactive, constructed nature of findings in social science research. It still, however, retains a commitment to modest realism (Guba & Lincoln, 1994, p. 107).

More recently, however, alternative more qualitative paradigms have emerged. Some of these, such as strong constructivisms, are characterised by a rejection of modest realism in favour of more relativist ontology (Guba & Lincoln, 1994). Because the term "qualitative" can refer both to a methodology as well as to an overarching research perspective, Maykut and Morehouse's term "alternate" paradigm (1994, p. 11) is preferred in this thesis for reasons of clarity, although it is acknowledged that there is more than one alternative to postpositivism.

Several authors (e.g., Guba & Lincoln, 1994; Marton & Svensson, 1979; Maykut & Morehouse, 1994; Wiersma, 1991) have contrasted aspects of the positivist/ postpositivist quantitative paradigm, with the more recent more naturalistic and qualitative alternative perspective. Whether these paradigms are presented as opposite ends of a continuum or as dichotomies appears to vary according to the philosophical stance of the authors. A simplified and generalised summary of some commonly drawn distinctions between the postpositivist and alternate paradigms is provided in Table 1.1, together with some examples of research traditions characterising each position.

Table 1.1: Contrasting features of postpositive and alternate paradigms in educational research

	Postpositivist paradigm	Alternate paradigm
Ontology	Critical/modest realism: a real reality is imperfectly apprehendable	Relativism or historical realism: realities are multiple, socio-psychological constructions.
Epistemology	Modified dualist/objectivist: there is a two–way relationship between the researcher and the subject of study, but objectivity is a "regulatory ideal" and findings can be probably true.	Transactional/subjectivist: the researcher and object of study are interdependent, and knowledge is created in the interaction between the two.
Methodology	Modified experimental/ manipulation: Hypothesis–driven using quantitative techniques with growing use of qualitative methods to redress and/or complement deficiencies in quantitative approach.	Dialectical: Grounded in dialogue or interaction between researcher and subject of study, therefore predominantly qualitative. Use of hermeneutical techniques, narrative description.
Aim of inquiry	Nomothetic: discovery of general explanations and prediction of phenomena	Idiographic: focus on context–specific experiences of individuals
Role of context	Important but generalisations possible.	Central so generalisability limited, research in "natural settings".
Examples of research traditions	Cognitive science, educational psychology	Phenomenology, phenomenography, ethnography

Source: Modified from Guba and Lincoln (1994, p. 109); Maykut and Morehouse (1994, p. 12).

The differences outlined above highlight the question of whether both paradigms are reconcilable; can aspects of each paradigm coexist within any logically consistent and coherent research framework? As argued by Guba and Lincoln (1994, pp. 115-116), proponents of the alternate paradigm assert that because of their contradictory philosophical foundations, the two paradigms are logically incompatible. However, from a postpositivist perspective consistent with the philosophical background of modest realism, there is no necessary conflict between the paradigms, as "all paradigms can be accommodated" (Guba & Lincoln, 1994, p. 115). As expressed by Walker and Evers (1988, p. 30), postpositivism represents a pluralistic view that accepts a range of epistemological positions as "equally legitimate and in no necessary conflict".

Paradigms in research into tertiary student learning

Accommodation of different paradigms and blending of their research findings is clearly evident in the eclectic field of research into student learning in higher education. In this area there is a strong tradition of idiographic research (e.g., Ramsden, 1985), that is, research based on context–specific experiences of individuals' learning (Burns, 1997, p. 3). There is also a long history of nomothetic research, that is, research aimed at discovery of general explanations and prediction of phenomena (Burns, 1997, p. 3). These nomothetic studies have been conducted by applying cognitivist models and psychometric instruments to student learning (e.g., Biggs, 1979; Entwistle & Entwistle, 1970).

Much of the early research into student learning in higher education was conducted along three initially independent strands in the early 1970s. Two initially nomothetic research programs, conducted independently by Biggs in Australia and Entwistle and colleagues in the UK, originated in the field of cognitive psychology within a positivist/ postpositivist paradigm. Concurrently, and from an alternative perspective, a range of researchers including Marton and colleagues in Sweden conducted idiographic research into how individual tertiary students learned. From these independent origins, within different research paradigms, emerged some similar ideas relating to students' approaches to learning and qualitative assessment of learning outcomes.

This convergence within and between paradigms was reflected in the organisation of a Working Party on Student Learning in mid-1978 (Entwistle & Hounsell, 1979, p. 362). The outcomes of the Working Party were reported in a series of papers on

"Student Learning in its Natural Setting", in a special issue of *Higher Education* in 1979. The editorial to the special issue addressed the issue of possible conflict between paradigms. It highlighted the potential for schism given the contrasting research approaches, but contended that this was unnecessary:

> The methodologies of competing paradigms could be used alongside one another, each providing distinctive yet equally valid types of evidence. It is our belief that progress in this field is more likely to come from evolution than revolution. (Entwistle & Hounsell, 1979, p. 363)

A similar line was taken by Marton and Svensson (1979), who argued that aspects of the traditional and alternative perspectives were complementary: "what we can see from one point of view we cannot see from another" (p. 484).

Summary

This section has established the theoretical foundation for this study and its postpositive orientation. Postpositivism is a research paradigm characterised by modest realism. It has a nomothetic focus, using quantitative and qualitative techniques to make generalisations about the learning of groups of students. Postpositivism contrasts, but is complementary to, an alternate paradigm with a more idiographic, qualitative focus. From a postpositivist point of view, these paradigms are complementary, and both perspectives have contributed to research into student leaning in higher education.

Nomothetic investigations into student learning

This section provides a general outline, of nomothetic research into student learning, categorised into three separate but related traditions, and some of its limitations. The first part of this section discusses the experimental tradition of information processing, which focuses on how the mind processes, represents and stores sensory input in relation to understanding (Demetriou, Christou, Spanoudis, & Platsidou, 2002, pp. 1-2). The developmental tradition is then discussed. This research, which is aimed at understanding the development of cognitive functions, includes Piaget's theory of cognitive development, neo-Piagetian lines of research and Ausubel's (1963) cognitivist account of meaningful learning. The third area discussed in this section is psychometric research. This focuses on measuring and explaining individual differences, often with a focus on predicting success (Kirby & Biggs, 1980, p. 2) and investigating relatively stable aspects of cognition (Demetriou et al., 2002, p. 2). Finally, the fourth part of this section focuses on the limitations of cognitive science and related arguments for the value of idiographic studies.

Information Processing

One approach to investigating how people learn is the information processing research tradition. This seeks to understand the basic processes by which people encode, store and retrieve information, and the way these processes change with development. This subsection outlines the role of memory in information processing, and describes some influential studies into student learning that have been conducted from the information processing perspective.

Memory is one aspect of information processing theory, and three systems of memory described in information processing models are short-term, working and long-term memory. Short-term memory holds a very limited amount of information for a very short time, and memory span increases with age up to adolescence (Boulton-Lewis, 1998b, p. 16). Working memory has been defined as "the processes enabling a person to hold information in an active state while integrating it with other information until the problem is solved" (Demetriou et al., 2002, p. 7). Long–term memory holds concepts organized into semantic networks, schemas, scripts and sensory information (Boulton-Lewis, 1998b, p. 17), for an infinite period of time. A range of information processing research reviewed by Boulton-Lewis (1998b) lead to her conclusion that learning for adults does not become more difficult with age, though may be slightly slower in the 60+ age group.

Working memory has long been linked to cognitive development in a number of ways. According to Case (1980), working memory underlies intellectual development, because although working memory capacity remains constant during development it shows a functional increase because of the mental space freed by automatisation of routines. Other research reported by Biggs and Kirby (1980b) suggested that working memory shows age–related expansion, which drives cognitive change.

Both of these views have been challenged in more recent research by Demetriou et al. (2002), which suggested a more complex relationship than had been assumed between cognitive development and working memory. Their research indicated that processing efficiency is causally related to both working memory and thinking, and that differences in mental age reflect differences in processing efficiency (Demetriou et al., 2002, p. 129) rather than working memory directly.

Research into tertiary student learning from the information processing perspective includes a widely cited study by Craik and Lockhart (1972), investigating the different levels of processing in memory. Craik and Lockhart (1972) suggested that the depth of processing of a stimulus influences its memorability. Shallow processing which focuses on superficial features of a stimulus using strategies such as rote repetition leads to a weak memory trace; whereas, deeper processing of the semantic aspects of a stimulus leads to a stronger more durable memory trace.

Subsequent information processing theories of Transfer Appropriate Processing (TAP) and the item — relational concepts have been reviewed in the context of student approaches to learning theory by Dyne, Taylor, and Boulton-Lewis (1994). As described by these authors, TAP theory incorporates a focus on context–related aspects of transfer and retrieval, rather than just levels of processing, in explaining qualitative differences in learning performance. These authors also reviewed evidence for the distinction between item and relational information, suggesting that processing of items of information and the relationships between those items both contribute to understanding (Dyne et al., 1994, pp. 380-382).

A different and earlier strand of information processing research includes Biggs' (1969) coding model of cognitive behaviour. This model related stable personality traits to coding and rehearsal strategies, which in turn were thought to be associated with differences in study behaviour and learning outcomes. This underpinned Biggs' early psychometric research into students' approaches to learning (e.g., Biggs, 1987).

Other learning questionnaires have been developed from the information processing perspective (e.g., Weinstein, Schulte, & Palmer, 1987, cited in Watkins, 1996, p. 4). In addition, an information processing theory of human intelligence by Sternberg (1987) identified three dimensions of intelligence (internal, experiential and external). Dimensions of information processing such as working memory have been used as explanatory constructs in SOLO, a model for evaluating the quality of learning that emerged from predominantly neo-Piagetian origins (Biggs & Collis, 1982).

In summary, information processing theory focuses on the mental processes used in dealing with information, in relation to cognitive development and learning. Different forms of memory are central in much information processing research, particularly the relationship between working memory, processing efficiency and development. Information processing research in higher education has distinguished between superficial rehearsal leading to a weak memory trace, and elaborative processing leading to a stronger memory trace. Other studies have examined TAP, the item — relational distinction, and coding and rehearsal strategies in relation to study behaviour. Working memory has been invoked as an explanation for structural differences in learning outcomes.

Developmental theories

This subsection describes major developmental theories of learning and cognitive development. The work of Piaget is outlined, followed by a discussion of researchers in the subsequent neo-Piagetian tradition and the cognitive psychology of Ausubel.

Piaget's theory of cognitive development

Arguably the most controversial, influential and well-known developmental theorist is Piaget. Central to Piaget's theory of cognitive development are the concepts of structuralism and functionalism. To Piaget, knowledge consisted of cognitive structures or schema (Gruber & Vonèche, 1977, pp. 767-770), that are formed by the invariant biological functional processes of organization and adaptation.

Organisation refers to total coherent systems of relationships between elements and implies some stage–independent properties of cognitive development (Flavell, 1963, p. 47). By contrast, adaptation refers to the mechanisms causing change in the development of cognitive structures. These adaptive mechanisms are assimilation of information into the existing organisation of cognitive structures, and simultaneous accommodation of cognitive structures in response to perturbation caused by novel information (Gruber & Vonèche, 1977, pp. 832-837). The continuous operation of assimilation and accommodation is a process of equilibration, which results in successive, discontinuous equilibrium states. Piagetian theory describes intellectual development as "a movement from structural disequilibrium to structural equilibrium, repeating itself at ever higher levels of functioning" (Flavell, 1963, p. 21).

A part of the individual equilibration process is the concept of equilibrated developmental stages:

> In Piaget's system, the panorama of changing structures in the course of development is conceptually partitioned into *stages* whose qualitative similarities and differences serve as conceptual landmarks in trying to grasp the process. (Flavell, 1963, p. 19)

Piaget's stage concept asserted that developmental stages reflect real qualitative differences rather than arbitrary conveniences, that they occur in an invariant hierarchical sequence, and that they are defined in terms of an integrated structural whole, called a structure d'ensemble (Flavell, 1963, pp. 19-22). The structure d'ensemble determines learning performance within a given stage, and results in "horizontal structure" (Campbell, 1993, p. 170), where learners are thought to progress evenly through stages across a range of domains. Uneven performance across intellectual domains, that is, horizontal décalage, was recognized by Piaget but considered anomalous.

Piaget recognised from three to five stages, and a number of sub-stages, to describe qualitative differences in children's cognitive development (van Geert, 1998, p. 636). Flavell (1963) cited three stages, with a preoperational "subperiod", but the most commonly cited version of Piagetian stage theory incorporates four developmental stages, which are summarised in Table 1.2.

Table 1.2: Piagetian developmental stages and their characteristics

Stage	Characteristics
Sensorimotor development (from 0 to 2 years)	During this stage infants coordinate and relate physical movements with sensory experiences to construct rudimentary cognitive understanding of their world.
Pre-operational thought (from 2 to 7 years)	In this stage children begin to develop symbolic representations of the world using words and images. Language and mental symbols in this stage enable children to think, though according to Piaget not to perform operations, that is, not to reason logically.
Concrete operations (from 7-11 years)	At this stage children demonstrate a coherent cognitive system to organise their world, and logical reasoning based on concrete referents becomes available.
Formal operations (appears between 12 and 15 years)	Individuals at this stage can think in abstract and propositional terms, and have the capacity to think about their operations; that is, to think about thinking. Immediate concrete referents no longer limit thinking.

(Santrock & Yussen, 1992).

Piaget's theory has attracted extensive criticism (e.g., Ausubel, 1963; Case, 1992; Flavell, 1963; Sternberg & Ben-Zeev, 2001). Many of his observations were conducted on a small, culturally homogeneous sample of children. Further, several researchers (reviewed by Sternberg & Ben-Zeev, 2001, p. 311) have challenged Piaget's fundamental assumptions that changes in cognitive development arise mainly from maturation, and that these changes occur in discontinuous stages rather than as a continuous process. In addition, Piaget's assumption of horizontal structure has been contradicted by an accumulation of evidence that horizontal décalage is very common. Children at a given Piagetian stage can be trained to reason at higher stages, and the ages at which Piaget believed various cognitive abilities to emerge have been questioned (Santrock & Yussen, 1992, p. 286).

In his critique, Flavell (1963) questioned the role of vocabulary in Piaget's research, in particular the relationship between growth-in-vocabulary and growth-in-cognition. He suggested that Piaget's monolithic stage theory may be too rigidly and simplistically structured, and questioned exactly what is meant by a stage, arguing that stages are influenced by factors other than chronological age (Flavell, 1963, p. 442). The importance of environmental factors on development has since been widely studied by cognitive developmental theorists, for instance in the dynamic systems approach to development (Thelen and Smith 1994 cited in Sternberg & Ben-Zeev, 2001) and Vygotsky's (1978) influential concept of internalisation.

Many of the criticisms of Piaget's theory, however, have in turn been criticised for barely addressing the fundamentals of the theory and the many worthwhile issues it contains (Lourenco & Machado, 1996). Ausubel (1963, p. 113), while forthright in his criticism of Piaget's methodology and reporting of results, argued that many of the criticisms of Piagetian stages are "irrelevant". Moreover, as argued by Sternberg and Ben-Zeev (2001, p. 306), the contribution of Piaget's theory rests more on its influence on subsequent research than its absolute correctness, and there is no doubt that Piaget's theory continues to have a profound and widespread influence on research into human development and education. As stated by one prominent cultural constructivist researcher, "Piagetian and neo-Piagetian theory has dominated educational research in the second half of the twentieth century and continues to do so" (Cobern, 1993, p. 52).

Neo-Piagetian research

Piagetian theory has spawned a flourishing neo-Piagetian research tradition. Much neo-Piagetian research accepts the idea of structuralism, and the existence of developmental stages in cognitive growth (for reviews, see Campbell, 1993; Case, 1992; Demetriou et al., 2002; Halford, 1993). It is argued that developmental stages are evidenced, at least in Western societies, by the predictable age-ranges during which children demonstrate the increasingly abstract behaviours of speaking, using symbol systems such as writing, and forming theories. Moreover, performances of different children within a given age are more similar than performance of individuals at different ages, and there are marked qualitative differences between learning performance on a given task across these age ranges (Biggs & Collis, 1991, pp. 60-61).

Despite these points of agreement, the neo-Piagetian tradition differs in many ways from classical Piagetianism, and disagreement is also present within its ranks. Among such issues are those related to frequency of décalage, stage number and structure, and the role of working memory in developmental stages.

Neo-Piagetians disagree about the frequency of décalage. A range of studies has been summarised by Biggs and Collis (1991, p. 60) as demonstrating evidence for relative evenness of performance within a particular domain, but not across different domains. It is clear that much evidence has accumulated indicating that horizontal décalage is relatively common (e.g., Flavell, 1963; Marton, 1981). Such evidence includes the finding by Biggs and Collis (1982, p. 21) of frequent décalage in the context of school learning, where students demonstrated uneven performance across different subjects, or within the same subject on different days. As argued by Biggs and Collis (1991, p. 60), this evidence cannot be accounted for by changes in cognitive development, but must reflect changes in factors such as learning context or motivation.

Until relatively recently, there has been a commitment in much neo-Piagetian research to the idea that stages develop evenly across different domains, which reflects an overall "horizontal structure" in development. Horizontal structure clearly poses a dilemma given the accumulated contradictory evidence of relatively frequent horizontal décalage. This commitment to horizontal structure in the face of evidence to the contrary has been necessitated given the developmental nature of working memory, thought by many neo-Piagetians to play a major role in development (e.g., Biggs & Collis, 1982, p. 26; Campbell, 1993, p. 170; Demetriou et al., 2002, p. 18). In addition, some neo-Piagetian models (e.g., Halford, 1993) invoked incremental increases in short-term storage capacity to explain transitions across stages (Campbell, 1993). It is the constraints imposed by the incremental increases in working memory capacity, that have led to the forced commitment of some neo-Piagetians to horizontal structure (Campbell, 1993, p. 170) despite the evidence for horizontal décalage.

This problem would seem to be partially resolved by the suggestion of Demetriou et al. (2002, pp. 128-129) that working memory is only indirectly associated with differences in mental age. Their proposed model explains development as a series of overlapping cycles of change in the network of factors that comprise processing efficiency and working memory, which can differ across different cognitive domains (Demetriou et al., 2002, p. 130). This model, according to its authors, can therefore account for uneven performance across domains, that is, décalage. In partially resolving one neo-Piagetian issue, though, this finding may have created another, as challenging the pre-eminent role of working memory in development may prove to have significant implications for neo-Piagetian research programmes.

Some disagreement is apparent in the literature about the number of stages in human cognitive development. The models of some researchers (e.g., Case, 1985; Halford, 1982) postulate the existence of four stages, which correspond in timing to the four stages of Piaget (Biggs & Collis, 1991, p. 61), while some models (e.g., Fischer, 1980) suggest three. Several researchers argue for a stage beyond Piaget's formal stage (Sternberg & Ben-Zeev, 2001, p. 313), suggesting that dialectical thinking comprises a further post-formal stage of development. In further contrast to the single sequence of stages in classical Piagetian theory, a number of neo-Piagetians (e.g., Case, 1992; Demetriou, 1993) have identified recurring cycles of four increasingly complex substages in cognitive development. In the model of Case (1985), for instance, the final level of one stage becomes the first level of the next stage, a notion also found in other models such as Fischer (1980), and later in the context of the SOLO model by Pegg and Davey (1998)

Ausubel's theory of meaningful learning

Another influential research program directly influenced by Piaget is Ausubel's cognitive view of meaningful learning. The existence of different cognitive developmental stages was accepted by Ausubel (1963, p. 115), albeit slightly differently from the Piagetian view (summarised in Table 1.2). Ausubel (1963, p. 116), argued for a concrete — abstract "dimension" of development, divided into the qualitatively different stages of preoperational, concrete and abstract operations. These stages underpinned Ausubel's principal of "readiness", which he described as a "crucial variable" for cognitive functioning and learning (1963, p. 111).

In his account of learning, Ausubel (1963) distinguished explicitly between rote and meaningful learning, and his distinction between these two types of learning rested on learning "set", or intention, as well as learning process (Ausubel, 1963, pp. 21-24). Rote learning was described as learning with the intention to "internalise material verbatim, as a discrete and isolated end in itself" (p. 22) and which uses processes that do not relate new material to existing concepts (p. 24). Meaningful learning, by contrast, was described as learning with the intention to relate new material to existing concepts in potentially useful ways; in Ausubel's words (p. 22), using a meaningful "approach to learning". Meaningful learning uses processes that facilitate the relating of new to old knowledge (p. 23).

The relationship between rote and meaningful learning and learning outcomes was also discussed by Ausubel (1963, pp. 23-24). He stated that meaningful learning leads to improved retention of information, more transferability, and the ability to understand important relationships between concepts; while rote learning leads to discrete units of unrelated information and relatively short retention.

Ausubel's theory of meaningful learning was the foundation for later work of researchers in science learning such as Novak (1988; 1998). Novak (1998, p. 20) proposed that human learning could be described by a continuum between rote and meaningful learning, that is, that these are non-orthogonal (non-independent) concepts. He also emphasised that meaningful learning is strongly dependent on prior knowledge. Novak (1988, pp. 86-87; 1998, pp. 22-23) drew on human memory systems from information processing theory to support the argument that the size of information "chunks" that can be operated on by working memory is dependent on the relevant knowledge stored in long term memory. In terms of science learning Novak (1988, p. 87) claimed that complex ideas should be broken down into smaller components, which are processed and then combined as a "chunk". He also suggested, following Ausubel, that scientific knowledge is stored hierarchically and found that meaningful learning is associated with the most sophisticated concept maps when used as indicators of learning outcomes (Novak, 1988, p. 88).

Other research into science learning from a Piagetian perspective includes the studies of Lawson and colleagues (e.g., Lawson, 1985; Lawson & Thompson, 1988). This research focused on the Piagetian stage of formal thought, aiming to test its validity, its relation to learning and teaching in science, and its relation to scientific misconceptions. Another strand of neo-Piagetian research used in science educational research is the SOLO taxonomy, a tool in assessing qualitative differences in students' responses to learning cues which was partially based on modified Piagetian stages (Biggs & Collis, 1982).

In summary, developmental theories of learning focus on age–related stages of cognitive development. Piaget's development theory recognised four major stages of sensorimotor, pre-operational, concrete operations and formal operations. Although his theory has attracted much criticism, it was extremely influential. The neo-Piagetian research tradition accepts the notion of stages, but some contention surrounds the frequency of décalage, the existence of horizontal structure and the number of stages. In his neo-Piagetian research, Ausubel distinguished between rote and meaningful "approaches" to learning, with rote learning leading to poorer retention and comprehension, and meaningful learning leading to better understanding and retention. Neo-Piagetian research into science learning includes the work of Novak and Lawson, and the SOLO taxonomy.

Psychometric research into student learning

The psychometric tradition is well represented in research into student learning in higher education. Many inventories and taxonomies of learning styles, strategies and approaches have been developed, using multivariate statistical techniques such as factor analysis and structural equation modelling to investigate the relationships between different variables of hypothesised relevance to student learning. This subsection outlines some influential psychometric research programs in tertiary student learning. These include work by Entwistle and colleagues in the development of the Approaches to Study Inventory, the research by Biggs associated with the Study Process Questionnaire, and several other learning styles inventories. Finally, the issues of stability and variability in relation to these learning questionnaires are discussed.

The Approaches to Study Inventory

In the early 1970s, Entwistle and colleagues in the United Kingdom investigated student learning in higher education using a psychometric approach (Entwistle & Brennan, 1971; Entwistle & Entwistle, 1970; Entwistle, Nisbet, Entwistle, & Cowell, 1971). This early research used questionnaires informed by previous studies and personality inventories to explore relationships between personality traits, motivation, study methods and academic performance of first–year tertiary students in England. They found a number of weak correlations between personality traits, study methods and academic performance (Entwistle et al., 1971). Later, Entwistle and Thompson (1974) recognised some limitations of this nomothetic approach and augmented it with semi-structured interviews, in distinguishing between three different kinds of motivation for academic success. The weakness of these early studies, however, was later recognised as their "failure to take account of the existence of very different approaches to studying used by students" (Entwistle, Hanley, & Hounsell, 1979, p. 365).

This weakness was later addressed (Entwistle et al., 1979), along with acknowledgement of the influences of experiential idiographic research (Marton & Säljö, 1976a; Ramsden, 1979), and other more nomothetically oriented research (Biggs, 1976; Pask, 1976) on the development of an inventory to measure "approaches" to study. The developing Approaches to Study Inventory (ASI) was tested further on a sample of over 2000 second year tertiary students in the UK (Ramsden & Entwistle, 1981). Further analyses suggested to Entwistle and Ramsden (1983, p. 53) that there were four orientations to study: meaning orientation linked to intrinsic motivation, reproducing orientation linked to extrinsic motivation, achieving and non-academic orientations. A revised and shortened version of the ASI was subsequently developed, with the four main orientations renamed Deep approach, Surface approach, Strategic approach and Apathetic approach (Tait & Entwistle, 1996, p. 105).

This evolution of the ASI demonstrates its emergence from a top-down psychometric approach, which was augmented by idiographic influences. As stated explicitly by Entwistle et al. (1979, p. 370), many of the items from earlier 1970s questionnaires were included in the pilot ASI, and used as the basis for six of its 15 scales. These earlier instruments had theoretical rather than empirical origins, were based on standard psychometric tests of ability and personality (Entwistle & Ramsden, 1983, p. 131) and incorporated variables hypothesised to influence study methods and academic performance. Some other scales were based on items of Biggs (1976) and Pask (1976). The developing ASI was augmented by items based on experiential idiographic research such as interviews (Marton & Säljö, 1976a; Ramsden, 1979), and it was argued by Entwistle and Ramsden (1983, p. 58) that their research strategy was bottom-up; that is, basing specific questionnaire items on qualitative analysis of student interviews with only *a posteriori* explanation sought from psychological theory. However, as explicitly stated by Entwistle and Ramsden in the same publication (1983) "the Approaches to Study Inventory made use of typical psychometric techniques" (p. 131).

The Study Process Questionnaire

At the same time as Entwistle's psychometric research in the early 1970s, Biggs in Australia was also investigating cognitive behaviour in the context of learning. His research was initially from an information processing perspective, and later used a similar psychometric methodology to Entwistle. Biggs (1969, p. 291) hypothesised that individuals with different personality traits would use different coding and rehearsal strategies to manage learning input, which would be associated with different study behaviours and learning outcomes.

Following on from this work, Biggs (1970a; 1970b) developed a Study Behaviour Questionnaire (SBQ) with which he investigated the study behaviour of first–year Arts and Science students in an Australian university. Biggs hypothesised differences in study behaviour based on the nature of the task, although he postulated some questionable generalisations about the nature of learning in Science and Arts and the difference between them. Factor analysis of the SBQ responses identified two main study strategies which he called "simplifying" and "opening out" strategies (Biggs, 1970a). According to Biggs, a student using the simplifying strategy would:

> merely assimilate as much as possible, deliberately withholding complex interpretation: the memory load can be lessened by narrowing the field of relevant information to one set textbook say, or to the musts in the reading list...he behaves like a piece of carefully and economically placed blotting paper. (Biggs, 1970a, p. 163)

By contrast, the "opening out" strategy was described as a more sophisticated study behaviour by which:

> the content would become organised according to structures generated by the student. He would welcome the opportunity of being thrown on his own resources in a fairly open end [*sic*] situation (cf. Hudson, 1968) and to be confronted with novelty and complexity; he would read widely and, in general, would indulge in "open system" thinking. (Biggs, 1970a, pp. 162-163)

The Study Process Questionnaire (SPQ), an instrument to investigate student approaches to learning, was derived from principal components analysis of the 10 scales of the SBQ, across three samples of university students in Canada and Australia (Biggs, 1978). On the basis of this, Biggs described three orthogonal dimensions of Internalising, Reproducing and Organising approaches, each of which was made up of values, motive and strategy components. In the 42-item Likert style SPQ, Biggs (1987) aligned his terminology with that from previous idiographic research of Marton and Säljö (1976b), renaming his learning approaches Surface, Deep and Achieving.

Other learning inventories

Several other instruments derived from a psychometric framework have been used in research into student learning in higher education. For example, Schmeck (1983) reported the development with colleagues of an Inventory of Learning Processes (ILP) that described four distinct learning processes, and showed conceptual overlap with scales on the ASI (Entwistle & Ramsden, 1983, p. 58). The theoretical framework for the ILP was the information processing research by Craik and Lockhart (1972), which identified levels of processing in memory.

In the Netherlands, Vermunt and colleagues (cited in Vermetten, Lodewijks, & Vermunt, 1999) developed an Inventory of Learning Styles (ILS) which addressed the four domains of domains of cognitive and metacognitive strategies, learning orientations and mental models. More recently, Meyer and Boulton-Lewis (1999) reported on the development of a Reflections on Learning Inventory (RoLI), aimed at investigating students' conceptions of learning. Although items were based predominantly "bottom-up" from excerpts of interviews or written statements, the development and analyses of the RoLI made use of standard statistical and psychometric techniques. Further inventories were described by Biggs (1993b, p. 4), in a discussion of the theoretical basis for the development of learning process inventories.

Stability and variability

One of the recurring themes in relation to many of the learning styles/approaches instruments described above, is the extent to which student use of any particular learning style or approach reflects stable individual characteristics, and the extent to which it is influenced by context. This tension between consistency and variability is explicitly addressed or implicit in much of the psychometric research. Instruments such as the SPQ and ASI were based initially on nomothetic assumptions of stable relationships between personality traits and study strategies/approaches (Biggs, 1970b, p. 295; Entwistle et al., 1979, p. 375), and accordingly asked students about the way they usually went about their studies. From these investigations some degree of consistency was established.

Nonetheless, these researchers also acknowledged that variability as a consequence of different contexts was to be expected. For example, Biggs (1970b, p. 295) argued that whether or not a particular predisposed strategy was used would depend on the "task conditions", highlighting the issue of consistency versus variability of learning approach, as later did Entwistle and colleagues (1979, p. 376). Evidence for both consistency and variability in learning strategies has been demonstrated by other researchers (e.g., Vermetten et al., 1999).

It has been argued by Entwistle et al. (1979, p. 367) that a research focus on either consistency or variability is legitimate, and the SPQ, ASI and other similar inventories have been used in research at both the general and context–specific levels. Much research has been based on use of these instruments in a general or unspecified context (e.g., Biggs, 1987; Entwistle & Ramsden, 1983), but the constructs measured in this general way have since been differentiated from those identified in more context–specific situations (Prosser & Trigwell, 1999). As context has become of more focal concern, researchers using instruments such as the SPQ, ASI, ILS and others have modified them by rewording items to relate to a specific learning context (e.g., Eley, 1993; Prosser, Trigwell, Hazel, & Gallagher, 1994; Vermetten et al., 1999). This change in focus from consistent, stable aspects of student learning to the more context dependent variability reflects in part the recognition of the broader limitations of nomothetic cognitivist research traditions.

In summary, psychometric research into student learning focuses on measuring and testing psychologically based ideas about how students engage with their learning. Research by Entwistle and colleagues initially from a psychometric perspective led to the development of the ASI, an instrument designed to measure students' learning approaches. Concurrent but initially independent research by Biggs also focused on students' learning approaches, and led to the development of the SPQ. Several other inventories and instruments exist, designed to investigate aspects of student learning. Many of the psychometrically based instruments such as the ASI and SPQ had a nomothetic focus, on relatively stable learning processes and patterns. This emphasis was later shifted to accommodate the influence of context, and the original questionnaires modified or reworded to reflect this more idiographic focus.

Limitations of cognitive science in student learning research

The limitations of cognitive science in researching student learning have been recognised widely, not least by practitioners (or ex-practitioners) of cognitivist research in higher education such as Biggs and Entwistle. In this subsection the limitations of nomothetic, cognitivist research into student learning are discussed.

As argued by Kirby and Biggs (1980, pp. 1-2), neither Piagetian nor psychometric approaches have elucidated the nature of individual differences in learning, or provided much practical help in teaching. Information processing models generated "top-down" from existing theory have been criticised for rarely being derived from an educational context and oversimplifying the complex nature of learning (Biggs, 1993a). According to Biggs (1994, p. 1), psychologically based theories can be "stretched to snapping point when applied to classroom and institutional contexts", and the cognitivist focus on universal mechanisms has therefore been criticised for retarding understanding of the "soft slimy swamp of real–life problems" that is the process of education (Schon, 1987 p. 3 cited in Biggs, 1993b, p. 8). This argument, though, has been refuted by researchers such as Dyne, Taylor, and Boulton-Lewis

(1994), who highlighted the relevance of information processing theories and their complementarity to other perspectives.

The growing acknowledgement of the value of idiographic explorations in natural contexts was apparent in research programs that had originated from a cognitivist perspective, within the traditional paradigm. Researchers such as Biggs and Entwistle who originally adopted a nomothetic focus associated with cognitive psychology both moved towards more alternative perspectives.

As early as 1970, Biggs (1970a, p. 172) pointed out that because of the complexity of learning situations which comprise interactions among "person, task and learning conditions", idiographic investigations would be of value. While Biggs' research remained more or less within the traditional paradigm, he was forthright in his criticisms of the cognitivist perspective. He acknowledged influences from early idiographic research of Marton and colleagues, and declared a personal shift away from a theoretical framework based on information processing theory towards the more eclectic research genre of student learning (Biggs, 1993a, p. 74).

Entwistle and colleagues also noted the central importance of learning contexts, and the limitations this placed on the applications of cognitive psychology. Entwistle and Wilson (1977) augmented their psychometric analyses with qualitative techniques, justified by arguments for combined quantitative and qualitative techniques in educational research, and by twenty years later Entwistle's research activity was clearly aligned with the alternate paradigm (e.g., Entwistle, 1997a).

In summary, the criticisms directed towards nomothetic cognitivist research relate in general to its oversimplification of the complexities of learning, and its lack of emphasis on context. Influential researchers such as Entwistle and Biggs explicitly realigned their originally nomothetic research to a more idiographic perspective, taking into account the influence of context on student learning.

Summary

This section has discussed studies from a nomothetic, cognitive science approach, which have contributed substantially to research on student learning in higher education. The three traditions of information processing, Piagetian and neo-Piagetian research, and psychometric studies, have respectively emphasised the role of working memory, developmental stages and psychological factors in students' learning. This section has also highlighted some of the limitations of nomothetic research, which have resulted in some of the influential cognitivist researchers in higher education espousing a more idiographic stance. This shift was in part a consequence of influences from independent idiographic research activity occurring within the alternate paradigm.

Idiographic investigations into student learning

An idiographic focus on understanding students' conceptions of their world runs through a variety of research traditions. The origins of much idiographic educational research, like the nomothetic tradition already discussed, can also be traced back to Piagetian research. While rejecting the focus on developmental stages and their associated assumptions, many researchers in the 1970s and 80s focused on the content of individuals' thinking, using detailed interview methodologies similar to those pioneered by Piaget (Cobern, 1993, p. 52). A consequence of Piagetian structuralism, via Ausubel's theory that meaningful learning relates new information to pre-existing conceptual structures, was a research focus on the different ways individuals construct their knowledge (e.g., Pines & West, 1986). In the science context, further impetus to this movement was provided by the ongoing debates about the nature of scientific knowledge, leading to research interest in different conceptions of science (Cobern, 1993, p. 52).

This section begins with a brief discussion of the emergence of idiographic studies into learning. Different forms of constructivism and student conception research in learning science are outlined, and then other idiographic research influential in investigations of student learning in higher education is described. Finally, this section includes a discussion of some limitations of idiographic research.

Constructivisms and student conception research in learning science

This subsection discusses the philosophical diversity of varieties of constructivism, and their influence on science education. Piagetian, personal and social constructivism are then described, together with their relation to student conception research.

Philosophical diversity of constructivism

In addition to spawning the neo-Piagetian strand of cognitive science, the research of Piaget contributed to the development of various constructivisms, arguably a current major influence on science education (Matthews, 1998, p. 2). The different varieties of constructivism have been defined *en masse* as:

> An emerging consensus among psychologists, science educators, philosophers of science, and others, that learners (including scientists) must construct and reconstruct their own meaning for ideas about how the world works. (Good et al., 1993, p. 74)

This view of learners as active constructors rather than passive recipients of knowledge is a fundamental principle of constructivism (Treagust, Duit, & Fraser, 1996, p. 4).

Another explanation of constructivism (von Glasersfeld, 1997 quoted in Arlidge, 2000, p. 1), though, highlights the differences among different forms of constructivism:

> Constructivism is a vast and woolly area in contemporary psychology, epistemology and education, because the people who unintentionally contributed to the mess, had perspectives that were every bit as divergent as the intentions of Mao Tse Tung and Jean Piaget.

This "mess" has developed because the term "constructivism" encompasses such a range of fundamentally different philosophical positions, and this is widely acknowledged to pose a hindrance to precise communication (Bickhard, 1997, p. 99; Good et al., 1993, p. 71). For instance, according to Guba and Lincoln (1994, p. 109), constructivism assumes ontological relativism. This is contradicted by the ontological realism which is evident in some constructivisms (e.g., Driver, 1989), and the agnostic ontology claimed by even radical constructivists (e.g., von Glasersfeld, 1993). Some epistemologically relativist constructivist positions (e.g., Roth, 1993; von Glasersfeld, 1989) are problematic to many practising scientists, because they disagree with the proposition of von Glasersfeld (1993, p. 25) that "the 'real' world remains unknowable".

Many researchers (e.g., Good et al., 1993; Kelly, 1997; Osborne, 1996) have therefore expressed concerns about the philosophical woolliness of constructivist ideas and the implication of this "mess" for science education, and it has been argued that the hegemonic position of contructivism in educational research is therefore "undeserved" (Osborne, 1996, p. 53).

Despite these philosophical challenges, constructivism has been hailed by its proponents as a new paradigm for science education (e.g., Tobin, 1993) and has been said to have "triumphed at the university/college teacher–education level" (Sutherland, 1992, p. 81). Constructivist pedagogy is gaining acceptance in tertiary science, particularly as an antidote to the traditional didacticism that still flavours much tertiary science teaching (Osborne, 1996). There are many examples of constructivist pedagogy which facilitates students' constructions of scientific knowledge by, for example, student–centred curricula and interactive discussions (e.g., science case studies reviewed by Prosser & Trigwell, 1999).

On the other hand, Arlidge (2000) argued that a truly constructivist curriculum can "create difficulties in most mass higher education settings". From the systems model described by Biggs (1993a) it might be more accurate to say that mass higher education settings create difficulties for constructivist curricula, and more complete to recognise that they also create difficulties for the students in those settings. Time and resources are needed to develop and maintain learning environments that are consistent with constructivist principles, particularly for students studying at a distance. It also takes more time for students to construct knowledge than to be "filled up", but time is currently "a scarce commodity for both teachers and students in educational settings" (Arlidge, 2000, p. 43).

From Piagetian to personal constructivism and student conception research

The intellectual lineage from Piaget to personal (and, more distantly, radical) constructivists is clear, and is signposted by Piaget's statement that "knowledge is essentially construction" (Nola, 1997, p. 43). Piaget was a realist (Nola, 1997, p. 43) and a rationalist (Case, 1992, p. 4) who saw his research as based in the scientific tradition of objective reasoning about accumulated truths, leading to scientific advancement (Good et al., 1993, p. 77). It is therefore ironic that Piaget has been claimed as the "great pioneer" of constructivism by radical constructivists such as von Glasersfeld (1989, p. 22), particularly as personal constructivism developed in part in reaction against Piagetian stage theory (Osborne, 1996, p. 53; Sutherland, 1992, p. 81). Constructivism in this sense is clearly related to Piagetian structuralism, in that new knowledge structures are thought to be constructed by individuals, rather than simply imported (Campbell, 1993, p. 169). Piaget's suggestion that knowledge is actively constructed by individuals is a fundamental tenet of constructivism, so well accepted that it has been disparaged by many constructivists as "trivial" (Treagust et al., 1996, p. 4).

Early forms of constructivism focused on individuals as constructing agents, and therefore have attracted the label of personal constructivism. According to personal constructivists such as Driver, Squires, Rushworth, and Wood-Robinson (1994, p. 1), students' conceptions of scientific phenomena are personal constructions based on their experiences in the world. In the context of tertiary science education, there has been much research interest on different personal constructions of scientific concepts, and how these "alternative conceptions" accorded with the scientific view (e.g., Kindfield, 1994; West & Pines, 1985).

As indicated by West and Pines (1985), tertiary science students bring to their studies qualitatively different understandings of scientific concepts. These alternative conceptions are often held intuitively, are extremely resistant to change, and are therefore frequently held instead of, or in conjunction with, less intuitive but scientifically more correct views (see also Driver, 1983). The classic example is where intuitive Aristotelian ideas of motion have been repeatedly shown to persist in university physics students regardless of instruction in Newtonian mechanics (Dahlgren, 1984, p. 32; Driver, 1983, pp. 4-5; Millar, Prosser, & Sefton, 1989). It has been shown that many tertiary science students are able to solve problems, remember and reproduce factual information and therefore pass exams, but have limited understanding of the concepts due in part to persistent misconceptions (Ramsden, 1992, p. 30).

From the personal constructivist perspective, meaningful learning is a process of deconstructing misconceptions, while constructing scientific conceptions in their place (Cobern, 1993, p. 54), for which prior knowledge is crucial (Pines & West, 1986, p. 584). Recalling Ausubel (1963), constructivists do not view rote memorisation as learning as it does not involve the learner constructing knowledge. A model explaining how conceptual change occurs in science has been suggested by Posner, Strike, Hewson, and Gertzog (1982). They suggested that changing scientific conceptions is a gradual and stumbling process, unlikely to occur at all unless existing conceptions are dissatisfying, and the new conceptions are both intelligible and plausible (Posner et al., 1982, p. 214).

According to the Piagetian perspective of Lawson and Thompson (1988, p. 734) overcoming embedded misconceptions requires formal operational reasoning, in order for students to evaluate the evidence surrounding alternative conceptions of scientific phenomena. For example, in a study of junior secondary science students these researchers found that misconceptions about genetics were significantly more frequent among concrete operational students than those using formal operational reasoning.

The field of personal constructivist and conceptual change research burgeoned in the late 1980s (Cobern, 1993), and remains a productive avenue of investigation into the ways students learn science. Nonetheless, personal construction does not take place in a social vacuum, and it has been argued (Solomon, 1989) that context, particularly social interaction, is a crucial part of learning in science.

Social constructivism focuses on the role of social context in learning, but even within social constructivism there is a multitude of philosophical positions (Phillips, 1997, p. 141). Arguments by Solomon (1989, p. 196) and others for the importance of social interaction in learning and the role of consensual ideas have been widely accepted, leading to changing learning environments that emphasise student-student interaction, student–centred cooperative learning and the teacher as facilitator (see e.g., Hand, Treagust, & Vance, 1997). The epistemological relativism of some of the more radical social constructivist positions, however, has received extensive criticism in the context of science education (e.g., Slezak, 1994).

In summary, constructivism contends that individuals construct their own meanings of the world. The term encompasses a raft of very different philosophical positions, and some of the more relativist constructivisms conflict with the modest realist stance of scientific practitioner/educators. Nonetheless, constructivist pedagogy contrasts with teacher–focused didacticism and has been widely advocated and influential in science education. Piagetian and personal constructivism focus on individuals as constructing agents, and in the context of science, different personal constructions of meaning lead to alternative conceptions of scientific phenomena which can be resistant to re-construction and change. Social constructivism, by contrast, focuses on the crucial role of social context in the construction of ideas.

Idiographic research into student learning in higher education

The investigation of student learning in higher education is currently recognised as a research genre in its own right (Biggs, 1993a, p. 74), originating from both nomothetic and idiographic perspectives in the 1970s. This subsection outlines the contribution of idiographic research into student learning in higher education, beginning with early studies of learning approaches, and then a discussion of phenomenographic research.

Idiographic research into learning approaches

Much idiographic research using qualitative, interview–based methodology has contributed to the understanding of how students engage with their learning. One of the most influential investigations of student learning in higher education is the research of Marton, Säljö and colleagues at Gothenberg University in Sweden, during the mid 1970s. These researchers took what was then a radical perspective, using qualitative analysis of interviews with students to investigate the relationship between learning processes and learning outcomes. In a study of the relationship between the quality of learning and learning processes of university students, Marton and Säljö (1976a) asked some students in an experimental situation to read a passage of text. They then interviewed the students about both the meaning of the passages and the processes they used when reading them.

Analysis of the interviews distinguished two "levels of processing" used by the students, which reflected a difference in learning focus. Surface–level processing was used by students who were focusing on learning the text ("*the sign*"), and who perceived learning as a "reproductive" activity and used rote-learning. By contrast, deep–level processing was used by students who focused on understanding the meaning of the text *("what is signified")* (Marton & Säljö, 1976a, pp. 7-8). A deep — surface dichotomy in learning processes (later called approaches) was strongly evident in the results of this study. These deep and surface levels of processing clearly resemble, though do not parallel (Gibbs, Morgan, & Taylor, 1982, p. 128; Richardson, 2000, p. 20), the contrast between superficial or elaborative learning foci and their connection to retention found in the information processing research of Craik and Lockhart (1972).

Subsequent idiographic studies (e.g., Laurillard, 1979; Ramsden, 1979; Säljö, 1979) focused on these and related aspects of learning, such as the importance of qualitative assessment of learning, and the importance of examining study processes in relation to content. As stated by Ramsden (1985), "these emphases gave enormous impetus to later work" (p. 54).

Phenomenographic research

The alternative perspective taken by Marton and colleagues in these early studies developed into the research approach of phenomenography, which has been highly influential in higher education (e.g., Bruce & Gerber, 1997; Prosser & Trigwell, 1999; Ramsden, 1992). Phenomenography is similar to early work of Piaget in its focus on describing and understanding the conceptions people have about phenomena they encounter (Säljö, 1988, p. 36), and in its interview–based methodology.

The research focus of phenomenography is simply "the variation in ways people experience phenomena in their world" (Marton & Booth, 1997, p. 121). Phenomenographic research uses qualitative analysis, usually of interview data, to identify this range of variation in individuals' conceptions and to interpret it by way of a small number of categories that describe the variation (Marton & Booth, 1997, p. 125). The categories of description that are the "outcome space" of phenomenographic analysis are frequently hierarchical, reflecting a hierarchy of qualitatively different and increasingly complex conceptions of phenomena (Marton & Booth, 1997, p. 125). Marton argued (1981, p. 183 and elsewhere) that these categories of description are valuable in their own right: that if students' alternative conceptions (experiences) are of interest, they must be explicitly investigated.

Marton and Booth (1997, p. 206) suggested that the relatively few different ways that people experience phenomena reflects limitations in awareness. The argument is that at any one time an individual is differentially aware of various aspects of a phenomenon, with some aspects in the focus of awareness, and others more in the background (Marton & Booth, 1997, p. 123). Differences in awareness and the associated qualitatively different ways of experiencing something can be described in terms of two intertwined aspects of structure and meaning. The structural component of an experience consists of discerning the whole from its context, and also being aware of the constituent parts and how they relate to each other and the whole (Marton & Booth, 1997, p. 87). This structure, though, is inextricably linked to the meaning. Awareness of a structure presupposes discernment of some meaning, while at the same time, meaning is derived from the structure of the awareness (Marton & Booth, 1997, p. 101).

Research into science learning in higher education has made considerable use of phenomenographic approaches. For example, phenomenography has been used to develop categories of description of first–year students' understandings of kinematics (Dall´Alba et al., 1989), which had implications for teaching and assessment strategies (Bowden & Dall´Alba, 1991). Other scientific topics investigated using this approach include photosynthesis (Hazel, Prosser, & Trigwell, 2002) and mechanics (Millar et al., 1989). A number of other phenomenographic studies of learning outcomes were reviewed by Prosser and Trigwell (1999), together with studies focused on teaching and conceptions of learning. In addition, Entwistle and Marton (1994) have identified "knowledge objects" from their phenomenographic studies.

In summary, idiographic research into student learning in higher education has been strongly influenced by the research program of Marton and colleagues in Sweden in the 1970s. This research informed an understanding of many aspects of students' learning, particularly the way students approach their learning, and how approaches relate to learning outcomes. The studies of Marton and colleagues were the forerunner of many other idiographic studies of tertiary students' learning in the 1970s, which used qualitative methods and were conducted in relation to natural settings and learning contexts. This research has also led to the later development of phenomenography. A phenomenographic approach has been widely adopted in studies of students' understandings of phenomena in tertiary education, including their understandings of scientific concepts.

Limitations of idiographic research

This subsection outlines some of the limitations of idiographic research, from a postpositive perspective. Issues of reliability, validity and researcher effects are discussed, including some criticisms levelled at phenomenographic research.

The value of much idiographic research lies in its use of qualitative methods and emphasis on the subjective experiences of individuals. These characteristics mean that some traditional concepts of reliability and validity are irrelevant in judging the worth of research, from within the alternate paradigm. More appropriate criteria such as authenticity and alternative forms of validity are outlined by Lincoln and Guba (2000, p. 173). From the postpositive point of view underlying this thesis, though, idiographic research in general has some limitations. These relate to reliability and validity, researcher effects (Burns, 1997, p. 13), and the difficulty of generalising across different contexts (Biggs, 1994, p. 9).

Much idiographic research, by virtue of its context–embedded settings and qualitative data, cannot be replicated and reliability, therefore, cannot be ascertained (LeCompte & Preissle, 1993, p. 332). The reliability of phenomenographic studies, in particular, has been argued to be problematic from several points of view. It was suggested by Hasselgren and Beach (1997, pp. 192-195) that there is no consensus, and a lack of critical analysis, on phenomenographic method. From a different perspective, the categories of description produced by phenomenographic analyses were questioned by Sandberg (1997), who pointed out that interjudge reliability procedures are based on objectivist assumptions of knowledge which conflict with the epistemology of phenomenography. Hasselgren and Beach also pointed to a lack of attention to content and construct validity, in part because of non-reflexive acceptance of the assumption that different ways of experiencing can be reduced to a small number of categories.

Researcher effects were highlighted as a particular problem in idiographic studies by Parlett (cited in Burns, 1997, p. 13), because of the intimate relationships between researcher and participants. Richardson (1994a, p. 452) also raised this issue. He suggested that the informal nature of some research in the phenomenographic tradition may lead to participants responding in a way to confirm researcher's expectations.

The issue of the generalisability of phenomenographic studies of student learning was discussed by Biggs (1994). He pointed out that the perceptions of individual students explored by phenomenography are influenced by more stable personality factors, knowledge of which is potentially useful. Biggs also highlighted the limitations of individuals' perceptions in informing practical questions relating to improved pedagogy.

A critical review of phenomenography by Hasselgren and Beach (1997), concluded that despite some limitations, it is a productive research tradition. Given the recent increase of phenomenographic research in student learning in higher education, many researchers agree. According to Entwistle (1997a, p. 129) phenomenography has burgeoned as a research approach because of the insights it provides into the different conceptions of students, and the relevance of this to teaching and learning.

In summary, from a postpositivist perspective, idiographic research including phenomenography has some limitations. These include difficulty in replicating findings, limited generalisability, and the problem of researcher effects. These limitations are associated with the concomitant advantages of idiographic research, in providing detailed explorations of students' context–embedded experiences.

Summary

This section has discussed idiographic research traditions, and their application in higher education. Idiographic research which emanated from Piagetian interview methodologies and Piagetian structuralism, contributed to the development of a range of different constructivisms. Piagetian, personal and social constructivism have had a major influence on research into science learning and pedagogy. Students' personal constructions of meaning result in their own alternative conceptions, which can conflict with accepted scientific views, and are resistant to change despite instruction.

A different strand of idiographic research focusing on student learning in higher education was pioneered by Marton and colleagues, who used interview studies to ask students about the way they approached a learning task and about their subsequent understanding of that task. Further idiographic studies explored students' learning in natural learning contexts, and later the research approach of phenomenography emerged, focusing on the limited range of variation of individuals' experience of a phenomenon. In the context of higher education this approach has been used, among other things, to explore qualitative differences in students' understandings of scientific concepts.

A model of learning and teaching in higher education

This section outlines the "3P" model of student learning. The 3P model is widely accepted and has been adopted by researchers from different research traditions (e.g., Dart & Boulton-Lewis, 1998; Prosser & Trigwell, 1999). It reflects the outcomes of convergent and complementary ideas emerging from the different research perspectives, and inter-relates a number of aspects of research in higher education over the past 40 years.

A version of the 3P model as presented by Trigwell and Prosser (1997, p. 242) is shown in Figure 1.1.

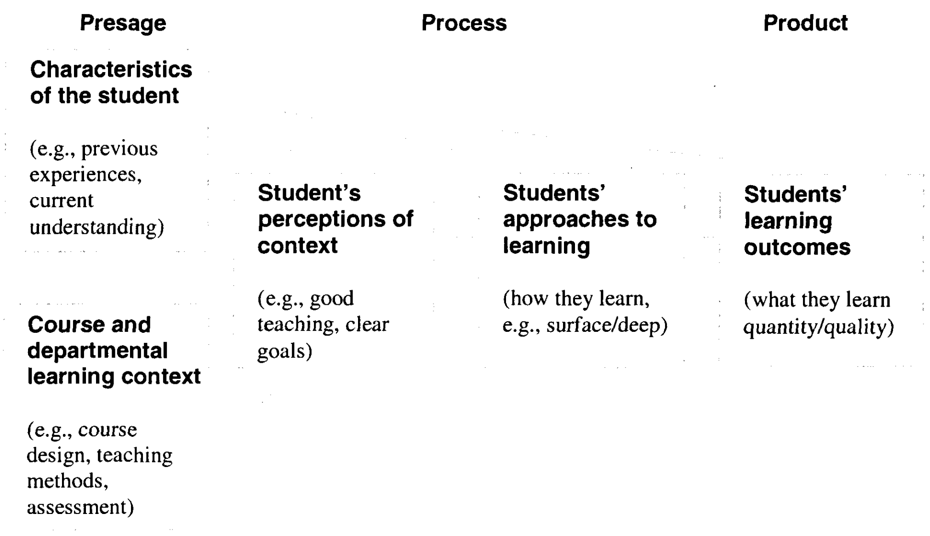

Figure 1.1: A version of the 3P model of student learning

As indicated in Figure 1.1, the 3P model integrates a number of dimensions of student learning. It highlights the relationships between *presage* components of student and context characteristics, *process* components including students' perceptions of the learning context and their approaches to learning, and *product* components, that is, the learning outcomes of students.

As Trigwell and Prosser (1997, p. 242) pointed out, the interactions between the different components of the 3P model can be interpreted from a number of perspectives. The model was derived from a cognitivist perspective, originally modified by Biggs (1978) from an earlier model of teaching published by Dunkin and Biddle in 1974 (cited in Biggs, 1993a, p. 74). Over the years, the model underwent a number of modifications reflecting in part the paradigm shift in student learning research. Biggs' most recent version (1993a, p. 75) is couched in terms of systems theory, with the components mutually affecting each other in continuous interaction towards equilibrium.

The interpretation of the 3P model consistent with a postpositivist philosophy is the "modified dualist" position described by Trigwell and Prosser (1997, p. 242). This perspective acknowledges a two–way relationship between the researcher and the subjects of study, and between the components of the model. It also, though, contends that the components of the model and the relationships between them comprise a reality which is more than subjectively constituted experiences. This modest realist foundation acknowledges the importance of learning context and students' subjective interactions with it, while not precluding the probable reality of components of cognitive functioning such as memory. A postpositive perspective allows qualified generalisations about components of the 3P model and relations between them, including possible causal relationships.

As well as relating various aspects of student learning, the 3P model also provides a useful framework on which to locate and relate the various research perspectives into student learning in higher education that have been reviewed in this chapter.

Many of the nomothetic research programs discussed in this chapter have focused on the *presage* components of students' characteristics. These include information processing theories of the role of memory, encoding and attention in how students learn; developmental theories of cognitive functioning (e.g., Piaget) including the importance of prior knowledge (e.g., Ausubel); and psychometric research focused on stable aspects of cognition and ways that students characteristically approach their learning (e.g., early work of Entwistle and Biggs). With greater recognition of the importance of the presage component of learning context, some of the nomothetic research using psychometric learning inventories shifted focus to the *process* aspect of the model by using inventories of learning approach in more specific learning contexts.

The idiographic research reviewed in this chapter has played a crucial role in highlighting the importance of the *presage* component of context, and the students' perceptions of that context. It has contributed greatly to understanding the *process* component of students' approaches to learning, and the relationship between learning approaches and the *product* of "categories of description" of learning outcomes. The constructivist perspective focuses on the *presage* component of students as active constructors of knowledge, the relationship of this to their learning context and particularly to the *product* component of learning outcome in terms of scientific conceptions and misconceptions. Finally, much phenomenographic research has focused explicitly on investigating variation in students' experiences of the relationships between all the aspects of the model, and providing categories of description of learning outcomes in the *product* component of the 3P model.

Summary

This section has outlined the 3P model of student learning, which has been used as a framework for many studies into learning and teaching in higher education. The model integrates *presage* components relating to students characteristics and learning context, *process* components of students' perceptions and approaches to their learning, and *product* components of students' learning outcomes. It can be interpreted from a range of philosophical perspectives, among which is the "modified dualist" position consistent with postpositivism. Much nomothetic research into student learning in higher education has focused on presage factors of relatively stable student characteristics. Idiographic research, in contrast, has focused on the crucial role of the presage factor of context in relation to the process component of learning approaches, and the relation of these to the product of learning outcomes.

Overview

Research into student learning in higher education and in science has been conducted from both traditional postpositivist and alternate paradigms, with complementary ideas on student learning emerging from both traditions. In the last few decades there has been a paradigmatic shift towards recognising the importance of context and the value of idiographic investigations in natural settings (e.g., Ramsden, 1985).

As predicted by Entwistle and Hounsell (1979), research into tertiary student learning has clearly evolved. Cross–fertilisation from different research programs within and between paradigms has occurred, which according to Biggs (1993b, p. 3) has enriched research in student learning in higher education. For example, the extremely influential concept of constructivism and student conception research has its roots in Piagetian idea of knowledge as construction (Nola, 1997, p. 43). Another example is the information processing concept of working memory, as a fundamental explanatory construct for much neo-Piagetian research, including a number of developmental models (e.g., Case, 1992; Halford, 1993), and the SOLO model (Biggs & Collis, 1982).

Of particular interest are the similar, if not parallel, constructs relating to two fundamentally different forms of learning apparent in all of the research programs outlines above. In chronological order, Ausubel (1963), from a neo-Piagetian research base, distinguished between meaningful and rote "approaches to learning" which comprised intention and process components. From an information processing perspective, Biggs (1970a) postulated "opening out" and "simplifying" study strategies, and Craik and Lockhart (1972) described "elaborative" and "superficial" "levels of processing". The novel interview–based psychometric research of Pask (1976) identified "comprehension" and "operation" learning. In the same year, the idiographic study of Marton and Säljö (1976a) found "deep" and "surface" "levels of processing", with the term "levels of processing" adopted from Craik and Lockhart on the basis of the "metaphorical resemblance" between the concepts (Marton, Hounsell, & Entwistle, 1984, p. 42).

Later, psychometric research from Biggs (1979) reflected the influence of Marton and colleagues in describing "deep" and surface" approaches to learning. The interpretation of Biggs' factors "was in terms of the SAL [student approaches to learning] framework, not the original IP theory" (Biggs, Kember, & Leung, 2001, p. 135), which explicitly acknowledges the influence of Marton and Säljö's deep — surface distinction on the SPQ. In the same year, Entwistle and colleagues (1979) also incorporated ideas from Pask, Biggs and Marton and colleagues in describing "meaning" and "reproducing" learning approaches using psychometric techniques and instruments.

Many of the studies outlined above also investigated the learning outcomes that were associated with the two different ways in which students went about their learning. Better outcomes were found to be associated with a deeper, meaning–oriented type of learning, from research within different programs and paradigms (e.g., Ausubel, 1963; Biggs, 1979; Craik & Lockhart, 1972; Marton & Säljö, 1976a).

Learning approaches and outcomes are two components of the 3P model of student learning and teaching. This model provides a practical and theoretically grounded framework for research into aspects of student learning in higher education, which is consistent with and interpretable from the postpositivist paradigm.

In summary, the discussion in this chapter features two important emphases. The first is an explicitly articulated philosophical research position. The second is a set of interlinked ideas relating to students learning approaches and outcomes in higher education. These concepts have been evident in much research from different paradigms, over a sustained period of time, and have been integrated by a flexible and enduring model of learning. The recurring and apparently robust nature of the concepts of students' approaches to learning, and their relationship to qualitative variation in learning outcome, suggests that these aspects of learning have meaningful and valuable theoretical and practical implications.

This thesis, therefore, aims to investigate the learning approaches and outcomes components of the 3P model, and the theoretical and empirical relationship between them, in tertiary science learning. A postpositive approach is taken in exploring these components of the model. The relationship of other components of the 3P model to learning approaches and outcomes is acknowledged, but as argued by Marton and Booth (1997, p. 123) focal awareness of all aspects of a phenomenon simultaneously is impossible. The research focus of this thesis is a pragmatic compromise between the benefits of a broad relational perspective, and the constraints imposed by space, time and limitations of focal awareness.

This chapter has introduced the core concepts relating to deep and surface approaches to learning, and qualitative variation in learning outcome, within a broad focus on convergent education research programs. The next chapter provides a more detailed review of relevant research into students' approaches to learning, learning outcomes and the relationship between these two aspects of the 3P model. The focus of this review is science learning in higher education.

Chapter 2

Review of the literature: Learning approaches and outcomes in higher education

Introduction

The previous chapter has outlined some of the influential strands of research into student learning in higher education, which have been conducted from both nomothetic and idiographic perspectives, and has highlighted their convergence in learning approaches theory. It described the 3P model which integrates a number of aspects of student learning, and highlighted the research focus of this study on students' learning approaches and outcomes in tertiary science learning.

This chapter presents a detailed summary of previous research relevant to this focus. The first three sections pertain to the three themes of: (i) learning approaches, (ii) learning outcomes and (iii) the relation between these two aspects of learning. The final section provides an overview and describes the research themes and more specific lines of inquiry for this study.

Student approaches to learning

The studies from different research perspectives and methodologies described in Chapter 1 have converged to provide strong support for two fundamentally different approaches to learning – deep and surface learning approaches. A range of issues related to student approaches to learning in higher education are reviewed in this section. The discussion begins with an outline of the characteristics of deep and surface approaches to learning. Studies of learning approaches in the context of tertiary science are then reviewed. Finally, some criticisms that have been levelled at the fundamentals of the deep and surface constructs are presented.

Deep and surface approaches to learning

In recent decades the concepts of deep and surface learning have played a central role in much tertiary education research. As stated by Webb (1997, p. 195):

> The notion of 'deep' and 'surface' approaches to learning has been a foundation stone upon which much of the research, theory and practice of higher education has stood for twenty years. It has become the canon for educational development.

The deep and surface constructs, as stated in a number of reviews of studies into students approaches to learning (e.g., Entwistle & Marton, 1984; Harper & Kember, 1989; Prosser & Trigwell, 1999; Richardson, 1994a; Watkins, 1998), can be recognized across a wide range of educational systems, in different content areas and learning contexts.

This subsection describes the characteristics of deep and surface approaches, including their relation to memorisation, and then the term "learning approaches" is distinguished from related concepts. The relational nature of learning approaches is then outlined, and the relationship between deep and surface constructs discussed.

Characteristics of deep and surface approaches

Deep and surface constructs have been operationalised slightly differently by different authors (e.g., Biggs, 1987; Marton & Säljö, 1976a; Tait & Entwistle, 1996). Essentially, though, the constructs comprise two core interrelated aspects. These are the intention or motivation for engaging in a task, and the processes or strategies that are adopted for learning that task.

Deep learning approaches comprise the intention of learning the meaning (Prosser & Trigwell, 1999, p. 91), or in terms of Marton and Säljö (1976a), learning what is signified. Learners when adopting a deep approach are motivated by intrinsic interest to understand the material and how it relates to other information and ideas. The strategies that are associated with satisfying this intrinsic motivation include reading widely, looking for connections, patterns and underlying principles, thinking about and questioning new ideas and integrating them into overall understanding and awareness.

By contrast, surface learning approaches are associated with the intention of meeting external requirements. Learners using a surface approach are motivated extrinsically to satisfy task demands, with a minimal expenditure of effort. The strategies that are associated with this pragmatic intention include rote-learning for accurate reproduction of information, with a focus on the essentials and individual aspects of the material. The focus of learning is at the level of words or formulae, that is, the "signs" (Prosser & Trigwell, 1999, p. 91).

The main characteristic features of learning for meaning or learning for reproducing are consistent, although the manifestations of deep and surface approaches can differ in different contexts: "the basic meaning remains constant, but its expression is variable" (Entwistle & Marton, 1984, p. 218). One manifestation of different expression of deep and surface learning approaches relates to what has been called the "paradox" of south-east Asian learners. The supposed paradox is that students from Confucian–heritage cultures rely heavily on memorising, and therefore seem to adopt a surface approach to learning, yet demonstrate the high–quality learning outcomes that would be expected of a deep approach. The solution to the paradox hinges on the learning intention of the students and the role of memorisation.

As argued by Kember (1990, p. 343) the intention to either understand or memorise is the most important distinguishing feature of deep and surface learning approaches. The Asian student "paradox" simply reflects the difference between memorising with the intention of understanding and mechanical memorising (i.e., rote-learning) without the intention to understand (Kember, 1990; Marton, Dall´Alba, & Kun, 1996, p. 76). Mechanical memorising or rote-learning is tied to a surface learning approach as the intention of this strategy is to reproduce rather than understand. Memorising with understanding is part of a deep approach to learning, where the intention is to understand through repetition, focusing on different aspects of a text with each repetition (Marton et al., 1996, p. 81). It is this type of deep memorising that characterises the learning of south-east Asian students, and is an expression of a deep approach to learning in that particular cultural context.

The studies showing combined intentions to memorize and understand cited by Kember (1990) were conducted predominantly on south-east Asian students. More recent phenomenographic research by Dahlin and Watkins (1997, cited in Meyer & Shanahan, 2003, p. 6) yielded congruent results for Nepali students, and highlighted the conceptual distinction between memorising before and after understanding.

Subsequent psychometric research by Meyer and colleagues (e.g., Meyer, 2000; Meyer & Shanahan, 2003) has reported similar findings for Australian first–year economics students, and distinguished six forms of memorising and repetition. Memorising before understanding and as a rehearsal strategy is consistent with surface approaches to learning, while memorising after understanding, memorising with understanding and repetition for understanding are consistent with deep approaches to learning (Meyer & Shanahan, 2003, p. 7).

Deep and surface: approaches vs orientations

Because of the range of perspectives and influences in this field of research, the term "learning approach" has been used in a variety of ways. Prosser and Trigwell (1999, p. 38-39) distinguished between related concepts that have historically been encompassed by the term "learning approach". The specific definition of *approach to learning* or *learning approach* used in this study is that of Prosser and Trigwell (1999, p. 88).

> An approach to learning is how an individual student goes about studying in a particular context. It is evoked by that situation (a relationship between the context and the student) and so it is not fully either a characteristic of the student or the context.

By contrast to this context–embedded definition is the concept of *prior orientation* to learning. This is a generalised more stable version of learning approaches, defined by Prosser and Trigwell (1999) as "a reasonably stable culmination of their experiences of studying generally" (p. 39). To clarify these concepts by example, a student typically having a deep *orientation* to learning may respond to a particular context, such as studying for an anxiety–inducing multiple–choice examination, with either a surface or deep *approach*, depending on their perception of the situation. Many researchers (e.g., Biggs, 1987; Entwistle & Ramsden, 1983; Zeegers, 2001) have used the term learning "approaches" in the broad sense to include learning orientations, or have used learning approaches and learning orientations interchangeably.

According to the definitions accepted here, the ASI and the SPQ in their original forms were measures of learning orientation, the more or less stable predispositions to studying. The items in both instruments consisted of statements asking students about their general study behaviours, motivations and values. They did not specify any particular context, other than implying a general academic context.

Entwistle and colleagues (1979, p. 376) identified their factors as learning orientations, and this is consistent with the prior orientation definition of Prosser and Trigwell (1999). Nonetheless, Entwistle and colleagues continued to use the term learning approach synonymously with learning orientation, in the same publication, in subsequent research and in the title of their "Approaches to Study Inventory" (ASI). Biggs (Biggs, 1987) also explicitly assigned the focus of his research to the more stable general orientation to learning:

> The writer has developed a theory of student learning that is more in the second tradition, and has designed instruments that measure the extent to which individuals typically endorse common approaches to learning tasks. (Biggs, 1987, p. 1)

Recent research into learning "approaches" of first–year university chemistry students by Zeegers (1999; 2001) is an example of the use of the SPQ as a measure of learning orientations, according to the definitions accepted in this thesis.

These study inventories, however, are also used to measure learning approaches, by specifying a particular context for their use. Biggs, Kember, and Leung (2001), argued that "SPQ responses are a function of both individual characteristics and the teaching context" (p. 137). They also suggested that for the purposes of establishing students' approach in a particular classroom situation, researchers should instruct students to reply in a given context, rather than in the context of studying generally. A number of recent studies have investigated tertiary science students' approaches to learning by rewording items in the SPQ to specific contexts (e.g., Crawford, Gordon, Nicholas, & Prosser, 1998b; Hazel et al., 2002; Prosser et al., 1994).

The discussion in the remainder of this chapter includes interpretations of student approaches to learning that by definition would be considered as prior orientations to learning. Discussion of learning "approaches" in this wide sense is necessary for a number of reasons, among which is that by definition, learning approaches and orientations are linked. In discussion of this issue Biggs (1993b, p. 5) argued that "the nature of the constructs addressed is closely related", a claim supported by studies showing high congruence between learning orientations and approaches in some contexts (e.g., Tang, 1994). In addition, some of the research methodology and instruments derived from investigations of learning orientations are also used in research into learning approaches.

Relational nature of learning approaches

Idiographic studies following the work of Marton and colleagues demonstrated clearly the relational nature of approaches to learning. The approach taken by students is interconnected to factors such as their conceptions of learning, prior understanding, their perceptions of the teaching context, and learning outcomes. Säljö (1979) reported that narrow and taken-for-granted conceptions of the nature of learning are thought to limit students to a surface learning approach, while more complex, reflective conceptions of learning can allow for a deep learning approach and real understanding.

Interview–based studies with undergraduate science students (Laurillard, 1979) found that over half of the students adopted deep or surface strategies depending on the perceived requirements of the task, with the remainder using only deep strategies. As pointed out by Laurillard, this suggests that a surface approach is context–sensitive rather than a stable characteristic of particular students. Ramsden (1979) interviewed students in different departments to investigate whether deep and surface approaches were associated with different contexts. This study found that Marton and Säljö's learning processes applied to learning tasks such as essay writing and problem-solving in science. It also highlighted the influence of assessment practices, a supportive teaching atmosphere, and background knowledge on students' perceptions of their learning environment, which strongly affected the approaches students took to their learning.

Relationship between deep and surface constructs

At issue in students' approaches to learning has been the assumed relationship between deep and surface constructs. In the original work by Marton and Säljö (1976a) in a very specific experimental situation, the distinction between deep and surface approaches was expressed as a dichotomy, corresponding to "the different aspects of the learning material on which the learner focuses" (Marton & Säljö, 1976a, p. 7). Deep and surface approaches were mutually exclusive; the learners' attention and intention were thought to be directed either at the text itself or at its meaning. It must be noted, though, that even in this seminal research, in some cases signs of both approaches could be found (Marton & Säljö, 1984, p. 42). Likewise Richardson (2000, p. 82) suggested that "in any particular learning task it would seem that a surface approach and a deep approach are mutually exclusive".

Idiographic research by Laurillard (1984) into the ways tertiary science students approached specific problem–solving tasks supported the deep/ surface dichotomy, with the students' intention either to understand the meaning or to memorise being the key to the approach adopted.

Later, Marton and Booth (1997, p. 22) posited a hierarchical relationship between the deep and surface constructs, because the deep approach implied nonfocal awareness of the text, or the "sign", but that the reverse was not true. A similar hierarchical relationship of learning approaches was postulated in a phenomenographic study into the learning of first–year mathematics students (Crawford, Gordon, Nicholas, & Prosser, 1994). Here also, though, the deep and surface motives appear to be viewed as mutually exclusive: "a student who has the intention of studying for understanding cannot simultaneously include an intention of just reproducing knowledge and procedures" (Crawford et al., 1994, p. 338). The word "just", though, has a crucial function in this slightly circular argument, which logically implies that the intention to understand can simultaneously include an intention of also reproducing (but not "just" reproducing).

These conceptions of deep and surface differ fundamentally from the relationship between rote and meaningful learning according to Novak (1998, p. 20). In this account of learning, there is a continuum between the opposite poles of rote and meaningful learning.

Both the mutually exclusive model of deep and surface learning (e.g., Marton & Säljö, 1976a), and the continuum model of meaningful and rote-learning (Novak, 1998) can be contrasted with the deep and surface (and achieving) concepts in the research of Biggs (e.g., 1979). Here deep and surface approaches were seen as independent ways by which students could engage in their learning. One of the assumptions of the SPQ was that the three dimensions (deep, surface and achieving) of the original SPQ were independent, so that some students could have mixed motives and adopt multiple strategies (Biggs, 1979, p. 383). Biggs (1987, p. 12). argued that it was possible to be motivated both to reproduce detail and to seek meaning (motivation associated with both surface and deep approaches), but argued that it was "difficult to see" how the surface strategy of rote-learning could be adopted simultaneously with meaning–seeking strategies.

Many of the subsequent factor analyses of the SPQ and its variants have assumed independence of the deep and surface scales and used orthogonal (Varimax) rotation. Some studies (reviewed by Watkins, 1998, p. 132) have examined the relationship of the scales using oblique (direct oblimin) rotation which resulted in similar factor solutions as had been previously found by Biggs with orthogonal rotation. In an investigation of the structure of the SPQ using oblique rotation, O'Neil and Child (1984) concluded that the scales were "virtually independent" (p. 232). These studies support the independence of deep and surface orientations to learning: as stated by Richardson (1994a), "in principle and practice scores on these factors are essentially independent" (p. 464).

The question of whether deep and surface approaches to learning are bipolar or orthogonal concepts was addressed in a study by Thomas and Bain (1984). These researchers developed a questionnaire that reflected aspects of deep and surface approaches to learning, which they called transformational and reproductive learning. Results of their study showed that transformational and reproductive learning in a given context were positively correlated, supporting neither an orthogonal (independent) or bipolar categorisation of approaches. The authors cited previous research where students had reported using both deep and surface approaches (Säljö 1981, cited in Thomas & Bain, 1984, p. 237), and concluded that a dichotomous classification of approaches did not reflect "the normal mix of activities used by students" (Thomas & Bain, 1984, p. 237).

Interestingly, Thomas and Bain (1984, p. 237) reproduced a personal communication from Ramsden that argued precisely the opposite to Biggs (1987, p. 12). While Biggs had suggested that joint deep and surface motivation was possible, but that joint strategies were unlikely, Ramsden saw joint deep and surface motivation as highly unlikely, but joint deep and surface strategies as possible. Although Thomas and Bain accepted transformational and reproductive learning as distinct approaches, they explicitly raised the possibility that "some students may intend to understand and to reproduce…Just how many students 'merely' intend to study one way rather than another?" (Thomas & Bain, 1984, p. 237).

A number of studies (e.g., Entwistle, Meyer, & Tait, 1991; Prosser, Trigwell, Hazel, & Waterhouse, 2000) focused on the adoption by students of "disintegrated" or "incoherent" learning approaches. Some students who bring to their learning aspects or mixes of both deep and surface approaches hold perceptions of their learning context which are not coherent with their approach adopted (Prosser & Trigwell, 1999, p. 96).

In summary, deep approaches to learning are based on an intention to understand, while surface approaches are associated with the intention to reproduce information. Deep approaches, therefore, can include rote-memorisation where this is adopted to aid understanding. The term "learning approach" in this study is the context–dependent way that students engage with their study, rather than the more stable learning orientations which are sometimes also referred to as learning approaches. Deep and surface approaches are relational, in that they are a context–specific way by which students engage with their learning. Finally, the perceived relationship between deep and surface constructs is somewhat variable. There are some arguments for a dichotomous, hierarchical, or continuum relationship but most research suggests or assumes independence between deep and surface, and the likelihood of some students adopting aspects of both approaches to some degree.

Learning orientations and approaches in tertiary science

This subsection reviews research into learning approaches of tertiary science students. It begins with a description of the ways that deep learning is manifested in science learning, and then reviews evidence for widespread use of surface and disintegrated approaches by university science students. Finally, some important links between learning approaches and other aspects of the 3P model of learning in science are outlined.

Deep learning in science

Some of the different forms of memorising highlighted in the Asian "paradox", as pointed out by Prosser and Trigwell (1999, p. 94), are also apparent in the expression of learning approaches in tertiary science. It had earlier been suggested, on the basis of analysis of student interviews, that a deep learning approach in science requires an attention to detail and procedures which is "empirically hard to separate from a surface approach" (Ramsden, 1984, p. 157), and may initially involve a stage of rote-learning of information in a way similar to a surface approach (Entwistle & Ramsden, 1983, p. 194).

The observations of Prosser and Trigwell (1999, p. 94) were that science and engineering students used memorising with understanding as part of a deep approach to learning. The use of memorising with understanding (deep-memorising) by students revising for examinations was also described by Entwistle (1998, pp. 82-84), and Tang (1994). Related to this issue is a study of tertiary science teachers' perceptions of the relationship between memorising and understanding (Cooper, Frommer, Gordon, & Nicholas, 2002). This research demonstrated conflicting views of university science teachers, with some seeing memorising and understanding as unrelated processes, and others seeing them as closely interlinked.

Apart from the use of deep memorisation, research has also shed some light on other features of a deep approach in the context of tertiary science. Entwistle and Ramsden (1983) described the following characteristics of the deep approach when used by science students.

> In the science departments, indications are most frequently of attempts to relate together the various aspects of a problem, particularly in a logical way (to 'see how it all fits together') (p. 143).

This research also highlighted that a deep approach in science students was characterised by efforts to relate concepts specifically to other ideas or problems in science. By contrast, a surface approach in science may be characterized by too much of a focus on techniques and specifics of procedures (Ramsden, 1984, p. 158).

Surface and disintegrated approaches in science learning

Research into the learning approaches of tertiary science students has found in general, relatively high proportions of students with surface, and mixed or disintegrated deep and surface approaches. In an investigation into learning approaches of first–year biology students at two metropolitan Australian universities, a quarter of the students adopted a surface approach, and nearly half of the students indicated use of disintegrated approaches to study of the topic of photosynthesis (Hazel et al., 2002, p. 744). A phenomenographic study by Prosser, Walker, and Millar (1995) indicated that three quarters of the commencing first–year physics students took a surface prior approach to their studies. Cluster analysis of student responses to a topic–specific version of the SPQ provided further evidence of incoherent patterns of learning approaches in learning first–year physics (Prosser, Hazel, Trigwell, & Lyons, 1996; Prosser et al., 2000). One group of students (41% of the sample) adopted neither a surface nor deep approach, and another group (15 % of the sample) reported using elements of both surface and deep approaches.

Comparisons of learning orientations across faculties have also indicated that science students in general tend towards a more surface orientation to study than their peers in other faculties. A study by Watkins and Hattie (1981, p. 384), using the SPQ at the University of New England, Australia, found that a deep orientation was relatively infrequently reported by science students, who tended to have extrinsic vocational motivation and to adopt surface study strategies. Biggs (1982) compared responses to the SPQ from over 2000 students from Arts, Science and Education faculties in Australia, and found that science students scored highest on surface strategies, and lowest on intrinsic motivation. A longitudinal investigation into learning orientations of first–year chemistry students by Zeegers (2001, p. 126) found "consistent reliance on surface strategies over deep strategies".

These findings are consistent with the learning approaches that might be predicted from the "custom–built irrelevance" (Lowe, 1994) that characterises many traditional first–year science units, that are compulsory prerequisites to "service" students for later more specialised options. Reliance on surface approaches is also consistent with didactic teaching approaches. A study of nearly 4000 first–year chemistry and physics students and 46 of their teachers (Trigwell, Prosser, & Waterhouse, 1999) found that surface approaches to learning were associated with teacher–focused information–transmission pedagogy, but not with a more student–focused conceptual–change constructivist teaching style.

Relationship between approaches and other aspects of the 3P model in science learning

A number of studies of tertiary students' learning have also demonstrated the importance of prior knowledge on the approaches and outcomes of learning science. Biggs (1970a) suggested that success in science was highly dependent on previous mastery of relevant scientific content. Idiographic studies reported by Entwistle and Ramsden (1983) compared perceptions of physics and engineering students with perceptions of students from other non-science departments. The students in general perceived that learning in science is "hierarchical, logical, heterogeneous and rule– and procedure–governed" (Entwistle & Ramsden, 1983, p. 165), and the authors argued that when knowledge is hierarchically structured, new concepts can only be mastered if previous stages are clearly understood (Entwistle & Ramsden, 1983, p. 175).

Ramsden later (1984) stated that in the sciences, a deep approach required good prior knowledge of the disciplinary area. This argument was supported by later research by Hegarty-Hazel and Prosser (1991c) into study strategies of first–year physics and biology students. They concluded that poor prior knowledge was associated with use of surface study strategies, and conversely that students with good prior knowledge adopted deeper study strategies. Similar findings were evident in the research of Hazel, Prosser, and Trigwell (2002), which demonstrated an association between poor prior knowledge and disintegrated learning approaches in first–year biology students.

Studies of students' approaches and orientations to learning in tertiary science have examined associations between learning approach and other variables such as age and time at university. Studies across a range of disciplinary areas (reviewed by Richardson, 1994b) have shown that mature students report more use of deep approaches and orientations to learning than their younger counterparts, and less use of surface approaches and orientations (Richardson, 1994b, p. 318), and this pattern has frequently been identified in science students (e.g., Harper & Kember, 1986; Watkins & Hattie, 1981; Zeegers, 1999, 2001).

Studies have also found that reported use of deep orientations to learning in science faculties does not increase over time. Biggs (1987, p. 53) showed a decline in deep orientation from first to third year, and a longitudinal study by Watkins and Hattie (1985) of students in arts, science and economics faculties, using the ASI, showed a decrease in meaning orientation from first to third year. Zeegers (2001) found that learning orientations of chemistry students showed no overall change from first to third year. An investigation of learning orientations of first–year medical students using the ASI by Coles 1984 (cited in Clarke, 1986, p. 320) found a decline in meaning orientation scores and an increase in reproducing scores for students studying a traditional curriculum, and no change in meaning and reproducing scores for students in a problem–based course.

This general trend is not specific for science or for Australian universities, and a similar picture is evident across a range of disciplines and university systems (e.g., Gow & Kember, 1990; Volet, Renshaw, & Tietzel, 1994). As noted by Gow and Kember (1990, p. 307), the decrease in deep approaches and increase of surface approaches during the course of a university degree is counter to the espoused aims of tertiary institutions, which usually emphasise the importance of independent self-directed learners.

In summary, deep learning in science can involve an initial stage of rote-learning, where this is done with the intention of understanding, and the use of memorising with understanding. Deep approaches also attempt to relate together different scientific concepts. Research into learning approaches of tertiary science students has shown considerable use of surface or mixed approaches, and that historically, science students have reported more surface orientations to learning than students in other faculties. Deep approaches in science are associated with good prior knowledge and occur more often in mature–aged students, and deep orientations to science learning tend to decrease rather than increase over the course of university study.

Criticisms of student approaches to learning theory

This subsection outlines some of the criticisms that have been levelled at students' approaches to learning theory. Although the deep and surface constructs are very strongly supported and widely accepted, the reliability of surface scale of the original SPQ has been questioned, and it has been pointed out that the task–appropriateness of approach is particularly important. The deep/surface binary and its hegemony in higher education have been critiqued from a post-modern perspective, and the relevance of the learning approaches model in mass tertiary education questioned.

The fundamental concepts of deep and surface approaches to learning have received support from countless studies in higher education. While some studies have questioned the reliability of some of the scales and subscales of the ASI and SPQ, the basic constructs of deep and surface learning approaches have attracted relatively little criticism. This was noted by Webb (1997, p. 198) as surprising, given the longevity and currency of these ideas.

One of the challenges to ideas on learning approaches was from an information processing perspective (Christensen, Massey, & Isaacs, 1991a, 1991b), which raised a number of questions about the surface and achieving scales of the SPQ. The authors also pointed out that many students could not be classified as using any particular approach, because of even spread of scores across all three dimensions and inconsistencies between interview data and SPQ scores. Christensen at al. (1991a; 1991b) also compared SPQ responses with an alternative framework from the information processing perspective (Weinstein & Mayer, 1986, cited in Christensen et al., 1991b, p. 250), and found no relationship between responses for two experimental tasks. They concluded that the taxonomy of Weinstein and Mayer provided a better basis for examining learning strategies than the SPQ.

In answer to some of these points, Biggs (1993b, p. 11) suggested that the factor solution of Christensen et al., when viewed in accordance with the conceptual framework of the SPQ, was in fact satisfactory. Although it was argued (Biggs, 1993b, p. 12) that results using the SPQ usually confirmed a three–factor model, subsequent research (e.g., Kember & Leung, 1998), also pointed towards a two–factor model, and a two–factor version of the SPQ was later developed without the problematic "achieving" scale (Biggs et al., 2001). Other researchers, meanwhile, had modified the original SPQ by deleting items pertaining to the Achieving approach (e.g., Hazel et al., 2002).

In terms of the non-relationship between SPQ responses and strategies from the Weinstein and Mayer taxonomy, Biggs (1993b, p. 13) pointed out that a relationship would not in fact be expected, given the difference between an artificial ad hoc task and the context of academic study. Biggs (1993b, p. 15) also criticised the information processing basis of the Weinstein and Mayer taxonomy as inappropriate to the complexities of the interactive system of learning and teaching, which is characterised by interrelationships between factors such as content, assessment procedures, student perceptions and departmental and institutional values.

A later discussion of student approaches to learning from the information processing perspective (Dyne et al., 1994) further questioned the deep and surface dichotomy. This discussion invoked transfer appropriate processing (TAP) theory in suggesting that task appropriateness was a better classification of learning strategy than the deep and surface strategies. The authors also suggested that that flexibility in using a combination of approaches is most beneficial to students, as neither surface or deep approaches are intrinsically more valuable.

Further criticism to students' approaches to learning theory was mounted by Webb (1997) and Haggis (2003), who questioned the growing hegemony of the ideas of deep and surface learning approaches for a number of reasons. Webb took issue with the differentiation of the "sign" from the "signified" in the original work of Marton and Säljö (1976a), applying the post-structural arguments of Derrida in suggesting that sign and signified are in a "constant and indeterminate play of différence" (Webb, 1997, p. 205). He also questioned the power of the deep and surface "metaphor" in higher education research and staff development, which he argued, reflects current power relations which marginalise discourses such as hermeneutics, post-structuralism and a number of others (Webb, 1997, p. 209).

Both Webb (1997) and Haggis (2003) criticised research into deep and surface learning approaches for a positivist focus on generalisation, its value–neutral position and for reproducing the orthodoxy of its discourse. Haggis (2003, pp. 92-93) also criticised implications in some literature that deep approaches and high–quality outcomes can be induced by changing presage factors such as assessment regimes. This, she argued, is counter to much research indicating that inducing deep approaches is very difficult. Finally, Haggis (2003, p. 89) suggested that although the model of learning approaches may apply to the "elite goals and values of academic culture, it says surprisingly little about the majority of students in a mass system". Accordingly she advocated attention to the development of context–specific academic literacies as an alternative complementary approach to understanding student learning (Haggis, 2003, p. 100). Aspects of this critique have sparked lively debate and some dissension (M. Prosser, J. Meyer et al., personal communication August 2003).

In response to Webb's critique, Entwistle (1997b, p. 214) highlighted the concordance of a deep approach with the goals of tertiary education, and hence queries Webb's criticism of the value judgements that accord with preference for a deep approach. Entwistle (1997b, p. 215) pointed to the quantity of empirical evidence from a range of studies other than phenomenography which supports the deep/surface metaphor and its use as a framework for research and educational development. In addition, Entwistle (1997b, p. 217) questioned the utility of post-modern discourse as an alternative in staff development.

In summary, the fundamental concepts of deep and surface learning approaches are widely accepted. Questions raised about the achieving scale of the SPQ have been addressed with its subsequent removal, and criticisms of the SPQ from an information processing perspective countered by highlighting its appropriateness to the complexity and context–dependent nature of learning. The criticisms relating to the hegemony and relevance of the learning approaches model have been refuted by some of its proponents. They have pointed to the large body of evidence, from a number of research paradigms and methodological traditions, which supports the learning approach model as framework for research into student learning in higher education.

Summary

Deep and surface approaches to learning are associated with fundamentally different learning motivations and strategies. Deep learning is meaningful learning, motivated by intrinsic interest in the subject matter and characterised by strategies such as reading widely and integrating new knowledge into previous learning. By contrast, surface approaches are based on extrinsic motivation; the intention is to satisfy externally imposed requirements by rote-learning information to reproduce it as required. These two constructs have been identified in numerous studies in many cultural contexts, although deep approaches to learning in many south-east Asian students involves a kind of memorisation superficially akin to a surface strategy.

Deep and surface approaches to learning are context–dependent, which distinguishes them from more stable deep and surface learning orientations. They are therefore closely linked to other components of the 3P model such as prior understanding and perceptions of teaching context. The relationship between deep and surface has been described variously as bipolar opposites, or as independent ways by which students engage in their learning. Mixed and disintegrated approaches to learning have also been recognized, suggestive of joint extrinsic and intrinsic motivation, and/or use of both deep and surface strategies.

Studies of learning approaches and orientations in tertiary science have indicated that deep approaches can require attention to detail and memorisation for understanding, as well as seeking to relate together aspects within and between scientific concepts. Science students demonstrate relatively high use of surface approaches and orientations, and prior knowledge in science is important. Good background knowledge is associated with deep learning approaches and with higher–quality learning outcomes. In addition, learning approaches are related to age, with mature–aged learners reporting more use of deep approaches. Unfortunately, though, deep approaches to learning in science do not increase over time, and therefore do not seem to be encouraged by current tertiary education systems.

Apart from some questions about scale reliabilities of the SPQ and ASI, there has been relatively little criticism of the basic constructs of deep and surface approaches to learning. It has been suggested that information processing theories are a better way of conceptualising and investigating learning strategies, although proponents of the student approaches to learning ideas argue that information processing frameworks are inappropriate to the complexities of real–life learning and teaching. The deep/surface dichotomy has attracted poststructural critique, and learning approaches theory has been criticised for marginalizing alternative research perspectives, for implying that deep approaches can be induced by particular assessment regimes and for being irrelevant to many students in the current era of mass tertiary education.

The quality of learning outcomes

The discussion below outlines some research into learning outcomes, beginning with a discussion of early research into qualitative differences in learning outcomes. The development of the SOLO model is then outlined, followed by discussion of the major features of SOLO and its applications in describing variation in learning outcomes in tertiary science. Some of the criticisms of SOLO are also outlined.

Central to this discussion is that variation in students' understanding and learning outcomes is qualitative, and not just a quantitative matter of degree. Variation in learning outcomes in science encompasses fundamentally different alternative conceptions (West & Pines, 1985), a range of incomplete understandings, and complete, scientifically acceptable understandings.

Qualitative variation in learning outcomes

In this subsection, the seminal research of Marton and colleagues into qualitative variation in learning outcomes is described. The results of later phenomenographic studies into learning outcomes are discussed, as well as some criticisms directed towards phenomenography as a method of analysing students' learning outcomes.

As well as investigating study processes, the research program of Marton and colleagues (e.g., Marton & Säljö, 1976a, 1976b) was simultaneously investigating qualitative measures of learning outcomes, and how learning outcomes related to learning approaches. The early research of Marton and colleagues into learning outcomes has been summarised by Dahlgren (1984). A number of qualitative analyses of student responses identified, in general, four levels of learning outcome that empirically represented qualitatively different ways of understanding (Dahlgren, 1984, p. 26). Although response categories were specific to the content, a pattern of structural differences was identified in many cases. For example, categories were frequently hierarchically related. Responses at the highest level contained elaborate understanding of the "intentional content" of the argument, and responses at the next lowest level contained only part of the intentional content. Responses at the lowest two levels either missed the point, or simply restated part of the question (Marton & Säljö, 1976a), and were associated with surface processing.

Similar patterns of hierarchically related levels of learning outcome in tertiary science have been identified in a number of subsequent phenomenographic analyses (Prosser & Trigwell, 1999, p. 122). For example, in a study of first–year biology students' understandings of photosynthesis using both phenomenography and SOLO (Hazel et al., 2002) the outcome space of the phenomenographic analysis showed four categories of response (two of which had two subcategories). Responses in the lowest category contained no information relevant to the point, and the next category contained incomplete responses that indicated the role of energy conversion but did not recognise key reactions in the process. The next category of responses recognised and partially described the two key reactions, while the final category of responses fully described "the process as a whole", with the most complete answers providing a biochemical explanation.

As noted by Hazel et al. (2002, p. 741), this pattern "exemplifies the hierarchical relationship between the categories of description, with Category 1 being the least inclusive and Category 3 the most inclusive". The response categories in Hazel et al. (2002), and other phenomenographic–type analyses, were derived empirically using a qualitative approach consistent with the alternate paradigm in educational research. No nomothetic assumptions underpin the recurrence in phenomenographic outcome spaces of four to five hierarchical categories of response.

Phenomenographic analyses of students' learning outcomes are open to more general criticisms of idiographic research method that were outlined in Chapter 1. These include difficulty in generalising across contexts (Biggs, 1994, p. 9), and questions about the reliability of the phenomenographic categories of description of learning outcomes (Richardson, 1994a, p. 452; Sandberg, 1997). From a different perspective, Säljö (1997, p. 188) regarded the abstractions generated by phenomenographic "categories of description" of learning outcomes as "not too unlike the search for general 'psychological processes' that we once objected to". He suggested that they do not describe students' ways of experiencing, but rather the students' attempts at communicating their experiences in a particular situation.

In summary, the early interview–based research of Marton and colleagues identified four qualitatively and structurally different levels of learning outcome. Better responses reflected understanding of "intentional content" while responses at lower levels contained only part of the intentional content, or missed the point or restated the question. Similar hierarchies of four or five levels of response have been identified in subsequent phenomenographic studies of students' learning outcomes. Although phenomenography remains a widely used analytic tool, it has received some criticism relating to generalisability and reliability, as well as explicit acknowledgement that phenomenographic categories represent students' descriptions of their ways of experiencing.

Development of the SOLO model

In arguing for the necessity of reconciling different but complementary perspectives in research, Marton and Svensson (1979) pointed to the SOLO model as an example of work that straddled the divide between the quantitative — qualitative dimension of different research perspectives:

> We can also find an intermediate model of description related to the qualitative — quantitative dichotomy. This is very clearly represented in Biggs' (1979) work. The SOLO levels, which are indeed based on thorough qualitative analyses and descriptions of the pupil's understanding of various learning tasks are utilised by him as a measure of quality of learning, using an ordinal scale which is correlated with instructional as well as individual variables considered as potential explanatory constructs. (Marton & Svensson, 1979, p. 477)

In this subsection the development of the SOLO model is traced, from its beginnings in Piagetian research, through a number of versions to the most recent two-learning-cycles per mode version. The characteristics of the modes and levels that comprise the SOLO hierarchy are described.

The theoretical framework of SOLO has changed and developed over the thirty years since its inception, but at the core of SOLO is a hierarchy of generic categories (modes and levels) describing increasingly more complex types of learning response, which can be applied to any specific learning context. The SOLO model originated from work by Collis and Biggs collecting examples of different Piagetian stages from school classrooms.

> Out of this work a taxonomy evolved which seemed to coincide with a generalised version of Marton's notion of levels and seemed to provide a means of measuring learning quality. We called this the SOLO taxonomy because it refers to the Structure of the Observed Learning Outcome. (Biggs, 1979, p. 384)

Since these beginnings, the SOLO taxonomy has evolved considerably, which Redden (1995, p. 44) suggested has reflected a fluidity common to theoretical frameworks. Milestones in the development of the SOLO taxonomy are summarised in Table 2.1.

Table 2.1: Major steps in the development of the SOLO model, and their relationship to Piagetian stages and different forms of knowledge:

Collis 1975	Biggs 1979	Biggs & Collis 1991		Pegg & Davey 1998		Form of knowledge
Modified Piagetian stages [1]	SOLO level isomorphic to Piagetian stage	SOLO mode isomorphic to Piagetian stage	SOLO levels, single learning cycle	SOLO mode isomorphic to Piagetian stage	SOLO levels, two learning cycles	
Formal operations (16+)	Extended Abstract (EA)	Postformal (20+)	U → M → R	Postformal (20+)	U_1 → M_1 → R_1 → U_2 → M_2 → R_2	Theoretical
Concrete Generalisation (13-15)	Relational (R)	Formal (16+)	U → M → R	Formal (16+)	U_1 → M_1 → R_1 → U_2 → M_2 → R_2	Theoretical
Middle Concrete (10-12)	Multistructural (M)	Concrete–symbolic (6+)	U → M → R	Concrete–symbolic (6+)	U_1 → M_1 → R_1 → U_2 → M_2 → R_2	Declarative
Early Concrete (7-9)	Unistructural (U)	Ikonic (18 months+)	U → M → R	Ikonic (18 months+)	U_1 → M_1 → R_1 → U_2 → M_2 → R_2	Intuitive
Pre-operational (4-6)	Prestructural (P)	Sensorimotor (birth+)	U → M → R	Sensorimotor (birth+)	U_1 → M_1 → R_1 → U_2 → M_2 → R_2	Tacit

[1] (as per Collis 1975, cited in Biggs & Collis, 1982, pp. 24-25)

The SOLO taxonomy was initially conceived as a single, unbranched hierarchy of five levels of learning responses centring on concrete thinking, which were considered as corresponding to, but "logically distinct" from, Piagetian stages (Biggs, 1979, p. 384) (see Table 2.1). In the later monograph describing the SOLO taxonomy (Biggs & Collis, 1982) some ambiguity surrounds the relationship of SOLO levels to Piagetian stages. Biggs and Collis (1982, pp. 24-25) depicted five SOLO levels (prestructural, unistructural, multistructural, relational & extended abstract), each having a one-to-one correspondence with modified Piagetian stages. In the same publication (Biggs & Collis, 1982, p. 216), a more complex dual linear hierarchy is also proposed, showing recurring "learning cycles" of different SOLO levels within each "mode of functioning" or developmental stage.

This ambiguity was clarified by Collis and Biggs (1983) where the SOLO taxonomy distinguished clearly between the degree of abstraction of content (the mode) and the structure of response (levels). In this and all subsequent versions it is the five modes (not levels) that are isomorphic to the original Piagetian developmental stages, while the five levels describe increasing quality of learning responses within each mode.

By 1991 (see Table 2.1) Biggs and Collis had established a terminology for the modes, and the typical age at which each usually becomes apparent, which has remained essentially unchanged. The next major features in the evolution of the SOLO taxonomy were the identification of multimodal functioning (Biggs & Collis, 1991), at least two cycles of levels within some modes (e.g., Pegg & Davey, 1998) and the hypothesised existence of at least two learning cycles within all modes (see Table 2.1). The first cycle (U_1, M_1 and R_1) has been identified by Pegg and Davey (1998, p. 121),as falling within the original unistructural category in the sense of Biggs and Collis (1991), while M_2 and R_2 are equivalent to the M and R of Biggs and Collis (1991).

SOLO modes and levels

As outlined above, the two factors which discriminate between quality of response in SOLO are the degree of abstraction and the structural complexity of responses. The degree of abstraction is the basis for the developmental stages recognised by SOLO as modes. The structural complexity of responses within any given mode forms the second order hierarchy of SOLO levels. The hierarchy of modes and levels that forms the backbone of the SOLO taxonomy is described in more detail in this subsection.

As shown in Table 2.1, SOLO comprises five modes, which in the normal course of events may become sequentially available to individuals from birth to young adulthood. These five modes of functioning are described in Table 2.2 in order of appearance from birth to maturity, based on descriptions in Biggs and Collis (1991, p. 61-67), and Collis and Biggs (1991, p. 188-191).

Table 2.2: Modes in the SOLO model and their characteristics

Mode	Characteristics
Sensori–motor (from birth to about 18 months of age	This mode involves tacit knowledge, the unarticulated "know-how" to perform motor skills in response to physical environmental stimuli. In infants where this is the only available mode it is associated with learning responses such as sucking, grasping and crawling. In adults, the sensorimotor mode is invoked in learning of skilled motor activities such as gymnastics or swimming, but this learning is augmented by more abstract modes.
Ikonic (from 18 months to about 6 years of age)	This mode represents a step of abstraction from action to thought by way of mental imagery or "ikon" generation. Such ikonic thought in young children is associated with intuitive knowledge that is perceived directly, and is prerequisite for and associated with the development of language.
Concrete–symbolic (from around 6-14 years of age)	The concrete–symbolic mode represents a further progression in abstraction. In this stage oral language is supplemented by more abstract symbol systems such as written languages, signs, maps and so forth. These symbol systems follow an internal logic, and relate in a logical manner to the experienced world that they represent. Mastery of these more abstract symbol systems requires explicit instruction, in contrast to the previous modes, and this is the task of primary and secondary schooling. This leads to declarative knowledge, where symbol systems are used to describe the concrete world. Most of the cognitive tasks in day-to-day living are within this mode.
Formal mode (from about 16 years of age)	Some individuals develop a more abstract system of thinking that enables manipulation of theoretical constructs that do not necessarily have any direct empirical referent. Formal thinking allows for hypothesis generation and propositional reasoning, and the theoretical knowledge associated with the formal mode is necessary for understanding abstract academic disciplines. It is therefore the target mode for undergraduate university study.
Postformal mode (from about 20 years of age onwards)	This mode is hypothesised to occur in a small minority of individuals. The postformal mode has not been subject to much examination or supported by empirical evidence, but is thought to be characterised by the ability to question and challenge the basic tenets and bounds of a discipline, and to make major innovations in a specific disciplinary area.

As the SOLO modes become available to individuals, the more advanced abstract modes do not replace preceding stages, as would be suggested by Piagetian stage theory, but augment them. Consequently, adults demonstrate a wider repertoire of modes than do young children and multimodal functioning becomes possible (Biggs & Collis, 1991, p. 62). For example, the formal mode can be used to support a learning task predominantly in the sensori–motor mode, for instance by applying theoretical aspects of water resistance to improve performance in a sensori–motor activity such as swimming. This is a case of using a more abstract mode to facilitate a learning task primarily involving a less abstract mode, but the converse also occurs.

Learning in the formal mode is frequently augmented by concrete–symbolic referents, so that in teaching an abstract scientific concept such as meiosis, different coloured lengths of pipe-cleaners are routinely used as concrete representations of the subcellular structures involved. In addition, while SOLO modes and the ages at which they occur reflect age–related developmental stages in learning, they do not predetermine the level of abstraction of learning performance. They merely constitute an upper limit to the heavily context–dependent business of learning, so a student performing in the formal mode in one situation, may respond in the concrete–symbolic or even ikonic mode in another less familiar or less relevant context.

While the modes of SOLO described above are based on the degree of abstraction of a learning response, performance within modes is thought to proceed through cycles of five levels of increasing structural complexity (Biggs & Collis, 1991). These levels can therefore be used to classify responses based on structural complexity; hence "Structure of the Observed Learning Outcome". The SOLO levels are described in more detail in Table 2.3, in order of increasing complexity, based on descriptions provided in Biggs and Collis (1982; 1991).

Table 2.3: Levels in the SOLO model and their characteristics

Level	Characteristics
Prestructural (P)	Responses at this level are engaged with the task, but contain only irrelevant elements, or are restatements of the question. No relevant information is provided.
Unistructural (U)	Unistructural responses provide one relevant element in response to a given question. Different unistructural responses can be equally correct but inconsistent with each other, reflecting focus on different aspects of the phenomenon.
Multistructural (M)	Responses at this level contain two or more relevant elements relevant to the question, however the elements are not linked or integrated. A range of multistructural responses could also be equally correct, depending on the focus of attention.
Relational (R)	These responses include most or all relevant elements and the interrelationships between them, integrating these into a coherent, meaningful conceptual scheme.
Extended Abstract (EA)	At this level the structure of a response is generalised, incorporating elements more removed from the given system in transition to a new more abstract mode. Thus the extended abstract level represents a link between relational responses at Mode N, and a unistructural response at Mode N+1.

The SOLO levels outlined in Table 2.3 are hierarchical, with each succeeding level subsuming its precursor, hence performance at any given level implies mastery of preceding levels. Clearly, these hierarchically related levels are not dissimilar to the structural differences and logical relations so frequently found between categories of description in phenomenographic analyses (e.g., Dahlgren, 1984, p. 26; Hazel et al., 2002). However, underlying the hierarchy of levels in SOLO is the argument that learners show a consistent sequence in learning any skill or cognitive task, and that the SOLO levels reflect this sequence (Biggs & Collis, 1991, p. 64). This suggests that a range of responses classified according to the taxonomy of SOLO might reflect a common developmental sequence in understanding of a particular topic, and therefore inform curriculum and teaching decisions.

The descriptions of the levels in Table 2.3 are based in part on the number of "elements" contained by responses. These elements are simply units or "bits" of data relevant to the cue or question (Biggs & Collis, 1982, p. 26). Unistructural responses consider one element, multistructural responses take account of several, and relational responses incorporate the interrelationships between elements. Extended abstract responses in many articulations of the SOLO model (e.g., Biggs & Collis, 1991) are the transition between two modes: a relational response in one mode is extended to form a new single more complex element of the next, more abstract mode. Where the relational response is not qualitatively more abstract it may also extend to form a new single more complex element of the next cycle in two-learning-cycle-per mode versions of SOLO (Pegg, 2003; Pegg & Davey, 1998).

The justification of this pattern of learning through levels is derived in large part from the information processing research tradition, in particular; the constraints of working memory, described by Biggs and Collis (1982, p. 26) as "capacity". In brief, SOLO levels are thought to reflect sequential demands of more and more working memory, with relational responses requiring the learner not only to hold the relevant "bits" of information in working memory, but also their interrelationships (Biggs & Collis, 1982, p. 26). Although recent research in information processing outlined in Chapter 1 questions the primary role ascribed to working memory in cognitive development, the link between working memory and cognition is still strong:

> It is to be stressed that the role of working memory in the functioning of thinking and problem-solving, although different from how it is conceived by

> neo-Piagetian theories, remains strong. It is one of the main factors underlying individual differences in thinking and problem solving. That is, working memory is a mechanism for the implementation of the processing potential of a given age into actual thinking and problem–solving skills and abilities. (Demetriou et al., 2002, p. 129)

According to the SOLO model (Biggs & Collis, 1991), learning is reflected by an individual's responses advancing through different levels within a given mode, then advancing through modes. Moving between levels occurs as the individual becomes aware of more elements and the relations between them. While this growing awareness is thought to reflect increasing availability of working memory, it would also be influenced by contextual factors such the learning environment and exposure to information. Advancing between modes occurs as a consequence of factors such as physiological maturation, relational responding in a previous mode, social support during Vygotsky's "zone of proximal development", and cognitive conflict between the known and the new, posed by a particular problem (Biggs & Collis, 1991, pp. 67-68).

In summary, the SOLO model has evolved considerably since its inception in 1979. The most recent model comprises a hierarchy of five modes of increasing abstraction, with the modes most pertinent to undergraduate education being the concrete–symbolic and formal modes. Within each of these modes are recurring cycles of three levels of responses (unistructural, multistructural and relational) which show increasing structural complexity. This hierarchy shows some similarities to phenomenographic categories of description, but is explained in terms of limitations of working memory.

Theoretical perspectives linked to the SOLO model

In this subsection the conceptual links between SOLO and related theoretical perspectives are discussed. As stated previously, SOLO grew out of Piagetian origins, and the links between SOLO and Piagetian stage theory are drawn out in this subsection, as well as the crucial points of departure between these two theoretical perspectives. The links between SOLO and information processing research are described, as is the influence on SOLO of previous idiographic research. Finally, similarities between SOLO and several cognitive science theories are outlined.

The intellectual lineage of SOLO clearly encompasses features of Piagetian stage theory and falls within a broad neo-Piagetian framework. The similarity between SOLO and the neo-Piagetian research of Case (1980) was highlighted by Biggs and Collis (1982, p. 220-221). The ambiguity apparent in early SOLO literature about the perceived link between Piagetian developmental stages, learning and learning outcomes is perhaps unsurprising, given the contrasting paradigms influencing the development of SOLO.

In 1980, Biggs stated that what he "was really doing was not establishing developmental stages, but assessing learning outcomes. The relationship between the latter, and the characterisation of the learner at a particular developmental stage is at best analogical" (Biggs, 1980, p. 105). A year later it was claimed that the SOLO levels "owe something to Piagetian ones but do not presuppose a stage theory of development; indeed they apply only to learning, not to development at all" (Biggs & Telfer, 1981, p. 263). However, later Biggs and Collis (1982, p. 15) stated that:

> we believe that there are 'natural' stages in the growth of learning any complex material or skill, and that in certain important respects these stages are similar to, but not identical with, the developmental stages in thinking described by Piaget and his co-workers.

Biggs and Collis (1982) argued that these stages are evident in the age–related capacity of learners to provide progressively more complex, abstract and better–structured cognitive responses to any given learning situation.

Notwithstanding its origins in Piagetian research, and assumption of developmental stages, the SOLO model is marked by fundamental and explicit differences from classical stage theory. These differences are outlined by Biggs and Collis (1982) and summarised in Table 2.4.

Table 2.4: Differences between Piagetian stages and SOLO modes

Piagetian stages	SOLO modes (initially termed levels)
Stages characterise an individual	SOLO modes can characterise only an individual's specific response, not an individual
Stages proceed sequentially, preceding stages replaced by subsequent stages	SOLO modes develop sequentially, with preceding modes augmented rather than replaced by subsequent modes
Stages determine the level of cognitive response	Modes provide an upper limit to quality of cognitive response, but responses may occur at a variety of levels below this upper limit
Performance is stable within any given stage, with rare instances of performance from different stages (décalages)	Performance commonly straddles different modes (multimodal functioning), with décalages the rule rather than the exception

As can be seen in Table 2.4, the crucial difference between SOLO and stage theory is that SOLO distinguishes clearly between learning outcomes and developmental stages, and uses learning outcomes rather than developmental stages as its point of reference (Biggs & Collis, 1982). The SOLO taxonomy is intended for application to specific responses to a learning task, rather than to the developmental base stage of individuals who made the responses.

This change of focus reflects an important underlying distinction between Piagetian Stage Theory and SOLO. The authors of SOLO by 1982 accepted the existence of developmental stages in learning, but denied that the "generalised cognitive structure" associated with an individual's developmental base stage is directly measurable, hence their adoption of the term "Hypothetical Cognitive Structure" (Biggs & Collis, 1982, p. 22). An individual's Hypothetical Cognitive Structure is not measurable because performance on any given task is inevitably influenced by factors such as teaching context, prior knowledge and, of particular interest in this study, learning intention and motivation. This point strongly resonates with an earlier criticism of Piagetian stages by Flavell, who stated that "a given stage, however defined, is typically a function not only of chronological age, but also, or so it sometimes seems — of everything else under the sun" (Flavell, 1963, p. 442).

Given this multitude of influences on learning performance, stability of performance across different tasks is not expected. The developmental stage of the individual that is the emphasis of stage theory and isomorphic to the modes of SOLO may provide an upper limit to response quality, but is only one of many factors influencing responses. By focusing on specific responses, SOLO serves as an indicator of learning outcomes that are achieved within the constraints of all the intrinsic and extrinsic factors associated with particular learning situations, including developmental stages. This underlying difference of purpose and focus, apparently triggered in part by influences from idiographic research into student learning in higher education, liberates the SOLO taxonomy from many of the problems associated with Piagetian theory outlined in Chapter 1. As stated by Biggs and Kirby (1980a, p. 200):

> much of the embarrassment inherent in the notion of décalages disappeared on the basis of this simple distinction; décalages across stages being theoretically damaging, while décalages across [SOLO] levels simply remain as instructionally challenging.

So, although founded in Piagetian theory, and evolving along neo-Piagetian lines, the development of SOLO differs fundamentally from this antecedent and has been influenced by research from other traditions.

One important influence on the development of SOLO was research from an information processing perspective. The authors of SOLO (Biggs & Collis, 1982) drew attention to the similarity between SOLO and four levels of quality in conceptual structure of written responses found from an earlier information processing model. The information processing model emphasised that response quality was context–dependent rather than consistent for individuals, and descriptions of the response levels (Schroder, Driver, & Streufert 1967 cited in Biggs & Collis, 1982, pp. 13-14) show marked similarities to later descriptions of the SOLO levels. More recently, the information processing concepts of item and relational information have been postulated as an explanation for the qualitative differences between uni- or multistructural and relational learning outcomes associated with different approaches to learning (Dyne et al., 1994, pp. 380-382).

The authors of the SOLO taxonomy also explicitly acknowledge some "conceptual debts" (Biggs, 1979, p. 382) to the idiographic research of Marton and colleagues (i.e., Marton & Säljö, 1976a; Marton & Säljö, 1976b). This relationship parallels the cross-links between the research of Biggs and Marton and colleagues into learning approaches that were highlighted in Chapter 1. The first four levels of the original SOLO model published from a Piagetian framework, were "virtually identical" with Marton's four hierarchically related levels of learning (Biggs & Collis, 1982, p. 14).

According to Biggs (1980, p. 105), this conceptual overlap was coincidental, but the coincidence clearly contributed to the thinking behind subsequent articulations of the SOLO model. Biggs (1979) suggested that the SOLO model was closer to Marton's levels than to developmental stages, and stated that "it was discussions with Marton and his colleagues that led the writer to make this minor, but nevertheless important, paradigm shift away from the Piagetian framework" (Biggs, 1979, p. 385). In making this shift, Biggs recognised the "vital" importance of distinguishing between the developmental stage of an individual and the "structure of the outcome of his or her learning" (1980, p. 105). This distinction was realised in later versions of SOLO and remains a fundamental distinction between SOLO and classical stage theory.

The SOLO model has notable similarities with a number of other theories of learning. Some similarity was pointed out by Biggs and Collis (1982, p. 220) between the SOLO levels and modes, and Bruner's three levels of learning within each of his enactive, ikonic and symbolic modes. They also, though, highlighted differences between the two theories relating to conceptual differences between SOLO levels and Bruner's stages.

Parallels between the SOLO model and the levels of the van Hieles' theory of mathematics education are outlined by Pegg and Davey (1998). Although the van Hieles' theory focuses on underlying levels of thinking, and the SOLO model deals only with observed responses, a synthesis of the two theories concluded that they contained many similar features and were mutually complementary. The van Hiele model represents a more global theoretical construct outlining thinking skills, but thinking skills are not necessarily manifested in the context–dependent individual responses, which are better described by the SOLO model (Pegg & Davey, 1998).

Further connections between the SOLO model and learning theories relate to "process — object encapsulation" theories emanating from cognitive science research into mathematics education. There are several of these theories (reviewed by Tall, Thomas, Davis, Gray, & Simpson, 2000), which have in common the idea that cognitive growth occurs "through actions on existing objects that become interiorized into processes and then encapsulated as mental objects" (Pegg, 2003, p. 246). The relationship between these theories and the two-learning-cycle model of SOLO has been explored by Pegg and Tall (2001, cited in Pegg, 2003, p. 247; Pegg & Tall, 2002, 2005) who suggested that the transition from a relational to a unistructural form of understanding in the next cycle represents the generation of a knowledge "entity".

In summary, the originators of SOLO have demonstrated changing ideas about the relationship between SOLO levels and Piaget's developmental stages, but some assumption of developmental stages is apparent in descriptions of the SOLO model. Nonetheless, SOLO differs fundamentally from Piagetian stage theory in that it takes into account the crucial importance of context and therefore focuses on specific outcomes rather than developmental stages. The development of SOLO away from Piagetian stage theory was influenced by the idiographic research of Marton and colleagues. Current versions of the SOLO model show strong similarities with a number of other theories of learning from the cognitive science tradition.

Applications of SOLO in higher education

This subsection reviews some of the applications of SOLO in higher education, particularly in relation to the 3P model of learning and the tertiary science context. Some of the criticisms of SOLO that have been raised in previous research are also outlined.

Versions of SOLO incorporating a single learning cycle per mode have been used as an assessment tool and research framework in a number of contexts in higher education. The use of SOLO in various aspects of teacher education, and its contributions to test item construction were reviewed by Hattie and Purdie (1998). SOLO was also used as a classificatory tool in a meta-analysis of study skills interventions (Hattie, Biggs, & Purdie, 1996). A study of postgraduate education students' by Boulton-Lewis (1992) used SOLO to examine qualitative variation in students' understandings of learning in written statements and final assessment essays. In a study of learning approaches and outcomes of first–year nursing students, Trigwell and Prosser (1991, p. 272) concluded that SOLO, as a measure of qualitative differences in learning outcome, may be more valid than quantitative achievement scores for research in student learning.

Other applications of SOLO in higher education have been reviewed by Boulton-Lewis (1995; 1998a), in terms of the 3P model. These reviews described uses of SOLO at the Presage level to determine students' prior understanding of a subject, at the Process level to provide models and examples to facilitate learning, and in particular, at the Product level to assess learning outcomes. It was concluded that the SOLO model was "a potentially useful tool in higher education both to shape and assess learning" (Boulton-Lewis, 1998a, p. 216).

Several studies have investigated the use of SOLO as a measure of learning outcomes in science, although many of these (e.g., Creedy, 1993; Levins, 1997; Panizzon & Pegg, 1997) focused on senior secondary students. In the tertiary context, the single learning cycle version of SOLO has been used in a number of studies. Tang (1998, p. 120) suggested that content–related assessment of an essay assignment for first–year physiotherapy students was inadequate, but that the SOLO model facilitated assessment of the integration, coherence and holistic understanding of the content. A more recent study by Hazel et al. (2002) used both SOLO (the single learning cycle version of Biggs & Collis, 1991) and phenomenography to investigate first–year biology students' answers to an open–ended question on photosynthesis. In the SOLO analysis, responses were coded as prestructural if they mentioned neither of the two key reactions in photosynthesis, unistructural if they mentioned one of the reactions, multistructural if they mentioned both unrelated reactions, and relational if they mentioned the two related reactions (Hazel et al., 2002, p. 741). This study found high correlations between the rank ordering of students using both phenomenography and SOLO methods, and suggested that both methods were "robust and suitable for use as measures of understanding in tests based on the process-presage-product model" (Hazel et al., 2002, p. 748).

The more recent two-learning-cycle version of SOLO (e.g., Pegg, 2003) has been much less used in research into learning in tertiary science. Panizzon (1999; 2003) used this version in a study of first–year science students' understanding of diffusion and osmosis. This study found that 71% of the written responses of first–year university students were categorised within the concrete–symbolic mode, with 23% falling in the first cycle and 48% in the second. The most frequently represented level was M2, which comprised 35% of the sample. Only 8% of responses were in the formal mode, that is, fell within the theoretical form of knowledge considered the target of tertiary education (Biggs & Collis, 1991, pp. 61-67) with three responses suggestive of a second learning cycle in the formal mode (Panizzon, 1999, pp. 198-199; 2003, p. 1437).

Criticisms of SOLO as a measure of learning outcomes

Some research applying SOLO to learning outcomes of students has raised some criticisms of the model. The SOLO model is subject to the criticisms levelled more generally towards nomothetic cognitivist research, which were outlined in Chapter 1. For example, the SOLO model, like other cognitivist theories, has been criticised for being over–simplistic (Redden, 1995, p. 282). Redden found that the standard SOLO model could not be applied to children's responses to particular arithmetic cues, and suggested that a better fit to his data was provided by a bifurcated rather than linear sequence.

Difficulties in applying SOLO to postgraduate student essays and short written responses have also been encountered (Chan, Tsui, & Chan, 2002). These researchers suggested that the structure and categorisation criteria of SOLO led to unstable categories, and were related to conceptual ambiguity. They added subcategories to improve the precision of the five levels of the SOLO taxonomy (the version of Biggs & Collis, 1982), but reported problems with inter-rater disagreement, and with applying the SOLO taxonomy in general (Chan et al., 2002, p. 517). Despite these difficulties, their study did conclude that SOLO was suitable for measuring cognitive learning outcomes.

A major consequence of the nomothetic assumptions underlying SOLO is the generality of application of the model. SOLO categories, because they are based on response structure, can theoretically be applied to any content material. Dahlgren (1984, pp. 29-30) suggested that while this generality of application is SOLO's greatest strength, it also represents its greatest weakness, because it may not account for differences in learning outcome that are tied to the specific content of a learning task. Dahlgren had observed structural differences reflecting the SOLO taxonomy in some analyses of response, but frequently found other differences dependent on specific content. On this basis he concluded that structural similarities, although useful, would be more informative if combined with "content–specific characteristics" (p. 30).

This criticism was recapitulated more recently by Trigwell and Prosser (1991, p. 273), who suggested that the content–free nature of SOLO categories may obscure relationships between quantitative and qualitative measures of outcomes. Consequently these authors suggested that phenomenographic analyses, because they include content–related aspects of responses, should be considered as an alternative qualitative measure of learning outcome. These comments highlight possible limitations of SOLO in distinguishing between commonly held alternative scientific conceptions.

In summary, the SOLO model has been used across a range of contexts in higher education, ranging from a tool in constructing test items, a research framework, and most importantly, a measure of qualitative differences in learning outcome and prior knowledge. Criticisms of SOLO relate to its linear structure, difficulties applying it reliably, and its generality of application in relation to qualitative content–specific differences in outcome.

Summary

In this section on learning outcomes, the ideographic studies reviewed have repeatedly identified four to five hierarchically–related levels of learning outcome, from least to most complete understanding. These empirically established categories are content–specific, and not predicated on any nomothetic assumptions of causality. Criticisms of phenomenographic analysis of learning outcome have been based on problems of generalisability and reliability of categories, and the perceived positivist leanings of some phenomenographic research.

By contrast to these studies, the SOLO model is a generic tool for identifying qualitative variation in learning outcomes, derived from the nomothetic tradition. The categorisation of responses in the SOLO hierarchy is based on the degree of abstraction (the mode) in conjunction with structural complexity (the level). The justification for this sequential hierarchy is based on information processing theory, in particular, the constraints imposed by working memory.

Although SOLO originated from a Piagetian framework, and retains conceptual links to neo-Piagetian research programs, two points mark its fundamental departure from stage theory. The first is that SOLO focuses on specific responses rather than the developmental stage of an individual, and the second is that SOLO explicitly recognises the importance of context on the response of individuals. Hence, décalages and functioning across different modes are expected. The initial SOLO levels coincided with the levels of learning outcome established in the ideographic research of Marton and colleagues, which influenced the subsequent evolution of SOLO away from its original Piagetian framework. SOLO has since been found to share points of similarity with a range of other theories of learning.

Various versions of SOLO have been used as a research tool in many contexts in higher education, and in science education. Only one study, however, has used the more recent two-learning-cycles per mode version of SOLO in a tertiary science learning context. Criticisms have been levelled at the SOLO taxonomy for being overly simplistic and difficult to apply, while it has been argued that the generality that is the strength of SOLO may also obscure important content–specific differences in learning outcomes.

Relationship between learning approach and learning outcome

It has been claimed that "one of the most central questions in investigations into student learning concerns the relation between learning activity (or process) and learning outcome" (Marton & Svensson, 1979, p. 480). Moreover, the apparent strength of this relationship has underpinned much research into learning in higher education; for example, "national programs of reform have been developed and funded around the associations between approaches to learning and the quality of the learning outcome" (Gibbs 1992 cited in Prosser & Trigwell, 1999, p. 92).

This section first describes the relationship between learning approaches and outcomes identified in idiographic investigations of tertiary students learning. Then the associations between learning approaches and outcomes in nomothetic research programs are summarised.

Idiographic studies

In this subsection the idiographic research into the relationship between approach and outcome is traced, from the early work of Marton and colleagues to more recent phenomenographic studies. The discussion focuses on studies of students' learning in a tertiary science context, and includes interview–based studies that have also used SOLO as a measure of students' learning outcomes.

The early idiographic studies of Marton and Säljö into learning approaches (1976a, p. 7) hypothesised a relationship between learning approach and outcome. Marton and Säljö were looking for an explanation of the variation they had earlier found in learning outcomes of students, aiming "to ascertain functional differences in the level of processing which might explain the differences in the outcomes of learning" (Marton & Säljö, 1976a, p. 9). This initial hypothesis was supported strongly by their study, with students using deep–level processing providing the highest quality outcomes, and those students adopting surface–level processing demonstrating the least satisfactory outcomes in a particular learning task (Marton & Säljö, 1976a, p. 10).

The relationship between learning approach and outcome was further investigated in a study which was explicitly located by its authors in the idiographic research tradition of Marton and colleagues (Van Rossum & Schenk, 1984, p. 75). Despite the acknowledged theoretical differences between SOLO and the idiographic tradition, the authors used an early version of the SOLO taxonomy to analyse the outcome data, because of the direct comparability of the SOLO levels with levels of outcome found by Marton and Säljö (Marton & Säljö, 1976a). This study found that a surface approach to learning limited the learning outcome to the multistructural level (Van Rossum & Schenk, 1984, p. 80).

Similar findings were apparent in a study of second–year Australian students across four university faculties (Watkins, 1983). In this study, students who in their first year had scored most highly on the meaning and reproducing scales of the ASI were interviewed in their second year about how they usually studied (learning orientation), how they went about a particular task (learning approach), and were asked to explain a particular learning task. The students' explanations were coded using SOLO, with responses at or below the multistructural level grouped into a low SOLO category, and relational or extended abstract responses comprising a high SOLO category. High SOLO levels were strongly related to meaning approaches, while low SOLO levels were associated with reproducing approaches to learning.

Other studies in the context of first–year science show similar results. An interview–based study showed that first–year physiotherapy students in a Hong Kong university who collaborated with others and showed many characteristics of a deep approach, attained higher SOLO scores for an essay assignment (Tang, 1998, p. 120). A study in the context of a first–year physics course in an Australian university (Millar et al., 1989) found a close association between learning approach and outcome. Students who used a surface approach showed little conceptual development in their understanding of Newtonian mechanics, and students adopting a deep or "mixed" approach showed "substantial" development (Millar et al., 1989, p. 52).

In summary, there is general agreement within results from idiographic studies that deep approaches are associated with the highest quality outcomes, and surface approaches with less desirable outcomes. Where SOLO was used as a measure of learning approach, surface approaches were associated with responses at or below multistructural level, while relational or higher responses were linked to deep learning approaches.

Nomothetic studies

This subsection outlines the results of nomothetic research into the relationship between learning approach and outcome. The discussion also encompasses studies using learning orientations, as much central and influential early nomothetic research into the approach/outcome nexus was actually investigating more stable orientations to learning. Research in the context of tertiary science is highlighted, especially that which has used SOLO as a measure of learning outcome.

Discussion of nomothetic studies into the relationship between student "approaches" to learning and learning outcomes is complicated by confounded definitions of learning approaches used in the literature. Where learning "approach" has been used in the sense of relatively stable learning orientation, there appears to be little consistent relationship apparent between learning orientation and learning outcomes.

Among the earliest nomothetic investigations into learning orientations and outcomes was a study by Biggs (1979). Explicitly following the research of Marton and Säljö (1976a; 1976b), Biggs (1979, p. 381) inter-related his two originally independent research interests of learning approaches ("orientations" by the definitions accepted here), and learning outcomes as measured by the SOLO taxonomy. He predicted that students reporting a surface orientation would be more likely to produce multistructural responses, while those students reporting a deep orientation would produce relational or higher SOLO responses (Biggs, 1979, p. 388). This hypothesis was partially supported in the study, which found a weak relationship between deep orientation and high SOLO levels, but Biggs concluded (1979, p. 393) that his results corroborated the previous work of Marton and colleagues.

Since then, nomothetic studies into the relationship between learning orientations and outcomes (whether measured quantitatively or qualitatively using SOLO) have also demonstrated conflicting or equivocal results. Watkins and Hattie (1981, p. 384), at the University of New England, Australia, found that success in science was related to a deep orientation. Tang (1994) found that SOLO ratings of written assignments by first–year physiotherapy students in Hong Kong correlated positively with the deep strategies scale of the SPQ, and that the SOLO outcomes for this task were related more to learning orientation than the actual strategies adopted in preparing for the task. A review by Richardson, Morgan, and Woodley (1999, p. 47) similarly suggested that academic performance was positively related to deep orientations to learning. However, many studies of learning orientations reviewed by Zeegers (2001, p. 118) suggested that scale scores on the ASI and SPQ did not predict or correlate with academic performance, leading him to suggest a "general lack of good agreement between questionnaire scale scores and academic outcomes" (Zeegers, 2001, p. 118).

Two studies (Cavallo, 1992; Reap & Cavallo, 1992) have investigated students' understanding of meiosis in relation to learning orientations, but these focused at the high school level. These studies used detailed analysis of students responses to open–ended questions to assess meaningful understanding, and scores from self-reports on a Learning Approach Questionnaire (Entwistle & Ramsden, 1983) together with teacher ratings as a measure of meaningful learning orientation. It was found that, for females only, meaningful understanding of meiosis was correlated strongly with meaningful learning orientation (Reap & Cavallo, 1992, p. 21). For a different sample, meaningful understanding of meiosis and its conceptual relationship to the Punnett square method was predicted by meaningful orientation to learning and prior knowledge of meiosis. Those students who attained meaningful understanding retained that understanding four weeks later (Cavallo, 1992). Good prior knowledge of meiosis, though, was not associated with retention of meaningful understanding of meiosis amongst students who learned by rote (Cavallo, 1992, p. 25).

Studies of learning approaches (in the strict sense) and learning outcomes have consistently suggested positive relationships between deep approaches and higher–quality outcomes, and surface approaches and poorer outcomes. For example, in an investigation into the learning of first–year mathematics students using a modified version of the SPQ (Crawford, Gordon, Nicholas, & Prosser, 1998a), two clusters of students were identified. One comprised a group of students who reported, among other factors, a relatively deep approach to their study of mathematics, and who showed relatively high achievement as measured by their final mark for the unit. The other cluster contained students who used surface approaches to study in that context, who also achieved a relatively poor final mark (Crawford et al., 1998a, p. 464).

A study in the context of first–year Electrical Engineering students at a South African university (Meyer, Parsons, & Dunne, 1990) used data from ASI responses and performance in analytic problem–solving test and examination results to test the association between learning orchestration and outcome. The authors used multidimensional unfolding analysis to examine their data and concluded that academic success was related to a clear meaning learning orchestration, while academic failure was associated with disintegrated study orchestration (Meyer et al., 1990, p. 67).

It must be noted, though, that better learning outcomes do not necessarily correlate with higher marks. Some studies using test or examination results as indices of learning quality (e.g., Tang, 1994) have shown that high marks can be associated with surface rather than deep approaches to learning. In this case, however, the test questions were assessing recall of lecture material rather than more developed understanding. Therefore, students who adopted a surface approach and were able to reproduce factual knowledge did well. It is recognized that assessment practices that emphasise recall of factual information to the detriment of higher–order thinking skills, can reward and therefore encourage surface learning approaches (Ramsden, 1992).

A relationship between deep approaches to learning and, more specifically, high SOLO levels has also been demonstrated in a number of studies. An investigation of the relationship between learning approaches and outcomes in the context of a first–year nursing course (Trigwell & Prosser, 1991) used the ASI to measure learning approaches, and SOLO and assessment results as qualitative and quantitative measures of learning outcome. Results showed a strong and statistically significant positive correlation between deep approaches and high SOLO levels (responses above the multistructural level), little relationship between surface learning approach and SOLO score, and no relationship between learning approach and assessment result. A study into first–year biology students' understanding of photosynthesis (Hazel et al., 2002, p. 745) showed that a deep approach correlated positively with three different measures of learning outcome (SOLO analysis of open–ended question, SOLO analysis of concept maps and phenomenographic analysis of open–ended question), but statistically significantly only with the SOLO analysis of the open–ended question. A similar study in the context of physics concepts (Prosser et al., 1996) found associations between deep approaches and SOLO measures of pre- and post-test understanding.

Many more studies have shown a similar pattern of results, linking deep approaches with quality outcomes, and surface or disintegrated approaches with poor educational outcomes (reviewed by Prosser & Trigwell, 1999; Ramsden, 1992).

> Surface approaches have nothing to do with wisdom and everything to do with aimless accumulation. They belong to an artificial world of learning, where faithfully reproducing fragments of torpid knowledge to please teachers and pass examinations has replaced understanding. 'Paralysis of thought' leads inevitably to the misunderstandings of important principles, weak long–term recall of detail, and inability to apply academic knowledge to the real world. A surface approach...leads down the same desolate road in every field. (Ramsden, 1992, p. 60)

In a similar vein, it has been argued (Svensson 1977 cited in Entwistle & Ramsden, 1983, p. 18) that persistent use of surface approaches renders impossible a deep level of understanding. The converse, though, is not true, as students using a deep approach may fail to attain a deep level of understanding on account of lack of time, effort or background knowledge. Hence, it appears that a deep approach is a necessary but not sufficient prerequisite for deep understanding.

In summary, associations between meaningful or deep learning orientations and better understanding have frequently been identified from previous nomothetic studies, although some studies have resulted in more equivocal findings. There is, however, very strong evidence from many studies of a relationship between learning approaches and outcomes, with deep approaches related to better outcomes, and surface or mixed approaches with poorer learning outcomes.

Summary

The relationship between learning approaches and learning outcomes is a central issue in understanding student learning in higher education. A relationship between approach and outcome was in fact hypothesised and then identified in early ideographic research, with deep approaches being associated with high–quality outcomes, and, conversely, surface approaches being related to poorer quality outcomes. A number of interview–based ideographic studies have used early versions of SOLO as a measure of learning outcome, and found that deep approaches were associated with SOLO levels higher than multistructural, while surface approaches were associated with multistructural, unistructural or prestructural SOLO levels.

Evidence on the relationship between learning orientations (often referred to in the original sources as approaches) and outcomes is equivocal, with little consistency in results. In the case of learning approaches in the strict sense, however, nomothetic studies have also consistently supported the findings from the idiographic studies, showing that deep approaches are linked to high–quality learning outcomes, and surface or disintegrated approaches are linked to poorer outcomes. In the nomothetic studies that have used SOLO as an indicator of learning outcome, again, deep approaches correlated positively with high SOLO levels. It must be noted though, that deep approaches may not lead to high–quality learning outcomes, as other factors in the 3P model (e.g., lack of time or background knowledge) may work against high–quality outcomes.

Overview and research themes

This chapter has presented a synthesis of previous research into learning approaches, learning outcomes, and their interrelationship. Research into these aspects of the 3P model of learning has been marked by convergence between very different underlying research perspectives and traditions, which were described in Chapter 1.

The field of student approaches to learning has become a research field in its own right. The concepts of deep and surface approaches to learning have been found to be robust over a range of cultural contexts, with deep approaches associated with intrinsic motivation and meaningful learning strategies, and surface approaches associated with extrinsic motivation and reproductive, rote-learning strategies. Different ideas are apparent about the relationship between deep and surface approaches, and there is evidence of mixed or disintegrated approaches to learning in some students. In the context of tertiary science, the expression of deep approaches seems to be characterised by attempts to relate concepts and to use meaningful memorising to aid understanding.

Much research into learning outcomes of tertiary students has investigated the qualitative variation in students' learning outcomes. In the tertiary learning context, phenomenographic analyses have frequently demonstrated a hierarchy of four to five categories of response, which are empirically based and content–specific. A generic tool that has been used for evaluating the quality of learning responses is the SOLO model. SOLO categorises learning outcomes based on abstractness of response (modes), together with structural complexity of response (levels).

SOLO falls within a broadly neo-Piagetian framework, though the justification for its categorisation scheme is drawn from information processing theory, and the model has been influenced by the ideographic studies of Marton and colleagues. In the context of tertiary science, a number of studies have used the single learning-cycle per mode version of SOLO to assess learning outcome, with one study (Panizzon, 1999, 2003) using the more recent two-learning-cycle version of SOLO. A recent study has found high correlations between phenomenographic analyses and SOLO codes as measures of first–year university students' understanding of a specific biological concept, and concluded that SOLO is a suitable tool for assessing understanding in the tertiary context (Hazel et al., 2002, p. 748).

Finally, learning outcomes are related to the learning approaches adopted by students, and this area of learning has received substantial research funding and attention. Deep approaches are associated with better learning outcomes, while surface approaches are linked to poorer outcomes.

Study rationale

From the body of research reviewed above, it is apparent that further investigation into learning approaches, outcomes and their relationship is needed, on both practical and theoretical grounds. From a practical point of view, information about the ways that tertiary students understand particular concepts is valuable in its own right:

> Studies of how specific subject matter is conceptualised and understood are an essential next step. The task is a broad one, encompassing the interrelationships of instruction, the learner's decisions, approaches to learning, and outcome space in relation to particular topics. (Ramsden, 1985, p. 64)

From a more theoretical perspective, very few studies at the tertiary level have used SOLO in conjunction with actual unit–related assessment items to measure learning outcomes. With some exceptions (Boulton-Lewis, 1992; Tang, 1998), most of the previous studies that have used SOLO (e.g., Hazel et al., 2002; Prosser et al., 1996; Trigwell & Prosser, 1991; Watkins, 1983) have used it to evaluate outcomes of tasks which were not part of the normal assessment of that setting. Studies which incorporated assessment responses as a measure of learning outcomes (e.g., Crawford et al., 1998a; Hazel et al., 2002; Hegarty-Hazel & Prosser, 1991a, 1991b; Trigwell & Prosser, 1991) used marks as a quantitative measure of outcome, rather than SOLO or other qualitative analysis of responses to assessment tasks. In addition, no research has used the more recent two-learning-cycle SOLO model as a measure of qualitative differences in learning outcomes in a natural first–year science setting.

Given that further research into the use of SOLO to measure learning outcomes in the tertiary context has been advocated (Boulton-Lewis, 1995, p. 216), it seems timely to take account of recent advances in the SOLO model in measuring qualitative differences in students' understanding using responses to assessment questions. In addition, although some research has focused on the relationship between learning approaches and outcomes using levels of the early single-learning-cycle versions of SOLO, no study has yet addressed the question of how learning outcomes as assessed by the new SOLO model relate to students approaches to learning.

Finally, much of the relatively recent research cited in this study (e.g., Crawford et al., 1994; Crawford et al., 1998a, 1998b; Hazel et al., 2002; Hegarty-Hazel & Prosser, 1991a, 1991b; Prosser et al., 1996; Trigwell, Hazel, & Prosser, 1996; Trigwell &

Prosser, 1991; Watkins, 1983) has been conducted in a few large metropolitan institutions, which have their own particular set of socio-economic and cultural student characteristics. In addition, most of these studies focused on students studying on-campus. Very little comparable research has been conducted in smaller regional institutions with somewhat different student characteristics, or has compared learning approaches and outcomes between distance and on-campus science students. This is despite increases within tertiary education of both distance study and student diversity.

Given these issues, it appears that a study of students' approaches to learning and learning outcomes in a specific tertiary context, which incorporates the more recent SOLO model, could contribute to an understanding of student learning on a number of levels. Such a study could further inform how learning approaches are manifested in a specific tertiary science context. The new SOLO model could potentially inform and assist the practical task of understanding how students conceptualise specific subject matter. In addition, such a study could offer a valuable addition to the empirical research base surrounding SOLO, and hence inform the developing understanding and conceptualisation of this evolving theoretical model. Finally, considering the acknowledged importance of the link between learning approaches and outcomes, further research into this aspect of the 3P model in a novel context comprising both distance and on-campus students would seem merited.

Research themes

The considerations outlined in the preceding discussion have underpinned the present study, which is an investigation of the learning approaches and outcomes of first–year biology students. In accordance with the findings of much recent research that "learning in institutional settings is bound up with content and context" (Ramsden, 1987, p. 275), this research is situated in the specific naturalistic learning context of a short topic in an introductory biology unit.

This research is framed and guided by the following three general themes, each comprising more specific lines of inquiry.

1. What approaches to learning are adopted by students in a particular tertiary science context?

On the basis of previous work in this area, it is hypothesised that general deep and surface approaches will be able to be identified, as well as evidence of mixed or disintegrated approaches to learning. Students studying by distance mode are different in many respects from students studying on-campus. For example, distance students are generally older than their on-campus counterparts and often have not studied for many years prior to enrolling in tertiary education (Richardson, 2000, pp. 175-176). Likewise, the learning experiences for students studying by distance and on-campus are quite different. For these reasons, comparing the approaches and outcomes of these two subgroups enrolled in the same academic unit is of interest. It is expected that differences in learning approach and outcome would be identified between distance (external) and on-campus (internal) students enrolled in the same academic unit.

The investigation of this theme is guided by the following four, more specific, lines of inquiry:

> 1a: What are the characteristics of the particular teaching and learning context which might influence students' approaches to learning?
>
> 1b: What do students' responses to a topic–specific learning approaches questionnaire (MSPQ) show about their approaches to learning in a particular topic?
>
> 1c: How do students describe in interviews the learning approaches they adopted in a particular topic?
>
> 1d: What is the relationship (if any) between the assessment of learning approaches using quantitative (questionnaire) and qualitative (interview) methods?

2. What is the variation in the quality of learning outcome from that particular context, as measured by the two-learning-cycle per mode version of the SOLO model?

The only previous examination of tertiary students' understanding of scientific concepts using the two-learning-cycle per mode version of the SOLO model (Panizzon, 1999, 2003) was also in the context of first–year biology, at the same institution as the present research. It was found that the majority of written responses to open–ended questions represented two cycles of SOLO levels within the concrete–symbolic mode, with a few responses from the formal mode. Comparable results are therefore predicted in the present research into students' understanding of a different concept, within a similar context. That is, it is hypothesised that two learning cycles per mode will be identified, and that most of the responses will be in the concrete–symbolic mode, with a substantial number also in the formal mode.

The investigation of this theme is guided by the following four, more specific, lines of inquiry:

> 2a: What are the categories of written responses to a specific question on a concept central to the study context, and do they fit with the SOLO model?
> 2b: What is the distribution of SOLO categories across the sample?
> 2c: What are the SOLO categories of students' verbal explanations of the same question in interviews?
> 2d: What is the relationship (if any) between the SOLO categories obtained for the written and verbal explanations of the target question?

3. What, if any, is the relationship between learning approach adopted, and SOLO levels?

Previous research using the single-learning-cycle versions of SOLO has suggested that surface approaches limit outcomes to multistructural levels or below, while deep approaches are associated with relational or extended abstract responses. Other previous work on the SOLO model (Pegg & Davey, 1998, p. 121) has suggested that the multistructural level of the single-learning-cycle version of SOLO is equivalent in the later two-cycle model to M_2, the multistructural level in the second cycle. Given these two premises it is hypothesised that surface approaches will be associated with SOLO codes U_1, M_1, R_1, U_2 or M_2 in the concrete–symbolic mode (Low SOLO outcomes). It is also hypothesised that deep approaches will be associated with SOLO codes at or above R_2, (i.e., R_2, U_{1F}, M_{1F}, R_{1F} and above – High SOLO outcomes).

These hypotheses, however, must be qualified. Because of the potential impact of a plethora of other variables such as lack of time, different background knowledge, examination techniques and other factors known to affect learning outcomes, deep approaches are not expected to be a sufficient condition for high–quality outcomes, and conversely, surface approaches may not preclude high SOLO outcomes.

Nonetheless, in line with previous research, some degree of relationship between approach and outcome is expected.

The four lines of inquiry along which this research theme is explored are:

3a: What are the relationships between quantitative measures of learning approaches and examination question outcomes?

3b: Do the relationships between quantitative measures of approaches and outcome differ between internal and external students?

3c: How do the learning approaches that students describe in an interview fit with the quality of their verbal explanations of meiosis?

In addition, another major aim of this study is to explore the relationship between the findings of the three research themes, and previous relevant work in the field. The purpose of this analysis is to identify any theoretical or practical implications emerging from the synthesis of studies conducted in different contexts.

This chapter, then, has reviewed literature pertinent to students' learning approaches and outcomes in higher education, and raised the research directions to be followed. The guiding lines of inquiry within each of the themes that have been outlined in this chapter are examined using a number of more specific questions, which are provided in later chapters of this thesis. The next chapter describes the scientific concept chosen as the contextual subject matter of this research, and the research methodology implemented to investigate the questions at the focus of this study.